5G TECHNOLOGY AND ITS KEY DRIVERS: CLOUD COMPUTING AND CLOUD RADIO ACCESS NETWORKS

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Abstract - This paper highlights the role of cloud technologies in 5G evolution along-with their fundamental concepts, architecture and implementations. 5G technologies require breakthroughs in wireless network innovations and the way subscribers use the internet. There is a demand for increase in data rates, processing power and storage capabilities. Cloud computing and Cloud Radio Access Networks provide the necessary platform to achieve these changes.

Keywords: 5G technology, cloud computing, cloud-RAN, latency, virtualized RAN.

I. INTRODUCTION

5G technology has revolutionized industry and society by providing an unimaginable level of innovation. There is a need to provide better connectivity and develop a new radio access network (RAN) to enable such technological growth. Cloud computing provides the necessary platform for virtualization and optimization of services. A Cloud-RAN or a Centralized-RAN is a new centralized radio access network that is based on cloud computing and helps in resolving capacity and coverage issues. Section 1 of this paper discusses 5G technology, its performance requirements, technology drivers and the emergence of cloud computing. Section 2 discusses cloud computing, its advantages, business models, characteristics and its architecture. Section 3 discusses cloud radio access networks, their need and architectural implementation.

II. 5G: AN EVOLUTION BEYOND MOBILE INTERNET

The transition from 2G to 3G was believed to enable internet on consumer devices, but it was not until 3.5G that an exponential development in terms of consumer experience happened. Mobile broadband networks combined with the technology of smartphones tremendously enhanced mobile internet experience contributing to the rise of application centric interface we utilize today. Emails, social media, music and video streaming have all been reaped the benefits of mobile broadband. The transition from 3.5G to 4G has enabled users to access data at faster speeds and low latency rates which dramatically changed the way people access internet on their mobile phones. The arrival of 5G technologies and Information and communication technology networks mark the beginning of a globally connected digital society. Internet access on the mobiles forms the basis of business in all industries. This is followed by a demand for flexible working practices. Rapid increase in mobile access to the internet and cloud based technologies allowing people to conduct operations that weren’t possible earlier.

5G technologies are the benchmark for welcoming breakthroughs in the field of ICT network infrastructure. Features such as ultra broadband and intelligent pipe network are just the beginning for achieving near instantaneous connectivity. Business growth and innovations are being driven by the transformation of ICT networks. [2]

2.1. 5G Complex performance requirements

Some performance requirements for mobile services which are needed to implement 5G are listed below:

1. Latency ranging from one millisecond to a few seconds
2. Signalling loads varying from less than 1% to approximately 100%
3. 1000x bandwidth per unit area
4. Duty cycles ranging from few milliseconds to entire days

5G networks face design challenges to meet all of the above service requirements simultaneously. Some performance requirements for 5G networks are listed below:

1. Data rates: Data rates of at least 1 Gb/s or more that support ultra high definition video and virtual reality applications.
2. Zero distance connectivity: For supporting mobile cloud services data rates of the order of 10 Gb/s are required.
3. Massive capacity: 1000 fold gains in capacity. Currently mobile network systems are supporting approximately 5 billion users, which will expand to several billions of applications and machines.
4. Zero latency and response time: Real time mobile control, vehicular applications and communications etc require a latency of less than a millisecond.
5. Zero-second switching: Switching time of maximum 10 milliseconds amongst different...
radio access technologies to provide uninterrupted services.


2.3. 5G technology drivers

In this section we discuss about the necessary breakthroughs in different fields that are inevitable to bring about the technological changes that define 5G:

1. Spectrum impact: Freeing up additional spectrum along-with flexible and efficient utilization of non-contiguous spectrum is a major requirement. Laws governing the spectrum bands’ usage and availability in a region will need to be in sync. Cloud architecture and Software Defined Networking will ensure that programmable air interface and spectrum map service requirements to optimum combinations of frequency and radio resources.

2. Multiple access and advanced waveform: Developments in coding and modulation algorithms are a prerequisite for betterment of spectral efficiency. This will also account for the much needed scalability for Internet of Things and lower the access latency.

3. Baseband and RF architecture: Adaptive air interfaces and techniques such as mass scale MIMO demand innovations in baseband and RF architecture. Designs for combining a large number of antenna and RF radio elements will be required.

4. Integrated access nodes and backhaul design: Nodes with the ability to self organize the spectrum blocks that are available for backhauling and access will be the key requirement. High frequency radio spectrum access will be enabled with the help of this feature.

2.4. Virtualized architectures and emergence of cloud computing

5G will provide the basis for new innovations in network deployments that will consist of ultra-dense radio networking with features like self-backhauling, dynamic spectrum reframing, device-to-device communications and radio access infrastructure sharing. Radio access infrastructures whose basis lies in cloud architecture technologies will cater to on-demand resource processing, storage and network capacity ubiquitously. Software-defined air interface technologies will be coherently embodied into 5G wireless access network architectures. This complete redesigning of Air-interface and RAN systems will develop towards a “hyper transceiver” approach to mobile access, and will help in realizing the optimization of joint-layer and efficient utilization of radio resources. Core network developments focus on enabling greater flexibility for creating new services and applications. Hence, it follows from the analysis that 5th generation wireless systems will undergo a drastic change which is analogous to the revolution brought about by cloud computing in computer networks. Cloud computing will be the base of such core networks and would enable the network to be leveraged according to the services provided. The next section discusses about cloud computing

III. OVERVIEW OF CLOUD COMPUTING

In the simplest terms, cloud computing means storing and accessing data and programs over the Internet and not on the computer’s hard drive. More or less the term “cloud” symbolizes the Internet. Cloud computing refers to the process of utilizing computer services such as data storage and computation wherein internet enabled devices operate the application software. [1] The continuous development of processing and storage technologies and the widespread growth of the Internet, has led to the development of cloud computing, in which resources (e.g., CPU and storage) are provided as general utilities that can be leased and released by users through the Internet in an on-demand fashion. As a result of this, computing resources have become more ubiquitously available than ever before.

Over the past few years, the emergence of cloud computing has made a tremendous impact on the Information Technology (IT) industry. Large companies such as Google, Amazon and Microsoft strive to provide more powerful, reliable and cost-efficient cloud platforms, and business enterprises look forward to mould their business models to gain benefit from this new technology. Technologies, such as virtualization and utility-based pricing, used by cloud computing are not new. Instead, cloud computing leverages these existing technologies to meet the technological and economic requirements of today’s demand for information technology.

3.1. Cloud Computing Advantages

Cloud computing offers several compelling advantages that are listed below:

**Demand based investment:** Since service providers simply leverage resources from the cloud depending on its own needs, they do not need to make huge investments in the infrastructure to generate profit. Cloud computing implements a pay-as-you-need model.

**Low operating cost:** Cloud computing provides rapid allocation and de allocation of resources based on demand. Hence, capacities need not be provisioned according to peak loads. This results in huge savings for the service providers as whenever the demand is low, resources can be released, thereby lowering the operating cost.
Scalability: Large numbers of resources are pooled from data centres by service providers. These resources are easily accessible. In case of rapid increase in service demands, the service provider can carry out expansion of services on a large scale. This process is based on a model that is sometimes referred to as Surge computing. [4]

Accessibility: Services hosted in the cloud are easily accessible through a variety of devices with internet connections as these services are web-based. These devices could be desktops and laptop computers, cell phones and PDAs.

Low maintenance expenses and business risks: As the service providers outsource the infrastructure services to the clouds, the business risks are shifted towards infrastructure providers. Also the capability to cut down hardware maintenance costs and staff training costs is one big advantage for service providers.

3.2. Cloud Computing Business Models
After the establishment of the cloud, different requirements decide the manner in which cloud computing services will be deployed. This results in different business models for cloud computing. The primary models are discussed below. [5]

- **Software as a Service (SaaS)** — Services and applications hosted in the cloud can be accessed by consumers who purchase them. An example: Salesforce.com where necessary information regarding the interaction between the consumer and the service interaction is hosted as part of the service in the cloud.

- **Platform as a Service (PaaS)** — Consumers can deploy their own software and applications in the cloud by purchasing access to the platforms. Consumer does not manage the operating systems and network access resulting in constraints on the deployment of applications.

- **Infrastructure as a Service (IaaS)** — The operating systems, applications, network connectivity and storage are managed and controlled by the consumers but they do not manage the cloud infrastructure. Communications as a Service (CaaS) is a subset model of IaaS which consists of hosted IP telephony services.

3.3. Cloud computing characteristics
Some basic features of cloud computing that distinguish it from traditional service computing are discussed below:

**Multi-tenancy:** In a cloud environment, multi tenancy describes the architecture in which multiple customers are served with a single instance of a software application. Customers are called tenants. They can customize some parts of the application but not the code. A single data centre holds services owned by multiple providers. The infrastructure provider and the service provider share the performance and management issues.

**Broad network access:** Since the Internet is a service delivery network for the cloud, all the devices with Internet connection have access to the cloud services. A large number of data centres of the clouds are present at numerous locations all over the world which results in high network performance. Broad network access consists of private clouds which operate inside a company’s firewall, public clouds, or a hybrid deployment.

**Resource pooling:** Resource consumers have access to a large number of computing resources that can be dynamically assigned to them by the infrastructure providers. The cloud enables the consumers to utilize data within the business management software simultaneously from different locations and different times. This phenomenon provides great flexibility to infrastructure providers.

**Service oriented:** The basics of cloud computing lie in a service oriented model. The Service Level Agreement is an agreement between the service provider (whether PaaS, IaaS or SaaS) and the consumer according to which the services are deployed. Hence in cloud computing there is a very strong emphasis on service management.

**Rapid Elasticity:** In cloud computing the allocation and de allocation of resources is continuously changing as it is based on demand, service providers can manage their consumption of resources based on their needs. Service providers are able to respond quickly to rapid changes in the demand (flash crowd effect) with the help of features such as Automated Resource Management.

**Dynamic resource provisioning:** The traditional model provides resources based on the peak demand whereas cloud computing is based on the dynamic resource provisioning model which enables service providers to acquire resources according to the current demand. This phenomenon helps in reducing the operating costs to a great extent.

**Usage-based pricing:** In cloud computing services, the consumers pay according to the usage. Pricing schemes differ for different service providers. Usage based pricing also helps in lowering the operating costs. An example that would illustrate this: An IaaS provider rents out a virtual machine to a SaaS provider priced hourly, who in turn provides Customer Relationship Management priced according to the number of clients (salesforce.com).
3.4. Cloud computing architecture

The architecture of a cloud computing environment can be divided into four layers: the hardware/datacenter layer, the infrastructure layer, the platform layer and the application layer. These layers are discussed below:

**Hardware layer:** The physical resources of the cloud such as power, switches, physical servers, routers etc are managed in this layer. For practical purposes, the data centres implement the hardware layer. Thousands of servers are present in data centres which are interconnected through routers and switches. Traffic management, hardware configuration, tolerance for faults are some of the issues present in hardware layer.

**Infrastructure layer:** This layer partitions the physical resources using virtualization technologies like Xen[F], KVM[G] and VMware[H] thereby creating a large number of storage and computing resources. The infrastructure layer is also referred as the Virtualization layer. Dynamic resource management and other key features are only possible due to virtualization technologies, thereby making this layer a very important component.

**Platform layer:** This layer resides on top of the Infrastructure layer and is comprised of operating systems and application frameworks. It minimizes the load of direct deployment of applications into VM containers. Control is limited to that of the platform or framework, but not at a lower level (server infrastructure). Examples include: Google App Engine or Microsoft Azure. Google App Engine operates at this layer and provides API support for implementation of web applications which involves database, storage and business logic.

**Application layer:** This is the topmost layer and comprises of cloud applications. A distinguishing feature of cloud applications is their ability to automatically scale, leveraging which helps in achieving better performance and lower operating costs.

Cloud computing can support a wide range of applications due to its modular architecture. All the layers are loosely coupled with the adjacent layers and thus this design is a lot similar to the OSI model.

As cloud computing physically separates user-based data input/output and remote computing, cloud radio access networks (C-RANs) carry out the separation of localized and distributed radio units from central information processing nodes. In the next section we discuss about Cloud radio access networks.

IV. CLOUD-RAN

C-RAN or Cloud RAN also called as Centralized RAN is a new network architecture for the next generation mobile network infrastructure. China Mobile Research Institute introduced it in 2010. C-RAN is a radio access network architecture based on cloud computing. It has the potential to support 2G, 3G, 4G and future wireless communication standards. Issues such as capacity and coverage are addressed by C-RAN architecture while supporting mobile Fronthaul and Backhaul solutions. It has the capacity to carry out optimization, configuration and adaptation of the network with software control and management through Software Defined Networks and Network Function Virtualization. C-RAN aids in bringing down the operational costs and improving the network’s security, flexibility and controllability.

4.1. Need for Cloud-RAN

**Alternative to fibre:** To accommodate for exponential traffic growth, there is a need to expand capacity and coverage of the network. A solution for this is fibre, but it is costly and difficult to install, hence more operators are turning to wireless solutions for less cost and less complication.

**Costly base stations:** Traditional BST( base stations) have limitations in their network architecture. Also they are costly to build and operate.

**Interference among BTSs:** For improving the system capacity, when more base stations are added, it results in frequency reuse. This ultimately leads to severe interference among base stations.

**Low utilization rate of BTS:** The traffic at every BTS fluctuates a lot as the mobile users are continuously moving. This phenomenon is called ‘Tide effect’. Hence the utilization rate of individual BTS drops very low.

4.2. The Cloud-RAN approach

The C-RAN is a distributed radio access network. In the C-RAN, CPRI (Common Public Radio Interface) or OBSAI (Open Base Station Architecture Initiative) interfaces are used to connect Remote Radio Heads (RRHs) to the baseband unit (BBU). The RRHs consist of three components: radio, the related amplification/filtering and the antenna. The implementation of the baseband unit is done separately and it performs the centralized signal processing functionality of the network. Decentralized the BBU provides a lot of advantages. Some of them include greater agility, savings in the costs, quicker service delivery and better coordination of radio capabilities among a number of remote radio heads. A centralized BBU can be formed by combining a number of BBUs as shown in figure 1. It depicts the transition from traditional RAN architecture to the Cloud Ran development. It is more or less a cluster of RRHs and BBUs in two dimensions. CRAN is of prime importance in LTE-
Advanced where new interference control methods will gain from the parallelism and greater processing power at the centralized baseband unit. [6]

![Fig.1. C-RAN Architecture](image1)

4.3 Virtualized RAN
The C-RAN architecture can evolve to a virtualized RAN which is a programmable architecture, capable of being software defined and tuned as shown in figure 2. In the virtualized RAN architecture, the BBU functionality and the services in its pool that can manage demand based resource allocation, interference control and mobility can be virtualized for a large number of interfaces using programmable software layers. V-RAN architecture enables capacities that are software defined. With V-RAN it is possible to cache selective content which lowers the capital and operational expenditure and also improves the user’s cloud infrastructure experience.

4.4 C-RAN Architecture Implementation Example
Inter-cell interference, land shortage for building base stations, costly and heavy infrastructure are all hindrances to improve network coverage and capacity. Cloud-RAN is a perfect alternative to resolve all the above mentioned issues. Figure 2 shows a cost efficient and scalable C-RAN for deployment in crowded urban areas.

This architecture is based on small cells capable of self configuration. Many such cells together use fronthaul E band radios to connect to baseband processing pools. There exists Line of Sight connection between cells and the baseband pool. Interference is managed by connecting baseband pools to each other and to the centralized EPC core and mobility is controlled by CPRI Interface. With these solutions cost can be reduced and network capabilities can be increased through integration of C-RAN and other applications by the SDN and RAN controller. [3]

![Fig.2. C-RAN Architecture with integrated SDN](image2)

CONCLUSIONS
5G is the next concrete step for the communication industry. Cloud technologies along-with SDN and NFV architectures will transform the entire communication ecosystem. In this paper we have discussed the various requirements of 5G technologies and how virtualized architectures gave way to cloud computing. The advantages, characteristics, business models and architecture of cloud computing that lay the foundation for cloud radio access networks (C-RAN) have been discussed. Finally, C-RAN architecture is implemented with integrated SDN that can increase network capabilities and accelerate 5G evolution. Cloud technologies, hence are the building blocks of future communication networks.

REFERENCES


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