Can mobile operators adopt Cloud computing for themselves?

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ABSTRACT

Cloud computing is the most talked about topic in information technology world. There are variety of definitions and perceptions about cloud computing. Some people think it as merely CPU and storage offering hosted on web, where one can buy capacity. While some others think that it's about hosted application on the web. However, apart from storage space on the web, the most common use of cloud computing is access of software as a service from anywhere. More and more consumers and organizations are looking for services rather than investment in software and technology.

Many different businesses are moving ahead on adoption of cloud computing. In this essay, I have attempted to research on identifying the feasibility and conclusion about **"Can mobile operators adopt Cloud computing for themselves?"** My research is based on study of architecture of mobile network and functionality of network elements, their location and connectivity types to evaluate whether the element is candidate for migrating to cloud. Apart from study, I also conducted interviews of technical expert as well as operator expert to ascertain the practical aspects. As the outcome of the analysis I reached a conclusion that, with the advances in signaling connectivity, most of the core network computing elements can be setup on cloud and mobile operators can avail it as a service. This subject still being at nascent stage further research is required.

[Word Count: 228]

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Introduction

My trigger point of thinking about Cloud computing was a curiosity from its usage as a consumer. From my mobile I click a photo and it automatically gets uploaded to SkyDrive. I use Gmail without buying any email software like Microsoft Outlook and Google Drive to store and share my documents. As I explored more about Cloud computing, I realized that adoption of the Cloud computing is gaining momentum as it enables individuals as well as organizations to avail computing services without worrying about the choice and spending on computing hardware or software. Today's Cloud computing paradigm is primarily used to deliver enterprise level applications and end-user applications over the Internet.

The Cloud services relieve enterprises from the operational and maintenance overhead of the computing infrastructure. When I looked for the various applications available on cloud I discovered that businesses like retail, travel, manufacturing, banking and education, instead of building own infrastructure, have started adopting cloud services from providers like Amazon EC2, Rackspace etc. Examples of such cloud based services for enterprises are SalesForce, NetSuite, Google Apps and many more. However, I came across a discussion where I found that mobile operators primarily use computing technology and make large investment in infrastructure to deliver services to the subscriber. The high investment requirements for mobile operators results in higher cost of service to the consumers. There could be potential for mobile operators to harness benefits of Cloud computing in order to reduce costs, improve profitability as well as provide affordability to the subscribers. I couldn't find any success story of cloud services for telecom. This prompted a question in my mind, "**Can mobile operators adopt Cloud computing for themselves?"**

Answer to this question required me to gather understanding of both areas of Cloud computing and mobile network architecture and connecting the two.

Overview of Cloud Computing

Generally, there are different views about definition of Cloud Computing. Some people consider Cloud computing same as grid computing that allows the use of hardware and software resources over a network [1]. Most people perceive that Cloud service means ordering computing resources like CPU, memory and storage space on the net for hosting own application. I also had same perception till I found its real definition.

Cloud Computing, as defined by NIST, "*is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*" [2].

Cloud computing can be offered to the businesses in the form of three service models[3], Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) or Infrastructure-as-a-Service (IaaS).

It can be offered as collection of technologies that can be implemented in different models[3] which are primarily based on the scope of sharing the Cloud infrastructure[4], such as:

Public cloud is the well-known implementation model where the providers offer services to any varied organizations or consumers and is accessible on public network like Internet.

Hybrid cloud [5] is the implementation model where the services use combination of private and public clouds. In this case the computing power for both local and remote is used in optimized manner.

Private cloud is the implementation model where the dedicated Cloud infrastructure is shared among the geographically dispersed entities of a business. [6]

Further the key development of virtualization technology has made it possible to abstract [7] the application and platform from the underlying physical hardware and network. Companies like, vmware, Microsoft, Oracle are pioneering these technologies providing immense flexibility in cloud computing paradigm.

Virtualization also brings an added advantage of high availability and business continuity[8] with minimal efforts. Thus virtualization would make the Cloud computing paradigm more attractive to Mobile Network Operator (MNO) for adoption.

Why should MNO embrace Cloud computing paradigm for themselves?

There are two key reasons, which could be the drivers for MNO to embrace Cloud computing for their own benefits.

Firstly, global mobile communication growth have exploded in last 16 years from small population of elite users in late nineties to large population of general users, with current subscriber base of nearly 3.2 billion[9] and estimated to add approximately 1 billion subscribers by 2017, as shown in Fig.1 and the corresponding revenue growth as shown in in Fig.2.

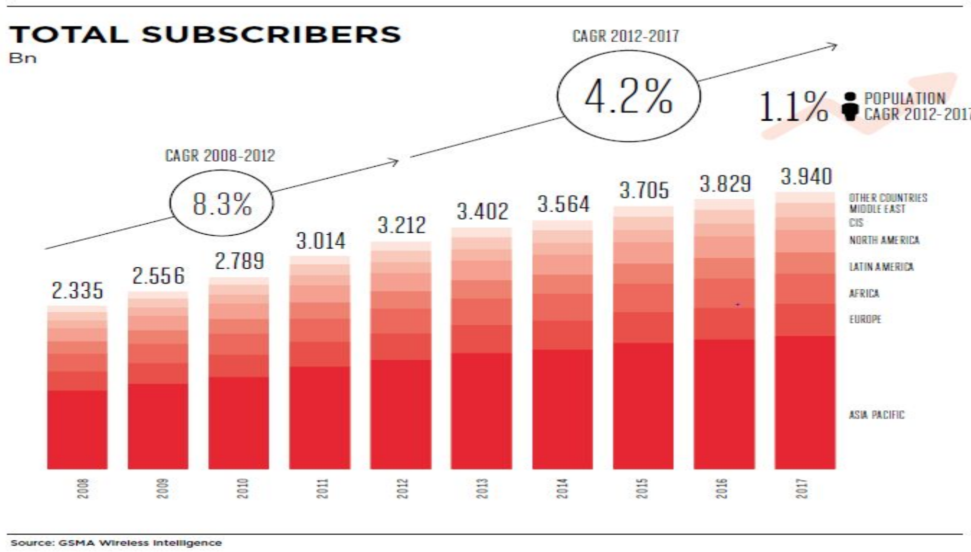

Fig. 1[10] Total Global Mobile Subscribers Trend 2008-2013 and projection

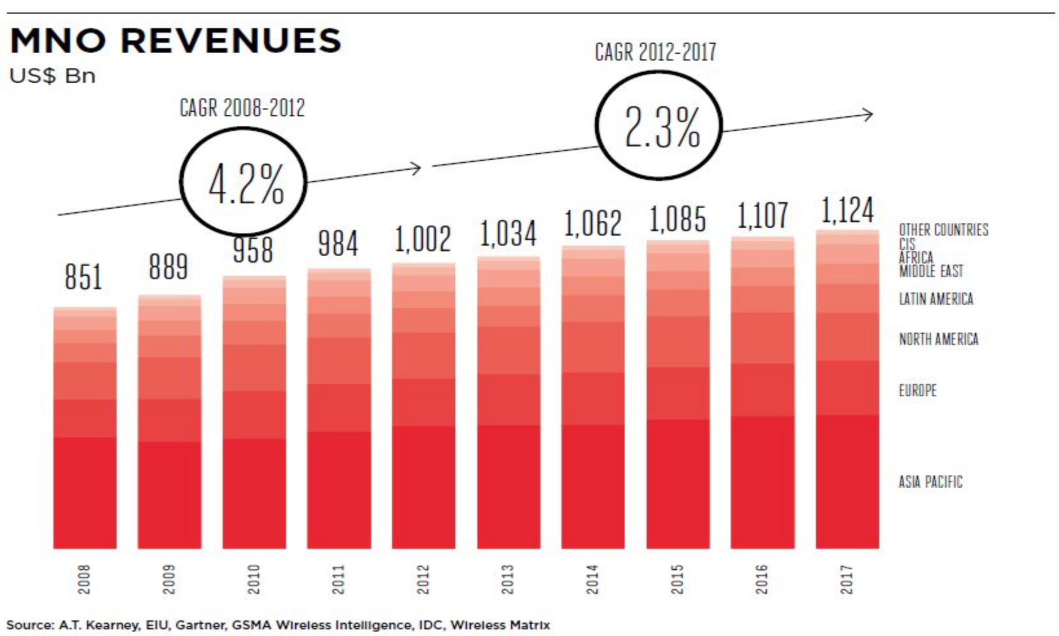

Fig. 2[11] Mobile Subscribers Trend 2008-2013 and projection

Comparing Fig 1 and Fig 2, clearly the growth in revenues for mobile network operators lag growth in usage due to continuous price declines [11].

Based on the interview and literature, I discovered that telecom regulators in various markets are driving subscriber growth by reforms and fostering competition. For example in India the regulator TRAI spurred the competition enabling 12 operators within a decade. Similarly in Europe the recent Regulation III of BEREC for decoupling of roaming has been towards the objective of reducing roaming rates for the end subscribers. [Appendix C]

Thus due to competition offered by new entrants and pressure from regulatory reforms, mobile operators continuously need additional investments to create new networks or expand existing networks.

Secondly, the technological advances have increased the pace, within a decade the wireless technology has quickly evolved from 2G, 3G and now 4G.[13]

As per the Network Working Group[13], "traditionally, the mobile core network equipment is dedicated telecom equipment; many of them are based on dedicated hardware platform, tightly coupled with the network". Thus it lacks flexibility[13] in the infrastructure to grow quickly. The overall network consist similar tightly coupled multi-vendor technologies.

It is difficult for operators to invest huge CAPEX quickly, while facing downwards pressures on the service pricing.

Emergence of many providers of Cloud computing and the adoption of open standard interfaces can open up avenues for operators to rollout new services quickly, than what they themselves could do.

With technological advances some of the applications or services become obsolete quickly either due to technology advances or regulatory changes. Example operators invested in systems for value added services like Welcome SMS, call correction, call back service, missed call alerts, etc. Now as these applications are becoming obsolete [Appendix C], it has resulted in dead investments for the operators in short span.

Cloud computing as well as services adoption would enable operators to release the computing resources easily or reuse them for newer applications.

Similarly, operators need not to worry about the upgrade and migration of application due to hardware obsolesces. The Cloud service providers can upgrade the hardware without impacting the application, thanks to advances in virtualization technology, for example vMotion developed by VMware Inc..

Mobile Network Architecture

The next step is to understand the architecture and various subsystems of the mobile network in order to determine which of the subsystems or elements may be candidates for outsourcing on cloud. In this section I have covered brief description of various functional blocks of mobile networks.

Mobile network operators typically service wide range of populations, starting from few thousands in small city to millions across highly populated geographies. Mobile networks are built up of large scale complex infrastructure that can be categorized into five major areas of operations, namely, Radio Access Network (RAN), Network and Switching Subsystem (NSS), Value Added Services (VAS), Operations Support Subsystem (OSS) and Business Support Subsystem (BSS).

RAN - The Radio Network Access consists of physical infrastructure to transmit radio signals of subscriber's mobile device to and from the local antennas and base trans-receiver stations (BTS). The radio trans-receiver antennas are installed on high towers or on top of the buildings. These are connected to the BTS. The BTS is connected to Base Station Controllers (BSC), which in turn connect to Mobile Switching Centre in the core network.

NSS – The Network and Switching System of mobile network consists of following key functional parts like Mobile Switching Center (MSC), Gateway MSC (GMSC), Home Location Register (HLR), Authentication Centre (AuC), Visited Location Register (VLR), Short Message Service Center (SMSC), Gateway GPRS Service Node (GGSN) and Serving GPRS Service Node (SGSN). There are also some more ancillary elements not listed here. All these elements interconnect with each other via Signaling Transfer Point (STP) connect to RAN via MSC to provide basic services like mobility, voice, short message and data services, to the subscriber.

Besides their own infrastructure, the mobile networks also invest in equipment to connect to other fixed line networks, known as PSTN, or mobile networks for global reach and to enable mobility.

VAS – The Value Added Services in mobile network are the subscriber services that are offered in addition to basic services. These are specialized services built by various innovators, which enhance the subscriber experience by offering service such as messaging, alerts, content, roaming value added services.

OSS – The Operations Support System comprises of the IT systems that help the operator to monitor, operate and manage all the network elements of RAN and NSS.

BSS - Business Support System, are the IT systems that support business operations like customer relationship management (CRM), Order management, Revenue management and billing processing for the operators. These systems are connected to the NSS and VAS elements and fetch the call detailed records from those elements for the billing processing.

Besides elements within the network, mobile networks also connect to other local and international networks through the gateway equipment like GMSC and GGSN.

Below Fig.3 illustrates the typical functional architecture of mobile network, reproduced from publicly available information and my understanding. This diagram is referenced in subsequent sections when describing the adoption model of Cloud computing.

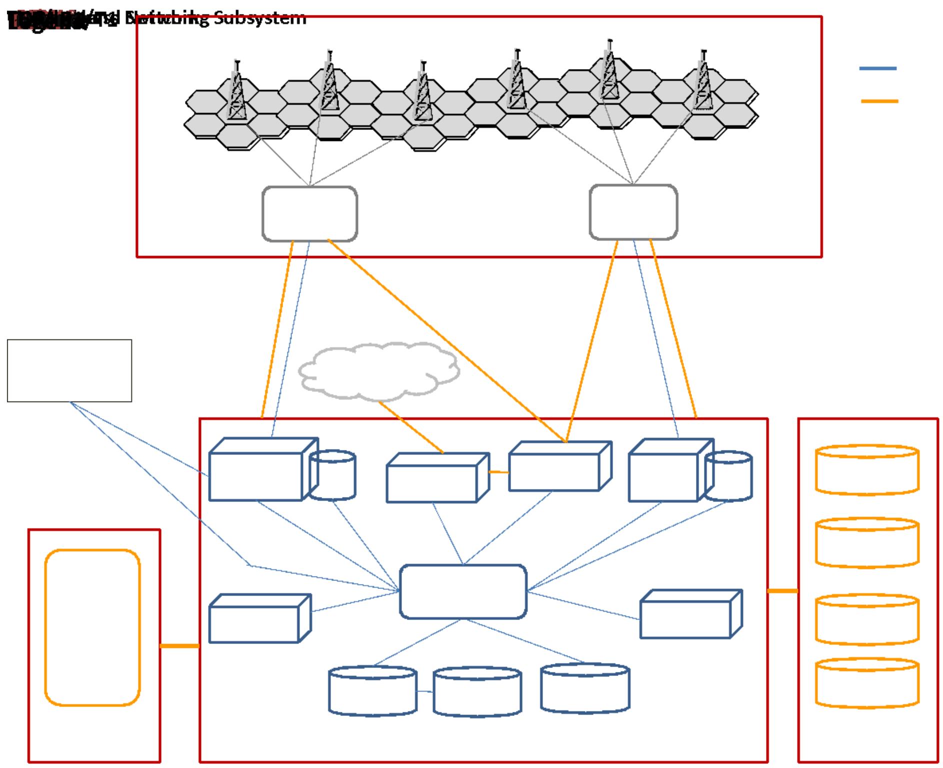

Fig. 3 Illustrative Functional Blocks of mobile network

Analysis of Network connections

In order to determine which subsystem can be migrated to cloud it is important to analyze the various network connections and determine the feasibility of connectivity to the Cloud computing infrastructure.

There are primarily three primary types of interfaces in mobile network:

- Signaling Interface – this interface connects various network elements with each other on well-defined standards and protocols by ITU-T.

- Media Interface – This interface essentially carries voice and media on the physical E1 or T1 lines.
- IP Interface – This interface is used for packet data services as well as connectivity with IT systems like OSS/BSS.

Media Interface

Mobile Switching Center (MSC) and other voice processing systems like interactive voice response systems, call conferencing etc. traditionally used ISDN lines to carry voice and media. In more than a decade the voice-over-IP (VoIP) has already been put in use by long distance carriers, enterprises and even mobile operators. This is extensive subject in itself so I have excluded it from my research as I believe that voice or media processing is not the right candidate for cloud service for the reasons mentioned in next section.

IP interface

From the technical perspective this is obviously supported in cloud model, hence I would not describe it further.

Thus out of all the three key interfaces, the core subject of my analysis is signaling interface.

Signaling Interface

Various network elements in mobile networks connect with each other using physical lines namely, E1 or T1. The signaling between the network elements is carried by Signaling System 7 (SS7).

Signaling System No. 7 (SS7) has been evolved from point to point signaling into routable signaling since 1976, as a highly reliable signaling system. The detailed description of the signaling system stack is beyond the scope of my subject. However, I would like to draw your attention to Message Transfer Part (MTP) which comprise of three sub layers MTP 1, 2 and 3, equivalent to physical layer, data-link layer and network layers of OSI model of IP world, respectively. Although the typical computing equipment is a server, it requires special adapter card for signaling processing, thereby increasing the cost of the system.

To further understand the existing telecom networking, I would like to briefly touch upon how the two systems interact through a routable topology.

For example, as illustrated in the Fig. 4, below the HLR and MSC interface with each other using SS7 signaling. Both these elements also connect to variety of the other elements within NSS and outside to other networks. Direct connections, though possible between the elements, it would become nightmare to manage the physical cabling and also will require large number of ports on each element. To optimize the connectivity between various elements a star topology is used where each element can connect to all other elements through Signaling Transfer Point (STP), whose role is to route the messages between the network elements.

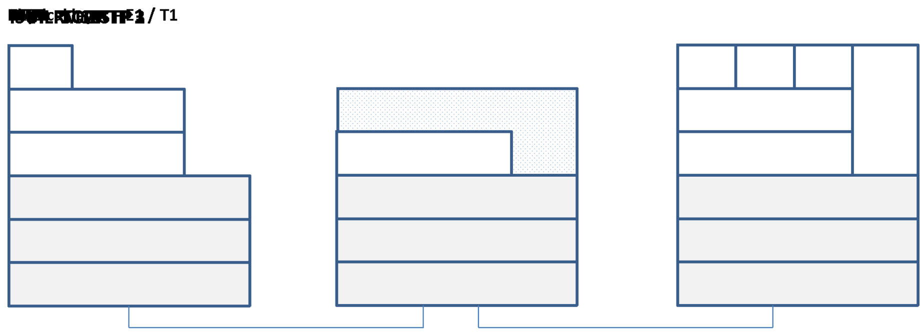

Fig. 4 Illustration showing connectivity between HLR and MSC via STP

Thus as shown in Fig.3 and Fig.4, STP could play a vital role in enabling connectivity to the cloud infrastructure. However the key challenge of this topology is that it is not feasible for cloud providers to setup E1/T1 connections as it would require high cost equipment at their end.

The requirement of E1/T1 links kept most of the systems confined to single location of the operator. Also in the Internet technology, the underlying transport protocols, namely, UDP and TCP commonly used in IT systems, were found unsuitable [14] for telecom signaling requirements.

With technological advances in IP networks it started becoming more evident that IP networks are more cost effective and flexible. In year 2000, IETF working group designed Streaming

Transport Control Protocol (SCTP) as highly efficient transport protocol for telecom signaling, replacing the UDP and TCP. SCTP was designed specifically to meet the transport layer performance as required by SS7 signaling [14].

This development resulted in further development of a carrier grade signaling system, called Sigtran, which together with SCTP provides emulation of SS7 layers in form of user adaptation layers[15] on IP network.

The user adaptation layers and different implementation models, defined by the Sigtran working group, are enabling variety of telecom equipment technologies transformed to use IP based connectivity.

Telecom equipment manufacturers have started building dual systems supporting both SS7 and Sigtran. This would help operators to slowly upgrade their systems to support IP.

Considering the same example as above, the HLR can now be hosted in IP network connecting to MSC with SS7 interface using specialized equipment called Signaling Gateway, which can translate SS7 signaling to and from Sigtran protocol. The signaling gateway functionality can be embedded in STP as shown in Fig.5 below.

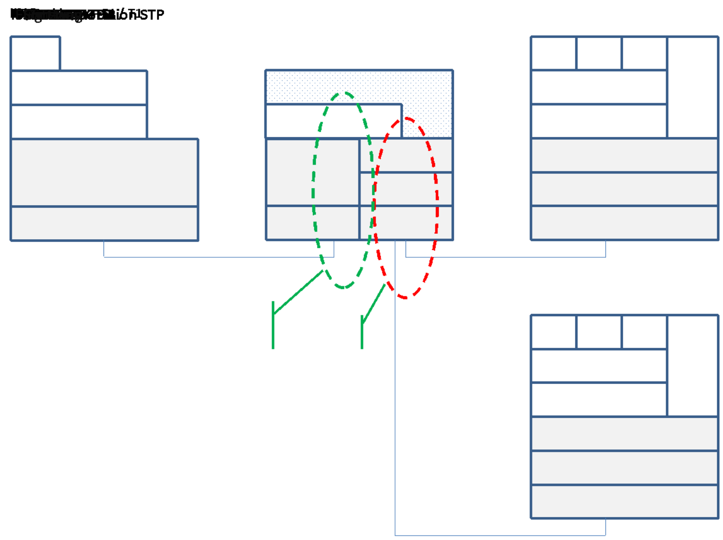

Fig. 5 Illustration showing Next Generation STP supporting SS7 and Sigtran

Now relooking at cloud deployment models, typical Public Cloud service provider provides service for consumers or enterprise applications supporting TCP/IP with enterprise grade performance.

There are three key reasons that public cloud may not be suitable deployment model for mobile operators,

(i) Sigtran requires high performance and high quality connections,

(ii) Most regulators require the subscriber data to be maintained within the country and under strict security compliance

(iii) The public cloud is more vulnerable to security threats and DoS attacks, thereby reducing the reliability of the service.

A cloud service provider may be able to offer dedicated cloud computing infrastructure which is highly protected from public access. It can be possible to support high performance Sigtran interfaces on such dedicated cloud. This can be possible either on Private Cloud or Hybrid Cloud.

Selection of Subsystems or elements that can be served by Cloud service

In this section I have analyzed the choice of subsystems or elements based on two main criteria, (i) functionality and (ii) type of interfaces.

RAN systems are not candidate for cloud service as these cannot be centralized due to wide geographic distribution and multiple types of interfaces. The RAN systems are connected to NSS via dedicated leased lines E1/T1.

For purpose of my subject, I focused on various connectivity required by the elements of NSS. It is important to understand what type of computation each element performs and kind of interfaces that it requires.

Mobile Switching Center (MSC) & Gateway MSC (GMSC):

Function & Location: This provides switching functions in the network and handles control messages and voice call control and switching functions. It handles high volume signaling transactions and media. For the usage of the voice service this system generates CDRs, which are used in the billing processing. GMSC is special function that enables connections to other networks and enables connection to own subscribers. *There are multiple MSCs and GSMCs* located in operator's own datacenters.

Interfaces: MSC connects to

(i) All the BSCs within its coverage SS7 and E1/T1 lines. These interfaces carry control functions and media.

(ii) Peer MSCs for routing of calls.

(iii) Voice processing equipment like IVR and call control services using E1/T1.

(iv) HLR, VLR and other VAS nodes using SS7 or Sigtran.

Analysis: This being the core control, media handling and billing point of the system, operators will want to retain this within their direct operational control. Also the Cloud computing paradigm is yet to include media processing and switching. Hence this element cannot be serviced by Cloud service.

Visited Location Register (VLR):

Function & Location: VLR is a database application that stores temporary subscriber profiles who is visiting [16] in its coverage area. VLR provides information to MSC and other service control points. MSC and VLR are commonly integrated into single system and are located in operator's datacenter.

Interfaces: Normally MSC and VLR are integrated with internal interfaces. VLR interfaces with HLR and other application nodes on using SS7/Sigtran.

Analysis: VLR being mostly integral part of the MSC, hence it also is not the right candidate for Cloud service.

Home Location Register (HLR) and Authentication Center (AuC):

Function & Location: This is a database application which consists of subscriber profiles with identity of subscriber, its mobile number and the services enabled. Various NSS elements connect to HLR query HLR to determine which services to be provided to the subscriber and how. HLR maintains subscriber profiles based on the information received from the provisioning system of BSS.

AuC provides authentication parameters to MSC to perform authentication procedures. [17]

HLR is located in operator's datacenter. AuC is generally integral part of HLR. [17].

Interfaces:

(i) HLR connects to STP using SS7/Sigtran.

(ii) HLR provides TCP/IP interface to connect the provisioning system in BSS

Analysis: Unlike normal enterprise applications connecting to the databases over TCP/IP, the NSS elements query HLR using a protocol called Mobile Application Part (MAP) using SS7/Sigtran.

Thus by building HLR which supports Sigtran, it can feasible to host on Cloud services.

However, AuC being highly sensitive to security and fraud, it may require the stringent security compliance from the provider.

Equipment Identity Register (EIR):

Function & Location: It is a database that contains information about the identity of the mobile equipment. It prevents calls from unauthorized, or stolen mobile stations.[17] EIR is located in operator's datacenter as part of NSS.

Interfaces:

(i) EIR interfaces using MAP protocol with MSC [18], using SS7/Sigtran.

Analysis: EIR supporting Sigtran can be a candidate for Cloud services.

Service Control Point (SCP):

Function & Location: SCP provides call control for Intelligent Network (IN) application services. This consist of variety of intelligent value added applications. The main application service provided by SCP is pre-paid charging. SCP is located in datacenter as part of NSS.

Interfaces:

(i) INAP or CAMEL protocol over SS7 or Sigtran for communication with HLR, MSC, SMSC and other VAS[6].

(ii) IP interface with Charging system and other VAS[6].

Analysis: SCP supporting Sigtran interface can be a candidate for Cloud services.

Serving GPRS Service Node (SGSN) & Gateway GPRS Service Node (GGSN):

Function & Location: SGSN delivers data packets from and to the mobile subscribers within its service area. This functions as identical to MSC-VLR. It provides data services and Internet access to subscribers through GGSN. Both SGSN and GGSN are located in operator's datacenter in NSS.

Interfaces: SGSN connects to

(i) BSC over TCP/IP interface

(ii) GGSN over TCP/IP interface

(iii) HLR, MSC-VLR and EIR over SS7 or Sigtran interface.

(iv) Other GPRS networks

GGSN connects to

(i) SGSN over TCP/IP interface

(ii) HLR over SS7 or Sigtran interface.

(iii) Packet Data Network and Internet over TCP/IP

(iv) BSS systems over TCP/IP

Analysis: Both GGSN and SGSN, supporting Sigtran, can be a candidate for Cloud service.

Value Added Services (VAS):

Functions & Locations: VAS systems provide value added services like messaging, intelligent call control and user experience beyond basic services. These are mostly located in mobile operator's own datacenters. However in recent years some of the VAS services providers have started offering hosted services like SMS VAS and MMS from the public network.

Interfaces: VAS systems connect to

(i) various NSS elements on SS7 or Sigtran

(ii) BSS systems over TCP/IP

Analysis: VAS systems, supporting Sigtran, can be a candidate for a Cloud service.

Operations Support Systems (OSS):

Location & Interfaces: The functionality of OSS is already briefed in Section 4. OSS is located in operator's datacenter and it connects to all the elements of mobile network over TCP/IP.

Analysis: These are IT systems and are obvious candidates for cloud services. However in case mobile operator as per my analysis in this section, RAN and MSC are not the candidates for cloud service. Hence these would need a portion of OSS in the NSS to be able to monitor and manage them.

Business Support Systems (BSS):

Location & Interfaces: BSS provide monitoring and management of all elements of RAN, NSS and BSS. It is located in operator's datacenter along with NSS, these systems connect to all the elements of mobile network over TCP/IP.

Analysis: These are IT systems that exchange the data with core network elements and do not require any signaling interface. These are can be run on cloud infra similar to any enterprise application.

Based on the analysis in section 5 and 6, the reference architecture of Fig.3 can be migrated into cloud infrastructure, as per my analysis RAN, MSCs, GSMC and SGSNs would need to be retained in NSS and implementing rest all elements to a Private or Hybrid Cloud as proposed by me in Fig.6 below. MSC may still require traditional SS7 signaling connectivity and routing, this will require the next generation STP to be retained in NSS. This STP can connect to STP, in the proposed Cloud, using Sigtran interface. The Cloud system shall host all remaining 100% IP based elements of NSS, OSS and BSS.

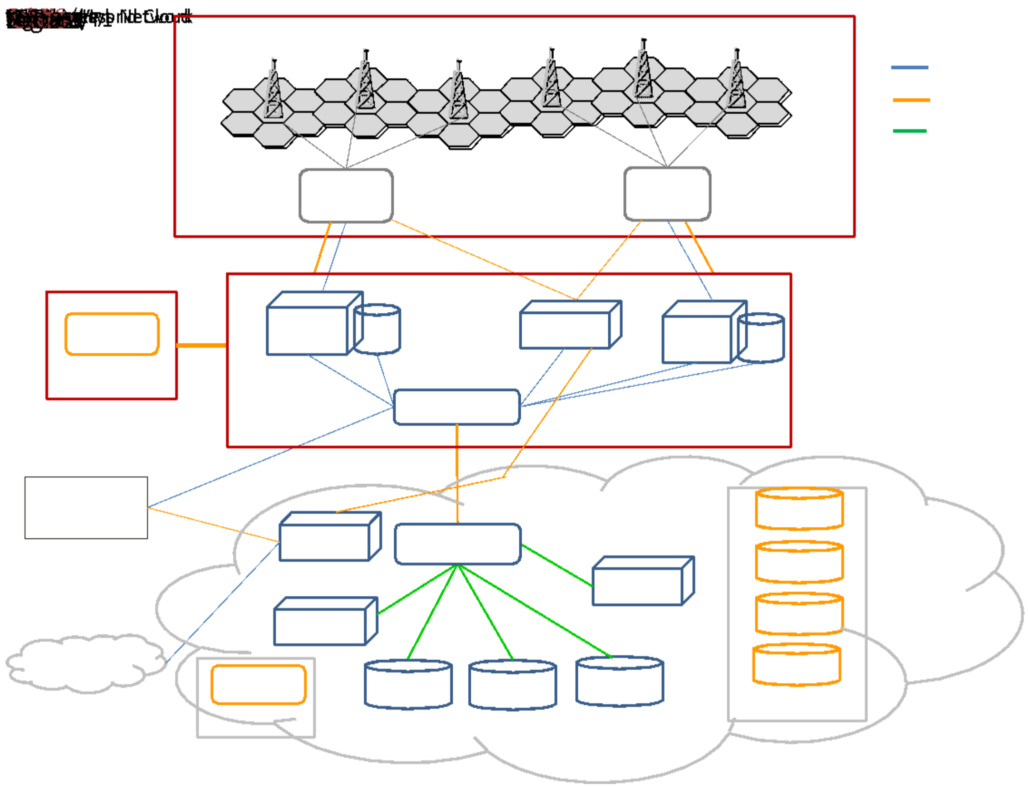

Fig. 6 Proposed Private Cloud setup for mobile operator

Conclusion

It is evident that the operators are being compelled to look for newer avenues of cost reduction, improving profitability as well as catering to regulatory compliance. The initiatives taken by IETF to build high performance transport layer SCTP has enabled the development of adaptation layers for supporting SS7 over IP networks. I can conclude that most of the equipment of NSS, VAS, OSS and BSS can be converted to full IP infrastructure. **Operators can start considering adopting Cloud computing,** in other words, they can outsource their infrastructure requirements to cloud services providers. Certainly the pure IT play applications like OSS, BSS can be migrate to cloud. Then starting from VAS and incrementally core NSS elements can also start migrating to cloud. I am aware that my research has been still preliminary and nascent, only considering the key aspect of connectivity. I do realize that in my proposed cloud architecture, there may still be technical complexities to be explored. Further research is required in other aspects of cloud architecture, like, security, performance, scalability and reliability, for mobile operators to accelerate the adoption of cloud computing.

[Word Count: 3898]

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Appendix A

Acronyms

2G	Second Generation network
3G	Third Generation network
4G	Fourth Generation network
AuC	Authentication Center
BEREC	Body of European Regulators of Electronic Communications
BSC	Base Station Controller
BSS	Business Support Subsystem
BTS	Base Trans receiver Station
CAP	CAMEL Application Part
CAPEX	Capital Expenditure
CPU	Central Processing Unit
CRM	Customer Relationship Management
EIR	Equipment Identity register
GGSN	Gateway GPRS Service Node
GMSC	Gateway MSC
HLR	Home Location Register
IaaS	Infrastructure-as-a-Service
IETF	Internet Engineering Task Force
INAP	Intelligent Network Application Part
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISUP	ISDN Services User Part
IT	Information Technology
ITU-T	International Telecommunication Union
MAP	Mobile Application Part
MNO	Mobile Network operator
MSC	Mobile Switching Center
MTP	Message Transfer Part
NIST	National Institute of Standards and Technology
NSS	Network and Switching Subsystem
OMC	Operations and Management Centre
OSS	Operations Support Subsystem
PaaS	Platform-as-a-Service

PSTN	Public Switched Telephone Network
RA	Revenue Assurance
RAN	Radio Access Network
SaaS	Software-as-a-Service
SCCP	Signaling Connection Control Part
SCTP	Streaming Control Transport Protocol
SGSN	Serving GPRS Service Node
SMS	Short Message Service
SMSC	Short Message Service Centre
SS7	Signaling System no. 7
STP	Signaling Transfer Point
TCAP	Transaction Capability Part
TCP	Transport Control Protocol
TDM	Time Division Multiplexing
TRAI	Telecom Regulatory Authority of India
UDP	User Datagram Protocol
VAS	Value Added Service
VLR	Visited Location Register
VoIP	Voice over IP

Appendix B

Interview #1

Interviewee Name **:** Purav Chovatia

Position **:** Principle Architect, R&D, Roamware India Pvt. Ltd.

Date & Place **:** 12/22/2013, Mumbai, India.

1) Which are the main functional blocks of telecom infrastructure?

Radio Access Network (RAN)

Core Network also known as Network Support System (NSS)

Value Added Services (VAS)

Operations Support System (OSS) / Billing Support System (BSS)

2) Where are these located?

RAN - This is network of are physical antennas and base trans-receiver stations spread across geographical area. These BTS connect to Base Station Controller, which in turn connects to core network MSC.

Core NSS - Elements like Home HLR, VLR, and MSC are located in datacenter of operator. For geographic redundancy there are two datacenters

VAS - These are end node applications and are located in the datacenter of operators. Some VAS application providers have started hosting the service in external datacenter

3) What are the lists of mobile network interfaces?

Telecom network has following interfaces

Signaling: Signaling System 7 (SS7) or SIGTRAN

Packet Data: TCP/IP

IT Systems: TCP/IP

Signaling interface are known as Circuit Switched Domain.

IP interfaces for packet data are known as Packet Switched Domain.

4) How SS7 works?

SS7 is the protocol stack that connects the two telecom equipment, in order to exchange the messages.

This two telecom equipment can be connected using a physical line like E1/T1, using special interface cards.

The traditional SS7 network across the globe is independent of public IP network. This requires Operators to lay down point-to-point links.

6) What systems are key systems involved in Core Network and what are their interfaces?

Core network consists of following elements:

Home Location Register (HLR) - It consist of database of subscriber profiles which identifies the unique identity IMSI, mobile number and various services enabled.

Various network equipment queries these HLR to fetch subscriber profile to determine which services can be provided to the subscriber and how.

Visited Location register (VLR) - It consist of database of subs visiting its area of coverage. This element is connected to various radio base stations using operators own network.

Mobile Switching Center (MSC) - This is the telecom switch with controls the signaling and calls handling in the network. Traditional MSCs have been supporting.

Gateway GPRS Support Node (GGSN) - this is the telecom node which control the data services for the mobile subscribers in home network.

Serving GPRS Support Node (SGSN) - this is telecom node which control the data services for the mobile subscribers in visited network.

7) What is the nature of telecom interfaces?

All the interfaces are sensitive to latency, as in real telecom network the call needs to get connected within finite time; user should be able to register on network quickly.

User experience is key to the service quality.

8) Are there any of the mobile operator services hosted outside their own network?

Yes, in recent years some VAS vendors have started offering hosted services. This primarily is related to SMS and MMS VAS.

It is because the interface between SMSC/MMSC and applications has been on TCP/IP.

9) What will it take for GSM operator to provide connectivity from their existing network to Cloud Systems?

The GSM operators these days are connected through IP backbones using IPX/MPLS. IPX based peering provides low latency high speed layer 2 connectivity on public networks. Same infra can be used to connect to cloud if the cloud provider also has such connectivity.

10) What are the market drivers for GSM operators to look for alternate options?

*The increasing objectives of regulators reducing the costs for the consumers and the market competition is forcing the operators and technologists to look for new avenues to reduce investments and costs.

*A typical technology adoption and investment takes long cycle. Also the investment in new technologies is risky and waiting for getting it proven results in longer time to market. If there is possibility of making the new technology available for quicker adoption and with lower risk it would help operators.

*With fast changing technology operators are not able to keep up pace with building in-house competency. They need faster service rollout and churn the services quickly.

11) What are the key challenges for operators to outsource the systems on Cloud?

The key challenges for the operators to outsource systems on Cloud are:

a) Security of data, regulatory compliance and legal issues.

Most regulators require the subscriber data to be maintained within the country. This prevents the operators to let the services to be hosted on Cloud infrastructure which is physically spread across the countries.

b) Quality of Service (QoS): Due to latency introduced by distances, the operators get concerned about the lower QoS when hosting outside.

c) System availability and performance: Operators would expect high level of system availability and performance.

Appendix C

Interview #2

Interviewee Name : Ashish Gayal

Position : Telecom Professional, Operator Experience <Company name restricted upon request>

Date & Place : 12/28/2013, Mumbai, India.

1) What are the key areas of investment for mobile operators?

Other than investment in normal business operations, the key areas of investment are a) spectrum b) radio and network infrastructure c) business systems.

2) What are the key challenges of the mobile operators?

a) Fast changing technology obsolescence requiring high additional investments.

b) Regulators want to open up market by promoting competition in telecom services. This requires operators offer services in competitive rates.

c) Cost reduction

3) What are the market drivers for GSM operators to look for alternate options?

*The increasing objectives of regulators reducing the costs for the consumers and the market competition is forcing the operators and technologists to look for new avenues to reduce investments and costs.

*A typical technology adoption and investment takes long cycle. Also the investment in new technologies is risky and waiting for getting it proven results in longer time to market. If there is possibility of making the new technology available for quicker adoption and with lower risk it would help operators.

*With fast changing technology operators are not able to keep up pace with building in-house competency. They need faster service rollout and churn the services quickly.

4) Can you give me some example of obsolesce?

I can give you many examples that I know. Many operators implemented welcome sms application, this required huge signaling and processing. Operators invested in it. The purpose of this value added application was to send useful local information when they travel. Lately due to smartphones and data services becoming affordable, users are able to get local info from web.

Another examples of once innovative applications like call back application, call correction were useful to operators when roaming rates were high. With regulators pushing operators to slash rates, these applications are now becoming obsolete.

SMS becoming cheap as well as availability of chat applications have caused missed call alert application useless.

5) How does regulator promote competition?

Regulator's create and enforce policies by which they enable new businesses to enter into telecom services markets. One of such policy category is to regulate and keep lowering cost for the consumers. One of the examples is recent EU Regulation III known as decoupling of roaming. Aim of this regulation is to lower the roaming costs for the subscribers. This is done by enabling new businesses as Alternate Roaming Providers.

Similarly in India TRAI opened up market in last five years such that from originally few operators, now there are more than dozen operators offering the services.

6) What is the impact of EU Regulation III to the operator?

The operator will lose the high margin roaming revenue, but will need to still support the subscriber to roam with alternate roaming providers. Thus it will continue incur the costs.

7) Can you explain how will operator incur cost when not offering Roaming service?

It is complex for you to understand. But at high level regulation is designed such that the subscriber should not require changing home SIM card when roaming.

This means the home operator is still required to support signaling with visited network, without any charges.

9) So this means home operator would spend extra without much returns, right?

Yes, in a way it will be burden to the operator.

10) Will you as operator adopt services on cloud?

For a large operator with millions of subscribers, it doesn't make business case to outsource to cloud computing. However specific systems like VAS can be considered on cloud.