Initiatives toward Moving Access Networks for Implementing Large-Scale Content Distribution Infrastructure into the Cloud

Here we introduce initiatives aimed at moving access networks into the cloud conducted in collaboration between RIKEN Advanced Institute for Computational Science, Tokyo Institute of Technology, and IIJ as part of research sponsored by the National Institute of Information and Communications Technology.

3.1 Introduction

These days fast, stable broadband access lines such as FTTH are available to a growing number of users. There are also an increasing number of services that utilize fast broadband networks such as SaaS.

In response to these changes in the Internet environment, RIKEN Advanced Institute for Computational Science, Tokyo Institute of Technology, and IIJ conducted research into access network cloud computing under the sponsorship of the National Institute of Information and Communications Technology. This was part of a study commissioned by the National Institute of Information and Communications Technology for the research and development of advanced communications and broadcasting, under the title of "Research and Development of Network Virtualization Infrastructure Technology for Supporting Next Generation Networks".

The access network cloud is a platform for an environment in which users' access lines are connected to cloud providing services. Access network cloud services appear the same to users as Internet-based network services, but they allow service providers to provide services in close proximity to access lines.

In this article we introduce the access network cloud while looking back at methods previously used to provide service.

3.2 Conventional Service Models and Their Issues

3.2.1 The Centralized Data Center Model

In the early days of the Internet, content was delivered via a client-server model. High performance servers or additional servers must be implemented to achieve high scalability under the client-server model, making investment in massive data centers that require a large number of servers necessary. For example, it has been reported that Apple invested a billion dollars in its new data center.

3.2.2 The CDN Model

The Content Distribution Network (CDN) model, which involves establishing dedicated networks, appeared as Internet services expanded.

The CDN model adopts the technique of installing small-scale cache servers in regionally distributed data centers, instead of massive centralized data centers. In addition to balancing traffic loads, regionally-distributed cache servers also reduce latency between users and content servers.

Akamai, one of the biggest CDN, improves the user experience by caching multiple files from content servers on cache servers, masking latency between content servers and users due to the low latency between cache servers and users. Akamai has over 100,000*1 servers worldwide, and now accounts for 30% of Internet traffic.

*1 Akamai Technologies GK press release (http://www.akamai.co.jp/enja/html/about/press/releases/2012/press_jp.html?pr=102612) (in Japanese).

3.2.3 The P2P Model

As computers became more powerful and dropped in price, user PCs came to possess enough resources to operate as servers as well as clients. This led to the appearance of the P2P model, in which services are implemented by constructing peer-to-peer (P2P) networks where each device operates as an equivalent node.

The BitTorrent content distribution system is a well-known P2P protocol.

The P2P model achieves high scalability without requiring heavy investment by constructing distributed systems using the PC resources of users*2*3*4*5. P2P makes up a third of all network traffic today*6, so its scalability is already proven.

3.2.4 The Issues with Each Model

Centralized data centers and CDN both require massive system infrastructure. Additionally, resources must be expanded to cope with traffic that is expanding at an annual rate of 30%*7. For example, it has been reported that due to data center growth, data centers accounted for between 1.7% and 2.2% of overall power consumption in the United States in 2010*8. It is clear that both approaches leave little room for future expansion. Furthermore, the hosting of interactive Web applications and real-time games is becoming another important service for data centers and CDN. Because the latency issue is even more crucial in these areas, regionally distributed data centers are needed, requiring more investment.

The biggest issue with the P2P model is that it is difficult to predict future behavior, or in other words how long it will take to complete delivery. This makes it hard to improve the user experience. The reason for this is that some users' home PCs are extremely unreliable, causing P2P networks to be frequently unstable. Communications performance also varies greatly between nodes, leading to large fluctuations. Resolving these issues would result in a content distribution system that provides a superior user experience without requiring heavy investment.

Until now, P2P content distribution systems specialized in file sharing, but interactive Web applications and real-time games are also becoming more important. This means there is strong demand for functions that host these kinds of services without significant investment in distributed processing infrastructure for implementing P2P delivery.

3.3 Introducing the Access Network Cloud

We can expect computers to continue to become smaller, cheaper, and more powerful. Virtualization technology is also becoming more common. These factors open up the possibility for building an environment able to provide services in optimal locations via an array of countless network-based computing nodes.

*2 Open Networking Foundation, "Software-Defined Networking: The New Norm for Networks" ONF White Paper, Apr. 2012 Hiroya Nagao, Takehiro Miyao, Kazuyuki Shudo, "A Study on Theory of Structured Overlays Based on Flexible Routing Tables" IEICE Technical Report, vol. 111, no. 277, NS2011-115, pp. 67-70, Nov. 2011.

*3 Yasuhiro Ando, Hiroya Nagao, Takehiro Miyao, Kazuyuki Shudo, "FRT-2-Chord: A DHT Supporting Seamless Transition between One-hop and Multi-hop with Symmetric Routing Table" IEICE Technical Report, vol. 111, no. 469, IN2011-149, pp. 73-78, Mar. 2012.

*4 Shohei Shimamura, Hiroya Nagao, Takehiro Miyao, Kazuyuki Shudo, "A Reachability Ensuring Technique for A Scalable Wide-Area Routing Method" IEICE Technical Report, vol. 111, no. 469, IN2011-170, pp. 199-204, Mar. 2012.

*5 Masatoshi Hanai, Kazuyuki Shudo, "Simulation of Large-Scale Distributed Systems with a Distributed Graph Processing System" IEICE Technical Report, vol. 111, no. 468, NS2011-272, pp. 529-534, Mar. 2012.

*6 See the Broadband Traffic Report "Traffic Trends over the Past Year" in Vol.16 of this report (http://www.iij.ad.jp/en/company/development/iir/pdf/iir_vol16_EN.pdf).

*7 See the following Cisco Systems G.K. white paper (http://www.cisco.com/web/JP/solution/isp/ipngn/literature/pdf/white_paper_c11-481360.pdf) (in Japanese).

*8 See IPA, "New York Report Jul. 2012" (http://www.ipa.go.jp/about/NYreport/201207.pdf) (in Japanese), Analytics Press, "Growth in data center electricity use 2005 to 2010" (http://www.analyticspress.com/datacenters.html).

Now, let us imagine a world where computing nodes are ubiquitous on networks. The exchange where a provider's access lines are consolidated and access lines are connected to is considered ideal for providing low latency, high quality services to users. By building small-scale server clusters within the access line exchange, and preparing an environment that enables computing nodes to be launched when necessary using virtualization technology, service providers can provide services in close proximity to users.

We consider the access network cloud to be a platform for providing services in close proximity to users, so they do not need to be aware of where a service is being provided from in relation to their connection line when using it (Figure 1).

Regarding related research, in the United States the U.S. federal government announced initiatives relating to the construction of a high-speed broadband network in June 2012*9. For this project, known as the US Ignite Partnership, virtual infrastructure called GENI racks*10 is directly connected to broadband access lines to create next generation application services in a broadband, low-latency environment. Access network cloud technology is necessary to achieve large-scale application platforms such as this.

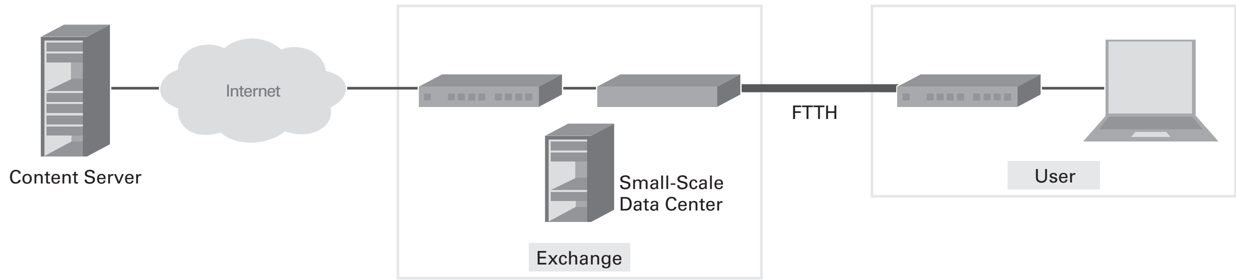

Figure 1: An Overview of the Access Network Cloud

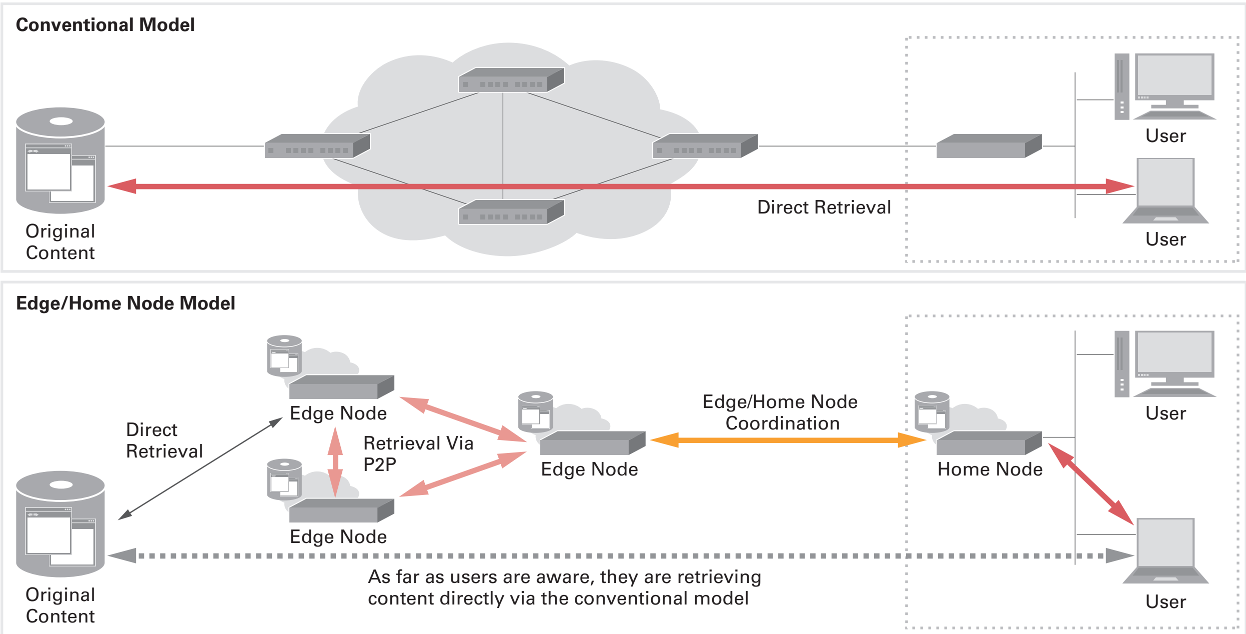

Figure 2: Comparison with Conventional Model

*9 US Ignite (http://us-ignite.org/).
*10 GENI Racks (http://groups.geni.net/geni/wiki/GENIRacksHome).

3.4 Methods for Providing Access Network Cloud Services

Access network cloud services are provided through coordination between home nodes operating on the user end of the access line, and edge nodes operating on the exchange end of the access line. Because edge nodes and home nodes coordinate to provide service to users, this is called the Edge/Home Node Model (Figure 2).

Home nodes have a role in directing users to edge nodes when they access services. The home nodes are located in the home of the user, and do not always operate on a constant basis. When users are not using a network service, it is possible to power down resources including home nodes to conserve power.

Edge nodes establish an environment for providing the services of content providers. They operate in stable access line exchange environments. Applications for providing services are run on edge nodes as required.

Service is provided in close proximity to users via the Edge/Home Node model in the following way.

1. Initially the applications for providing a service are not running on the edge nodes.
2. When a user starts using a service, they access a remote server as usual.
3. The content provider runs the application for providing a service on an edge node located in the consolidated exchange that the user's access line is connected to.
4. Once the edge node side preparations are complete, the content provider instructs the home node to switch to the service on the edge node.
5. Because the home node directs the user's access to the edge node, the user can make full use of their access line when using the service.

3.5 Conclusion

Here we gave an introduction to the joint research on moving access networks into the cloud conducted by RIKEN Advanced Institute for Computational Science, Tokyo Institute of Technology, and IIJ, while also sharing some of our thoughts on it. We envision that making the access network cloud a reality will usher in a world where low-latency, stable services are available to users.

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