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[パネル討論] 移動通信による世界的計算集約と衆知による情報処理

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あらまし　クラウドコンピューティングという概念で表現される情報処理環境が現れてからモバイル応用において何が変わったかを述べる．結果的にそれが”クラウド”の定義を与えることになる．第２世代携帯網により常時接続パケット通信が実現され，i-mode に代表される情報端末としての携帯が現れたが，今日のブロードバンド化とクラウドコンピューティングの組み合わせにより携帯の使われ方に相変化が起きようとしている．携帯がＰＣと大きく異なる点は２つある．１つはセンサーハブである．実世界の情報をクラウドに集約する．もう一つは個人情報ハブである．携帯を通して画像，音楽，メイル，スケジュール等の個人データがクラウドに集約される．さらにこれが個人を超えて社会的ネットワークとして集約され衆知が価値化されようとしている．クラウドコンピューティングを「通信による世界的計算集約と衆知による情報処理」と解釈しその現状を議論する．
キーワード　クラウド, 衆知,　ワイヤレスブロードバンド，センサーハブ，パーソナルデータ，クラウド端末

[Panel Discussion] Mobile, Cloud, and Crowd Computing

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Abstract　This is a story about evolution paths of mobile computing architectures after the emergence of cloud computing. As a result, the story gives us the definition of “cloud.” We firstly summarize the current progress of cloud computing in view of broadband cellular networks which offers Mbps-order, low-latency, and always-on packet connections. Many cell-phones are now being equipped with many I/O devices including GPS, microphones, motion sensors, and CCD cameras. Thus mobile “cloud” applications are going to be associated with real environments that will bring us context-aware capability. Moreover, cell-phones are now becoming crossroads of personal information such as mail, schedule, address, picture, and music, and consequently those connections facilitate new information hubs with the context-awareness. That mobile infrastructure has brought a highly-personalized and community-based popular communication culture that was never seen. The integration of the sensor hubs and the information hubs over people beyond individuals is now becoming a killer application incubation environment. We call it “crowd computing.”
Key words　cloud computing, crowd computing, wireless broadband, sensor hub, personal data, cloud device

1. Introduction

“Cloud computing” is a marketing buzzword in some communities with no real user experience. Does cloud computing mean gigantic scale server integration with scale-out technologies? The question is hard to respond for people who haven’t experienced benefits from cloud applications without knowing those are from clouds. More insights are needed to understand what it really means.

The concept of cloud computing is not far from Tim O’Reilly’s insight: Web 2.0 [21]. In 2005, what we saw was a paradigm shift in which the key concept consists of (1)The web as platform, (2)Harnessing collective intelligence, (3)Data is the next Intel Inside, (4)End of the software re-

Table 1 Web1.0 v.s. Web2.0.

Web 1.0	Web 2.0
DoubleClick	Google Adsense
Akamai	BitTorrent
Britannica Online	Wikipedia
Personal Websites	blogging
domain name speculation	search engine optimization
page views	cost per click
screen scraping	web services
publishing	participation
directories(taxonomy)	tagging("folksonomy")
stickiness	syndication

lease cycle, (5)Light weight programming models, (6)Software above the level of a single device, and (7)Rich user experience. In [21], we can see many examples of Web2.0 as listed in Table. 1.

What is changing from the original web.2.0 concept is that data aggregation and integration by clouds (i.e., web-scale servers) is in full progress and those have reached to a critical stage for communication paradigm shift. You can see those examples in Google applications [17],Twitter [13], [15], Facebook [16], Amazon mechanical turk [5], [14], etc.

This report conveys three major messages: 1.emergence of cloud devices and its impact to communication culture among people, 2.role of wireless broadband, especially of 3G Long Term Evolution (3G LTE) in the era of cloud devices, and 3. people and data as the essence of cloud computing. Let us figure out, through the report, the concept of cloud computing in a mobile telecommunication aspect.

2. Emergence of Cloud Devices

Since DOCOMO's 3G cellular network was launched in 2001, Japan, mobile network applications have been characterized by the following multimedia applications: e-mail, web browsing, games, video-clip & music download, and multimedia mail [12]. Those are early applications, in the emerging 3G mobile network era, ported from "fixed-line" Internet. Thus, those mobile applications have been considered as a degraded version of Internet applications due to limitation of available bandwidth, latency, connection reliability and text typing capability, where cell-phones are also considered as miniature portable PCs. Borrowing many ideas from Internet, however, the mobile infrastructure has brought a highly-personalized popular communication culture that was never seen before.

2.1 Cell-phone as Sensor Hub

Many cell-phones are now being equipped with sufficient I/O devices including GPS, microphones, and CCD cameras. Consequently, content delivery, interaction with contents, and e-commerce are going to be associated with real

Table 2 Cell-phone Sensors.

I/O	HTC	i-phone	3G Japan
Infrared	N.A.	N.A.	> 90%
Bluetooth	○	○	> 50%
Assisted GPS	○	○	> 80%
Accelerometer	○	○	> 50%
Digital Compass	○	○	N.A.
Proximity Sensor	N.A.	○	N.A.
Ambient Light Sensor	○	○	> 50%
NFC	N.A.	N.A.	> 50%

HTC: DOCOMO's first android phone since July 2009, 3G Japan: typical Japanese 3G phone with demographic data as of late 2009, NFC: near field communication a.n.a. Felica.

environments that will bring us context-aware capability. Table 2 summarizes the current I/O devices equipped on 3G phones in Japan's market as of late 2009.

Now we can recognize cell-phones in this way: cell-phone as sensor hub. Here is the clear distinction between mobile web and Internet web [11]. As depicted in Fig. 1, the sensor hub connects our real worlds to back-end servers. One good example is distributed speech recognition(DSR) developed by the author's colleagues in 2006 [19]. Fig. 2 shows the DSR architecture, in which the cell-phone is dedicated for phonetic feature extraction and the recognition process is rendered to the back-end server. Another example is Shazam [23], which is a music discovery engine for cell-phone users. By sending several seconds of captured audio data to Shazam's back-end server, the user can identify the music title.

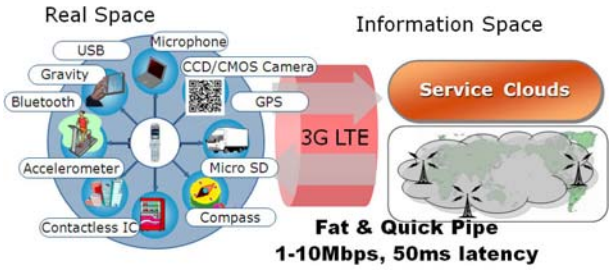

Fig. 1 Cell-phone as Sensor Hub.

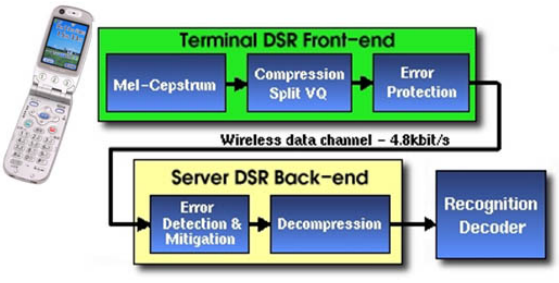

Fig. 2 Distributed Speech Recognition.

We can see many applications where cell-phones are working as front-end devices. Fig. 3 shows other applications:

Fig. 3 Sensor Hub Examples.

from left to right, wine label identification based on SIFT technology [18], 2D barcode, and e-commerce with near field communication. Regarding the visual search such as the above wine label identification, one of state-of-the-art applications is Google Goggle [1], which has integrated character recognition and fingerprint identification of CD titles and sightseeing pictures.

2. 2 Cell-phone as Information Hub

Let us take cell-phones the key to leverage the cloud computing as a powerful killer application enabler. With that aspect, we call cell-phones as "cloud devices." If the assumption is true for the term cloud device, we must pay attention to another aspect in addition to the peripheral enhancement. The second aspect is that cell-phones are now becoming crossroads of personal information such as mail, schedule, address, picture, and music, and therefore those connections facilitate new information hubs with the context-awareness.

The author's Android phone can be a good instance of the information hub, "Google calender" invokes "Google map" to guide users to meeting places. Thus schedule and navigation are linked by the personal data. Automatic lyrics finder, "TuneWiki [2]", teaches users lyrics for stored music contents. Moreover it promotes a social network which allows users to add, edit and synchronize lyrics to audio and video files in all languages; and displays location based charts and maps of music played around the globe. Situation-based application management framework, "Locale [3]" changes the phone setting, for example WiFi and ringer settings, based on user location. It is a tool which allows users to perform a number of actions based on conditions which the user predefine in the application. Actions include "Twitter [15]", and it can tweet user situations accordingly. Not limited to those Android applications, such personal data in cell-phones is now integrated, aggregated, and correlated each other. Moreover, owing to cloud servers, the data is now being off-loaded from the cell-phones. Fig. 4 summarizes what we are seeing about cell-phones as information hubs. As of late 2009, it is said that Google has 10M Servers, Facebook has 60B+ images with 25TB of new image data upload /week, and Youtube has 30-hour video upload/min. Before the cloud computing emerged, cell-phones remained as gadgets which store personal inoformation to carry. After the emergence, the cell-phones have become cloud devices. That is essentially noteworthy point to consider the communication paradigm shift. That differentiates the new paradigm from the old web2.0 concept. The section 4. will describe the shift.

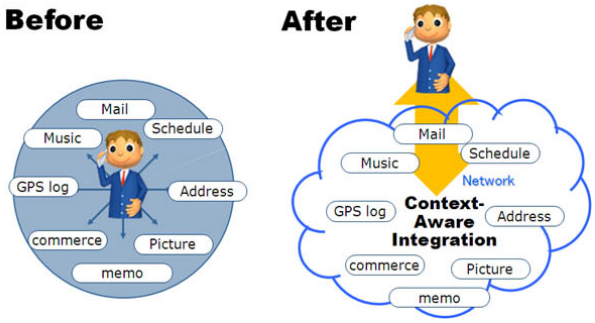

Fig. 4 Cell-phone as Information Hub.

3. Role of Wireless Broadband

Heart of cloud comuting is not only cloud servers but also cloud devices. Here we must realize the other essential component for what we are seeing nowadays as cloud services (e.g., Facebook, Google applications). That is wireless broadband as a part of the three entities as depicted in Fig. 5.

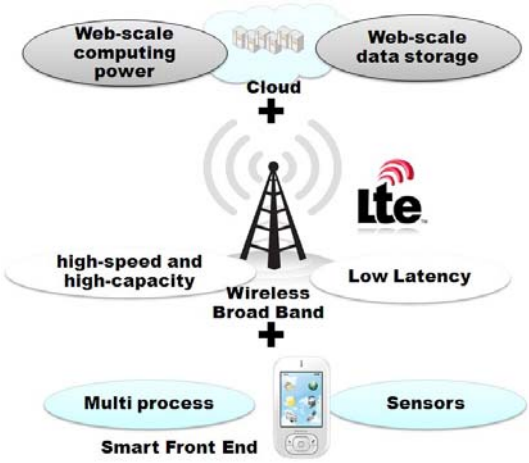

Fig. 5 Wireless Broadband as Imperative.

Cloud devices of Web2.0 require a broadband and low-latency connection by its definition (see Fig. 6). Smart phones, such as Android phones, are going to support multi-process running environments, and thus those offer local data mashups. Server-enforced thin client applications require a short round trip time also. Latency over wireless networks has become a vital performance measure to be tackled.

3G LTE [10], [20] will give the answer to that requirement. Owing to OFDM and Multiple Input/Multipe Output(MIMO) technologies, 3G LTE will give us four times increased spectral efficiency and 10 times user capacity per cell in comparison with existing 3G technology, HSPA. The 3G LTE technology will support such cloud devices in two years by providing a fat pipe with very low latency, say 10msec. Latency is expected to be very low as listed in Fig. 7.

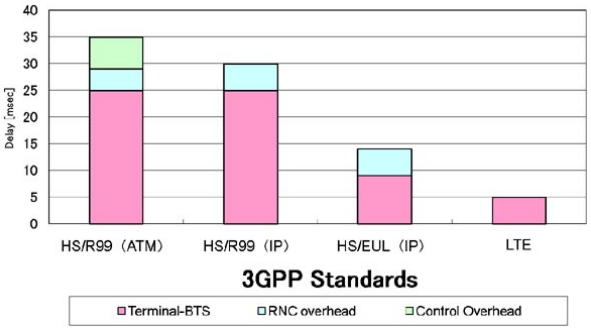

Fig. 7 3G LTE Latency.

	W-CDMA	HSPA	LTE
PHY	DS-CDMA		OFDMA SC-FDMA
Channel Bandwidth	5MHz		1.4, 3, 5, 10, 15, 20MHz
Peak Speed (for downlink)	384kbps	14Mbps	150Mbps(2×2MIMO) 300Mbps(4×4MIMO)

Channel Bandwidth	downlink		uplink	
	64QAM + MIMO (4x4 MIMO)	64QAM + MIMO (2x2 MIMO)	64QAM	16QAM
20 MHz	≈300 Mbps	≈150 Mbps	≈75 Mbps	≈50 Mbps
15 MHz	≈225 Mbps	≈112.5 Mbps	≈56.3 Mbps	≈37.5 Mbps
10 MHz	≈150 Mbps	≈75 Mbps	≈37.5 Mbps	≈25 Mbps
5 MHz	≈75 Mbps	≈37.5 Mbps	≈18.8 Mbps	≈12.5 Mbps

User Throughput
- for downlink: 2-3 times at Cell Edge, 3-4 times on average, than HSPA
- for uplink: 2-3 times, than HSPA

Fig. 8 3G LTE Advantages.

We can intuitively describe 3G LTE user experience as "WiFi equivalent" in terms of a fat and quick pipe. Without switching a cellular connection to WiFi if that is of 3G LTE, moreover, users can perceive a WiFi-equivalent connection anywhere anytime with low battery consumption(see also Fig. 8).

4. People and Data

Cloud devices with personal data integration will be an extremely fertile incubation environment for new and innovative killer applications. Recent five years, cell-phone has become an sensor and information hub in our daily life. "always-on" mobile infrastructure has brought a highly-personalized and community-based popular communication culture that was never seen. Fig. 9 shows the communication paradigm shifts which we have experienced in the last two decades. In 1980s, communication was mainly on landlines and personal devices were potable audio tape gadgets. In 1990s, we saw the dawn of personal communication with always-on anytime anywhere connection by phone, e-mail, and web browsing. Many web services emerged. Years 2000-2010 are characterized by social network services. i-phone has become an irreplaceable gadget for facebok and Twitter in US and Europe. People are now using cloud devices to share (quasi) real-time information with their friends and family. That is a different communication style besides the personal communication in 1990's.

Now, the personal data is surely being stored into clouds through information hubs(i.e., cell-phones, see again Fig.4). All the data is not necessary to carry. Those are stored in the clouds, and invoked over wireless broad band networks when necessary.

The author is using Apple's MobileMe [9], Evernote [6], Google's services [17], SugarSync [7], and DOCOMO's address book backup service [8]. Those applications represent data store and integration as essential functions. Fig. 10 describes DOCOMO's i-concier service. It updates local, traffic and weather information along with the integration of DOCOMO's other services including calendar, coupon service and address books. It will have a variety of functions to provide support for user activities, and allow 3rd parties to deliver content related to the scheduler function and future GPS-tracking functions. O'Reilly said, in [21], "The race is on to own certain classes of core data: location, identity, calendaring of public events, product identifiers and namespaces. In many cases, where there is significant cost to create the data, there may be an opportunity for an Intel Inside style play, with a single source for the data. In others, the winner will be the company that first reaches critical mass via user aggregation, and turns that aggregated data into a system service." That is really taking place everywhere every single day.

Fig. 10 NTT DOCOMO's i-concier.

The core data must be not only personal ones but also community ones. With the recent popularity of Facebook,

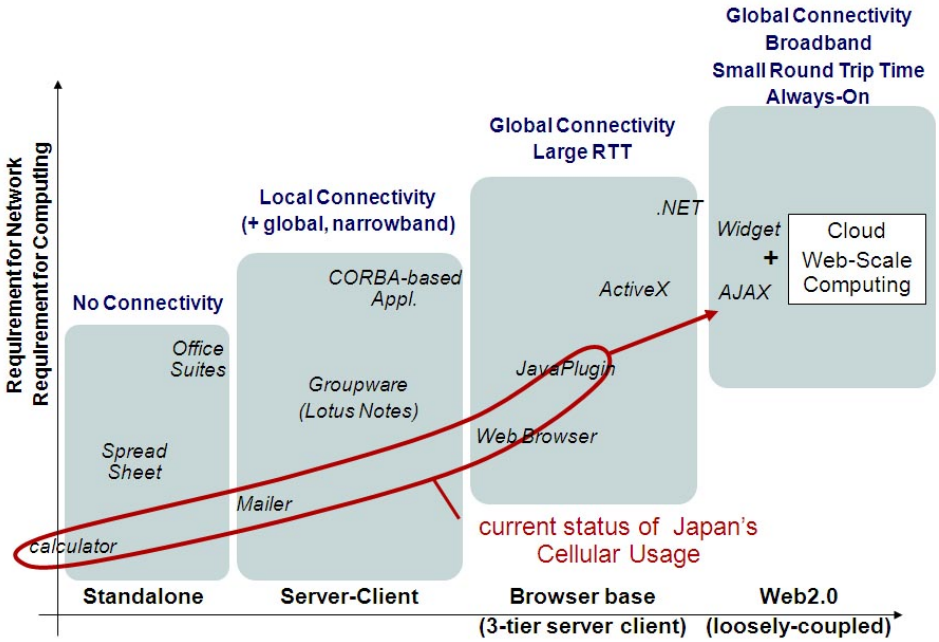

Fig. 6 Web 2.0 Communication Architecture.

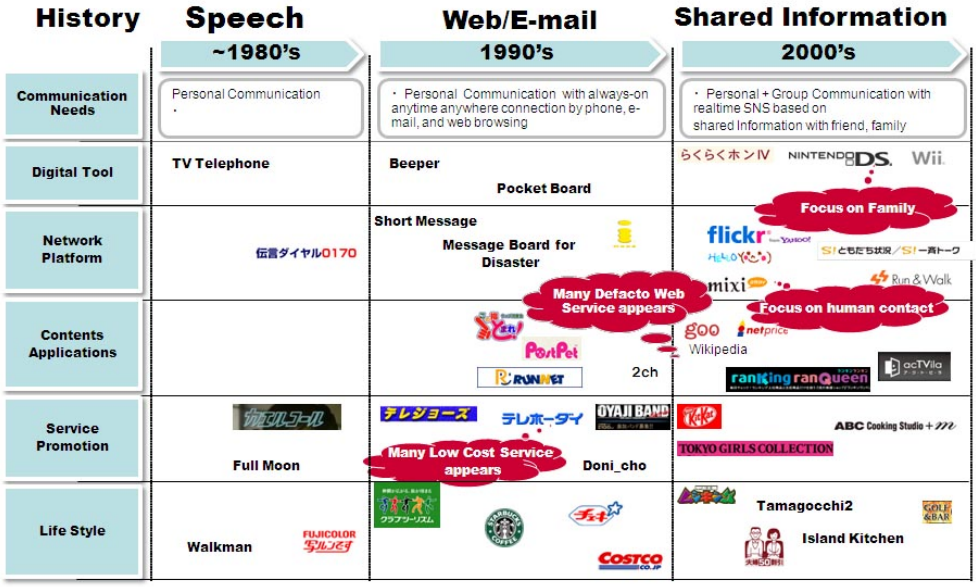

Fig. 9 Communication Paradigm Shift.

Twitter, and similar microblogging systems, we must note that it is increasing "social capital [22]." According to [13], Twiter is used for (1)daily chatter, (2)conversations, (3)sharing information/URLs, and (4)reporting news. Those usage are shared over people by clouds, specifically information srouce, information seeker, and friends. In other words, those are shared by crowds.

Recently, the author experienced a shared live video streaming service provided by Ustream [4]. Amazingly, that streaming was announced by a celebrity via Twitter, and thousands of people got together and many of them commented on streamed presentations via Twitter. Fig.11 shows a snapshot of that streaming. Ustream allows people to broadcast live video to a global audience. It creates a way for people of all ages around the globe to connect with each other through the power of live online video broadcasts, while people also can put their feedback comments to the broadcasts. In that way, Ustream.TV and Twitter are work as a platform of sharing live information, connecting people, interacting and engaging with one another more deeply. Note that the microblogging system is not only the tool for "talking about daily routine or what people are currently doing" anymore.

The race just began on to aggregate and to integrate the

Fig. 11 Snapshot of Ustream.

data over poeple so as to promote the data to social capital. Location, identity, schedule, addresses, and SNS connection of people online with whom we have a shared connection will create interpersonal functions. A system based on the integration may foster relationship building by allowing users to interact other members of their community. Thus, on the Earth, we individuals are living with personal mobile devices, i.e., cell-phones. In the heaven, the cloud servers are taking data integration over people. How far can we integrate the data over the people beyond individuals? That depends on the consensus of our society. If the society and individuals allow the data under our trusteeship, we may have the paradigm shift in communication. It's going to be beyond "Harnessing collective intelligence" and to be a communication facilitator.

Fig. 12 Crowd and Cloud.

5. Conclusion

Without cloud device and crowd, the concept of cloud comuting makes no sense. The integration of the sensor hubs and the information hubs over people is now becoming a killer application incubation environment. Here are definitions in the mobile communication aspect:

- Cloud computing: utilization of data aggregation and integration over people by extremely scalable (i.e. web-scale) world-wide back-end servers
- Cloud devices: cell-phones(i.e., personal gadgets in general) which work as sensor and information hubs in cloud comuting
- Wireless broadband: essential enabler of cloud devices
- Crowd computing: SNS as a Platform. Integrated communication over people is taking place. Cloud comuting with cloud device will fostar a paradigm shift beyond "Harnessing collective intelligence."

Let us see next five years for what application will emerge.

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