Broadband Wireless Access Supporting a Human-Centric ICT Society

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Fujitsu is promoting a new vision: "Use information and communications technology (ICT) to create a human-centric intelligent society that brings prosperity and security to peoples' lives." This paper first presents some characteristics of networking functions that are key to realizing such a human-centric ICT society, including "easing constraints on use," "providing smooth responses," and "eliminating cumbersome procedures." It then examines the use of wireless local area network (WLAN), Mobile Worldwide Interoperability for Microwave Access (Mobile WiMAX), and Long Term Evolution (LTE) technologies for providing broadband wireless access, which is the key to providing smooth responses, and summarizes their characteristics. Examination in light of the increasing volume of information flow revealed that LTE is the most promising. Achieving more human-centric networking functions requires a mechanism able to understand the state of wireless resources available to the user and to control the timing and execution of user requests accordingly. An approach is presented to developing such a mechanism, one that virtualizes the wireless access link and that controls it in accordance with changes in the wireless resources available as the user changes location. The effects that can be expected from this approach are discussed.

1. Introduction

Conventionally, most information and communications technology (ICT) has been used as a means to "speed up fixed tasks," and there has been a strong tendency for developers of ICT to increase speed by pursuing increased performance. Today, however, ICT is penetrating broadly and deeply into peoples' lives as indicated by the spread of smart phones and social media, and there is growing expectation for technology that brings new value, beyond simply performing tasks more quickly. ICT is seen mainly as being used to develop "systems" that will solve societal problems, such as the aging population of Japan, or as providing a "place" to find new acquaintances or new information. As ICT permeates society more thoroughly, the need to discuss new value from the perspective of the user rather than the provider is being reaffirmed more and more.

In this paper, we first overview the "Human-Centric Intelligent Society" being promoted by Fujitsu and discuss the requirements of one of the elements needed to support such a society: the network. We then summarize the characteristics of three technologies used for broadband access in front-line areas, closest to people, namely wireless local area network (WLAN), Mobile Worldwide Interoperability for Microwave Access (Mobile WiMAX), and Long Term Evolution (LTE). We further discuss whether these broadband access schemes conform to the requirements of human-centric ICT, which is aimed at providing value to people. Finally, we overview a wireless link virtualization technology as an example application for advancing a human-centric ICT society and introduce the results of basic evaluation experiments.

2. Human-centric ICT society

Fujitsu is promoting a vision focused on "building a human-centric intelligent society in which people can live their lives securely and abundantly through the use of ICT"[1] rather than on simply supporting the ICT provider. Building a society in which people can fully enjoy the benefits of ICT requires a framework that can comprehend the environment in which a person is enveloped and provide specific services that are of value to that person.[2] The ICT functions required for this are shown in **Figure 1**.

Terminals are used to enter data such as sensor observations or human-created text into the information sphere and, conversely, to present value to users in the form of services [1) in Figure 1]. Then, applications convert information retrieved from the real world into value [2)]. Both terminals and applications have tended to increase in both quantity and variety. Beyond communications terminals and information devices, sensors, and even devices such as automobiles and vending machines, are becoming terminals that can provide new value through connection to networks. The increase in the quantity and variety of applications results from, among other things, the increase in game software and music downloading and streaming services.[3] Also, information processing [3)] and distribution [4)] provide intermediary, common functions among these new applications and terminals. We envision information processing functions such as statistical processing and abstraction, which take information coming from the real world and make it easier to handle for applications. Conversely, other functions select options desired by the user from among the various application options and infer appropriate timing for delivering them to the user (as provided by our "wireless link virtualization technology" described in the final section).

3. Human-centric networking

In this section, we summarize the characteristics of networking functions (information distribution) required to build a human-centric ICT society.

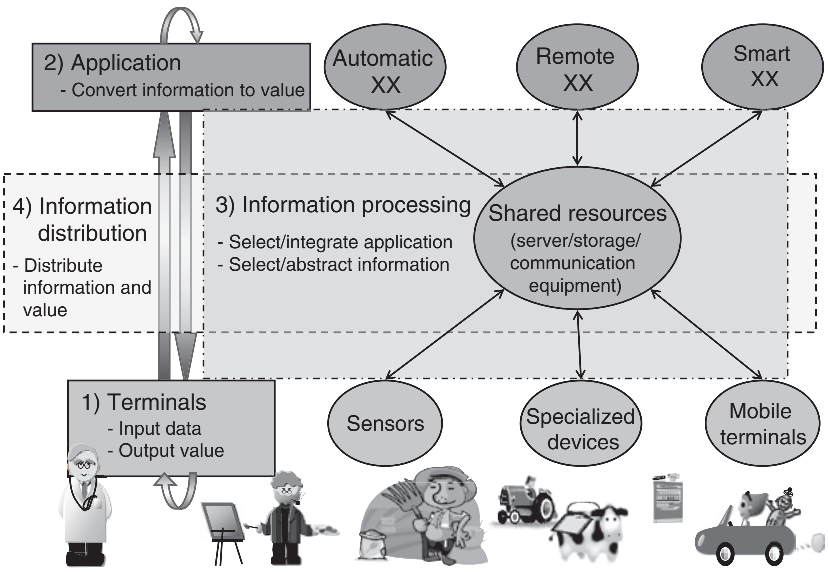


Figure 1
ICT functions required for framework that can comprehend environment and provide specific services.

3.1 Relaxing constraints on user environments

A catch-phrase often heard in ubiquitous networking research is "Anytime, anywhere, anyone, and anything." Development in accordance with this idea must place no limitations on users' communication and control in terms of time, place, or service object (i.e., the communications counterpart or the entity being controlled or observed). The use of wireless access is indispensable in relaxing constraints in this way and expanding the range of situations to which services can be applied.

3.2 Improving perceived responsiveness ("smooth responses")

Consider the case of downloading video content to mobile phones. Users have become accustomed to waiting for a download to complete without even realizing it. To enable users to receive such services without frustration, all the device operations must be smooth, and, to achieve this, the wireless-link bandwidth must be expanded so that it is comparable to that of wired links, and delay times must be reduced.

Quality of service (QoS) is an index expressing network performance parameters such as transmission delay, and, in the past, it occupied much of the discussion among technologists. Recently, however, discussion of QoS related to quality of experience (QoE) has become more prevalent. This also indicates a significant shift toward more "human-centric" approaches.

3.3 Expanding the scope of automation

Opportunities to use ICT can be increased by automating more operations that have conventionally been done manually and by increasing usability. Below we introduce three examples of automating operations.

1) Context-aware push communications

The amount of manual work for users can be decreased by delivering the desired applications and content to users automatically and with appropriate timing, rather than requiring users to select and retrieve them manually. To be able to do this, an ICT system must infer the state of the user and ICT resources and decide on appropriate applications and delivery timing. This involves an information processing function called context awareness. A wireless sensor network, which gathers state information on the user and ICT resources and delivers it to the context-processing module, plays an important role in providing context awareness.

2) Simplified maintenance

As the complexity of maintenance tasks such as checking battery status, checking memory use, synchronizing timers, and performing anti-virus software updates becomes more troublesome, systems become less-and-less human-centric. Thus, functions that are aware of the need for maintenance and can push notifications to the appropriate maintenance personnel are necessary.

3) Maintaining continuity

Networks require continuity in order to provide a smooth sense of responsiveness. A handover function is needed that can monitor the state of the terminal connection and automatically switch to a better wireless link and thereby maintain a mobile terminal connection. Without such a function, services can be interrupted, and the quality and accuracy of sensor observations can drop. Re-establishing a connection can also be troublesome for the user.

4. Broadband wireless access schemes

As discussed in the previous section, a wireless network with bandwidth comparable to that of wired networks is needed to improve the perceived speed and provide smooth responses. **Table 1** summarizes the characteristics of the WLAN (IEEE 802.11 standard), Mobile WiMAX (IEEE 802.16e-2005 standard), and LTE (3GPP standard) broadband wireless access schemes,

Table 1
Characteristics of broadband wireless access technologies.

	WLAN (IEEE 802.11 standard)	Mobile WiMAX (IEEE 802.16e-2005 standard)[5)–7)]	LTE [8),9)]
License	Unlicensed band (some interference)	Licensed band (no interference)	Licensed band (no interference)
Maximum transmission speed (Mb/s)	802.11: 2 802.11b: 11/22 802.11a: 54 802.11g: 54 802.11n: 600	UL: 28, DL: 63 (10 MHz, 2 × 2 MIMO)	1) UL: 5, DL: 10 (No MIMO) 2) UL: 25, DL: 50 (2 × 2 MIMO) 3) UL: 50, DL: 100 (2 × 2 MIMO) 4) UL: 50, DL: 150 (2 × 2 MIMO) 5) UL: 75, DL: 300 (4 × 4 MIMO) (All bandwidths 20 MHz)
Propagation distance	Approx. 100 m (some limitations indoors)	1 to 3 km	1 to 100 km (depends on frequencies, area)
Delay targets	Not specified	Not specified	Radio access network latency: 5 ms Standby→Ready for communication: 100 ms Intermittent reception→Ready for communication: 50 ms
Mobility support	Has handover for VoIP	Has handover (50 ms or less)	Has handover (interruption permitted)

MIMO: Multiple input multiple output
VoIP: Voice over Internet protocol, UL: Uplink, DL: Downlink

which provide transfer speeds of the order of Mb/s.

5. Evaluation of current wireless access schemes

In Japan, one need only look around on a commuter train to see that people crave information when on the move. In fact, based on a survey by the Ministry of Internal Affairs and Communications,[4)] from 2001 to 2008, the amount of information distributed increased by a factor of 1.86 (9.3%/year). Within that, the amount of information that people received through the Internet increased by an extraordinary 51.25 times (on average, 76%/year).[4)]

Table 2, also a result of the survey described above,[4)] shows the amount of information distributed in the year 2008 in Japan, as well as corresponding per-day, per-person values. The amount of information distributed over the Internet per-person, per-day was 1 Gbit. With the spread of smartphones and other touch-panel-type terminals, information distributed over networks is expected to continue to increase, as is the amount distributed through books (classified as Printing/Publishing in Table 2), music on CDs, and video on DVDs (both classified as Package software).

Table 2
Information distribution in Japan in 2008.

Distribution method	Distribution volume (bit)	Daily information distribution per person (bit)
Telephone	4.46×10^{17}	9.55×10^{6}
Internet	4.61×10^{19}	9.87×10^{8} (1 G)
Broadcasting	7.03×10^{21}	1.50×10^{11}
Post	1.92×10^{18}	4.11×10^{7}
Printing/ Publishing	3.34×10^{19}	7.15×10^{8}
Package software	1.25×10^{19}	2.68×10^{8}
Total	7.12×10^{21}	1.52×10^{11} (152 G)

Source: MIC Institute Report on Japan's Indexing Systems and Measuring Methods for Information Distribution Volume. (in Japanese) (2009).

People want to receive their daily volume of information (1 Gbit via the Internet, and 152 Gbit via all types of media) more and more quickly. The per-user transmission speed thus required can be approximated by dividing the amount of data by the "desired download time" (**Table 3**). Table 3 indicates, for example, that transmission speeds of several to several tens of Mb/s/user are required to download all Internet information viewed by a person in one day during a short break of several minutes. Further, to receive all information used by a person in one day during such a short period would require per-user transmission speeds of the order of 1 Gb/s.

We next examine the WLAN, Mobile WiMAX, and LTE wireless access methods and discuss their differences in terms of propagation distances, handover functions, and delay times.

1) Propagation distance

Because WLAN uses an unlicensed band, the transmission power output is limited to 10 mW or less, and the propagation distance is a maximum of about 100 m. In contrast, the two mobile technologies offer orders of magnitude greater distances, and, depending on the telecommunications carrier's operating policies, Mobile WiMAX is able to transmit over 1 to 3 km, and LTE over 1 to 100 km. We discuss these differences from the perspective of access network design below.

For discussion's sake, suppose a wireless network provides a transmission speed of 20 Mb/s regardless of the distance to a base station. By dividing the total transmission speed of the system by the transmission speed required per user (Table 3), the number of users able to use the wireless system at the same time can be calculated (**Table 4**). Assuming the users are distributed uniformly, the area for this number of users and the radius of a circle of the area are as given in Table 4. In these calculations, the highest population density in Japan, for Nakano Ward in Tokyo, was used for the "Dense area," and the average population density for all of Japan was used for the "Sparse area."

Table 3
Transmission speed required per user.

Daily information distribution per person (bit)	Desired download time	Required transmission speed per person
Via Internet 9.87×10^8 (1 G)	8 h (work time)	34.3 kb/s
	1 h (commute)	274 kb/s
	10 min (short break)	1.65 Mb/s
	1 min (washroom break)	16.5 Mb/s
All media including broadcasting 1.52×10^{11} (152 G)	8 h (work time)	5.28 Mb/s
	1 h (commute)	42.2 Mb/s
	10 min (short break)	253 Mb/s
	1 min (washroom break)	2.53 Gb/s

Tables 3 and 4 show that, as the amount of time over which users want to download 1 Gbit of data decreases, the required transmission speed per-user increases and that the number of users that can be multiplexed, and thus the size of the coverage area, decreases. For example, to receive 1 Gbit of data during a 1-h commute, 274 kb/s is allocated to each user, so 73 users can download data at the same time. Therefore, for users to be able to receive their daily 1 Gbit of information via the Internet during a 1-h commute, the system must be equipped with one WLAN access point or one Mobile WiMAX or LTE base station per 73 users.

Let's assume a sparse population density: 73 users distributed over an area of 216 080 m^2 (equivalent to a circle of radius 262 m). Such an area can be covered by a single base station if implemented using Mobile WiMAX or LTE, which can achieve propagation distances of the

Table 4
Wireless area design examples.

Transmission speed (presumed)	Required transmission speed per person (from Table 3)	No. of users that can be multiplexed	Radius of user distribution area equivalent circle	
			Dense area 1 user/50 m^2	Sparse area 1 user/2960 m^2
20 Mb/s	34.3 kb/s	583	96.3 m	741 m
	274 kb/s	73.0	34.1 m	262 m
	1.65 Mb/s	12.1	13.9 m	107 m
	16.5 Mb/s	1.21	4.39 m	33.8 m

order of a kilometer. In contrast, an 802.11b signal, propagating 100 m, would not reach all users in a 262-m radius. A design for such cases would require consideration of either multiple access points or multi-hop relay.

2) Handover function

WLAN was designed for static use, so there is no basic support for a handover function. Without handover support, reconnecting after being disconnected is time consuming, and in some cases can require inconvenient user intervention. In contrast, Mobile WiMAX and LTE support handover in coordination with the terminal at the system level, so service continuity can be maintained.

3) Delay

As shown in Table 1, only LTE specifies targets for delay time. Whether or not there are quantitative targets for delay time is very important for discussion of QoE that includes applications. For example, to provide a solution requiring real-time response or a voice communication service using voice over Internet protocol (VoIP), guaranteeing the data transmission time between terminal and base station makes it possible to calculate other system performance values beforehand, such as time to display on the terminal, application execution time, and transmission time on the core network.

6. Wireless link virtualization technology

In an attempt to make networking functions such as LTE more human-centric, we have proposed an application control method that makes the state of wireless resources available to the application (i.e., recognizing the location of the mobile terminal). We refer to it as "wireless link virtualization technology." **Figure 2** gives

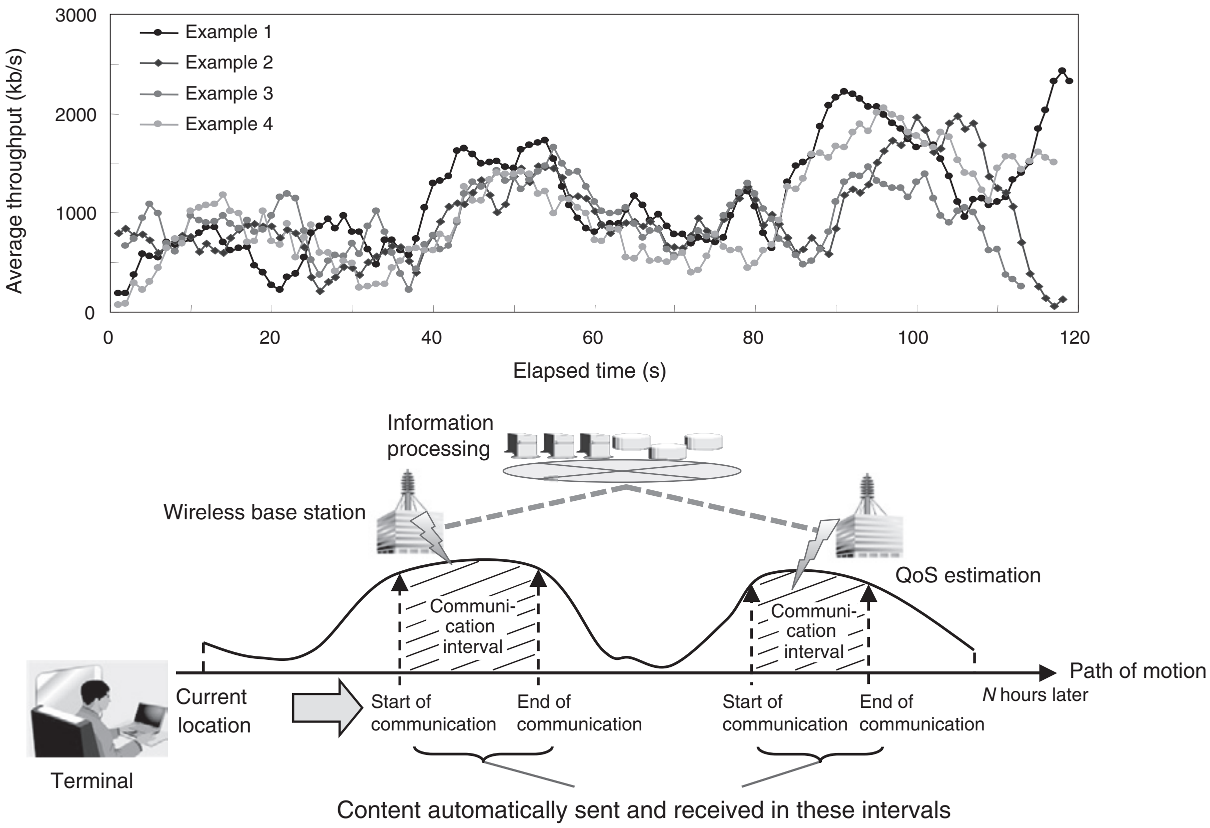


Figure 2
Examples of wireless signal throughput fluctuation and wireless link virtualization technology.

an example illustrating throughput fluctuation while a user is in motion. For routes such as railways that are basically fixed, the throughput fluctuation experienced by the user is somewhat predictable.

Thus, if it is possible to predict that the terminal will move into an environment with higher throughput, the terminal can delay the download of a large file until entering that area. This approach is commonly used in delay tolerant networks.[10)]

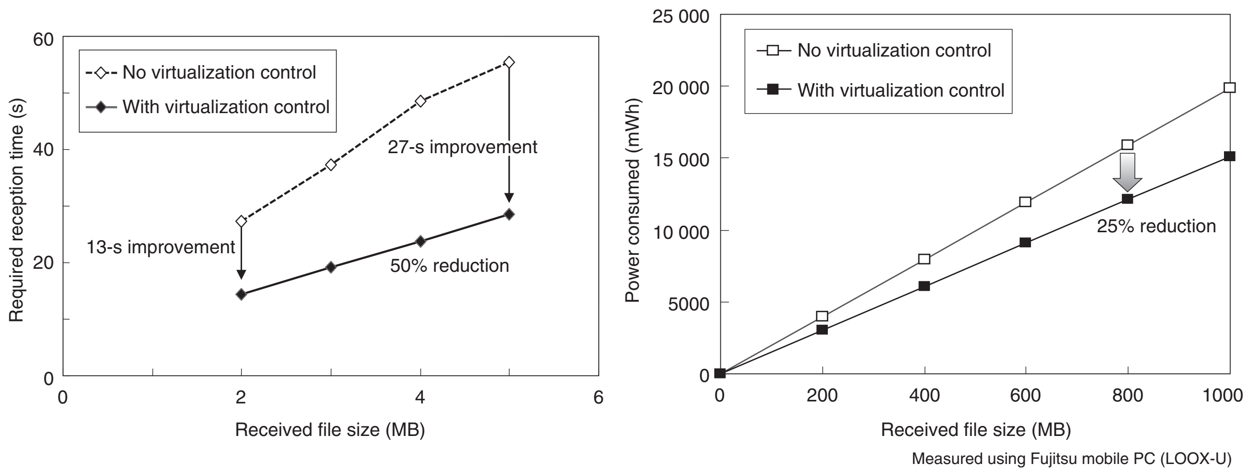
On the basis of this approach, the measurement results in Figure 2, and such prior knowledge as that the throughput will improve, we conducted simulation experiments initiating a file download during a brief period while passing through a higher throughput area. As shown in **Figure 3(a)**, the time required for wireless communications was reduced by about 50%. As shown in **Figure 3(b)**, the estimated terminal power consumption was reduced by about 25% due to reducing the communication time by 50%. This extends the terminal battery-use time and enables the user to use services for longer periods of time in mobile environments.

7. Conclusion

Fujitsu is promoting a new vision: "Use information and communications technology (ICT) to create a human-centric intelligent society that brings prosperity and security to peoples' lives."

In this article, we have presented some characteristics that are necessary for human-centric networking functions; namely easing constraints on use, improving perceived performance (smooth responses), and expanding the range of automation. We also summarized the characteristics of the WLAN, Mobile WiMAX, and LTE broadband mobile access methods. To provide smooth responses, it is important to be able to design a system based on transmission speed but also on known service continuity parameters during handover and known delay. We showed that LTE provides regulation for these parameters, making it the most promising of the three methods.

Control methods that infer the state of the user and ICT resources and dynamically adjust how services are provided are useful for making networking functions even more human-centric. We have proposed a wireless-link virtualization technology for launching applications in accordance with the state of the wireless link as the user (terminal) is in motion. Use of this method would help reduce the power consumed



(a) Reception time

(b) Power consumption

Figure 3
Reduction in time required for wireless communications through use of wireless link virtualization technology.

by the terminal.

References

1) M. Yamamoto: Giving Shape to Dreams. (in Japanese). Fujitsu Forum 2010 Keynote Address (May 13, 2010).
2) T. Tomita: Introduction to Fujitsu Research Laboratories. (in Japanese). Chinese Technology Forum 2010 (Nov. 17, 2010).
3) MIC Institute for Information and Communications Policy, Investigation Group: Report on Japan's Indexing Systems and Measuring Methods for Information Distribution Volume. (in Japanese) (2009).
4) MIC Institute for Information and Communications Policy, Investigation Group: Report on Japan's Indexing Systems and Measuring Methods for Information Distribution Volume. (in Japanese) (2009).
5) K. Etemad: Overview of Mobile WiMAX Technology and Evolution. *IEEE Communication Magazine*, Vol. 46, No. 10, pp. 31–40 (2008).
6) Mobile WiMAX Forum Publication: Mobile WiMAX Part 1 Overview and Performance. (in Japanese) (Aug. 2006).
7) M. Nakamura et al.: Standardization Activities for Mobile WiMAX. *Fujitsu Sci. Tech. J.*, Vol. 44, No. 3, pp. 285–291 (2008).
8) 3GPP TS36.306 v10.1.0 (2011-03).
9) 3GPP TR25.913 v9.0.0 (2009-12).
10) S. Yamamura: DTN: Delay Tolerant Networks. (in Japanese). *IEICE Communications Society Magazine*, No. 16, pp. 52–56 (2011).

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