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# A New Direction in 4G Infrastructure Research –Growth into a Ubiquitous World–

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*On March 15, 2004, NTT DoCoMo held its second 4G Tech Forum and announced a new direction for the research of 4G infrastructures with special reference to the slogan "Growth into a Ubiquitous World".*

*In this article we put forward our vision for the future of 4G research based on this new direction. The new concept of "Mobile Ubiquitous" is introduced from the viewpoint of service and network development, and it is shown that ubiquity is as important in networking as broadband capability. As a promising configuration for Mobile Ubiquitous Networking, we discuss the idea of using mobile terminals as gateways for expanding mobile networks into ubiquitous environments in real space. Technical challenges in implementing the idea are also addressed.*

## 1. Introduction

It is less than twenty years since the appearance of mobile phones in Japan, but due to a dramatic growth in users in the late '90s, the mobile market is now larger than that of fixed-line telephony services which took more than a century to grow. On the other hand, commercialization of the Internet in the early '90s also resulted in a global boom, and there are now more than 30 million Internet subscribers in Japan. What is remarkable about Japan's market for mobile communications and the Internet is that both services are collaborating with each other to implement new types of services such as i-mode which provides Internet access (e-mail and web browsing) through mobile phones. This mobile Internet service is very popular in Japan, where it has currently reached some 70 million subscribers (over half the population).

Although the Internet has provided a medium for the development of various mobile communication services, telephony services still account for a large portion of the communications traffic. For the further development of mobile communications business, it is essential to cultivate new service areas. Japan was the first country to introduce Third-Generation (3G) mobile communication services in 2001, and considerable progress is now being made in exploiting the high speed of 3G networks to provide multimedia communications and rich content delivery.

When Fourth-Generation (4G) mobile networks are deployed, it is expected that even greater speed and bandwidth will be harnessed to provide more vivid and impressive communication with realistic audio and video. At the same time, so called "Ubiquitous Networking Services" will emerge in providing exciting new forms of service that not only support communications between humans but also provide network connections for all kinds of computers embedded in diverse real environments to allow them to provide behind-the-scenes support for human activities.

In this article we discuss the concept of new 4G network architecture and how it will support the forthcoming Ubiquitous Networking Society. Technical challenges are also presented based on the discussions at the second DoCoMo 4G Tech Forum on March 15, 2004, in which we showed our new direction for 4G infrastructure research.

## 2. Development Trends of Mobile Services and Networks—Enhanced-reality Communications and Ubiquitous Services

The steps in the future development of mobile services can be organized as shown in **Figure 1**. Digital cellular networks were implemented for Second-Generation (2G) systems, where packet communication networks and browser phones were used to introduce the i-mode service that provides Internet access from mobile networks via gateways. Mobile services were expanded from conventional voice communications services to accommodate non-voice media such as data and images. This i-mode service has successfully taken root as a "Mobile Internet service". Next, in 3G systems, wideband communications is being introduced through the use of Wideband Code Division Multiple Access (W-CDMA) technology, and together with the growing popularity of camera-equipped mobile terminals from 2G systems, the development of audiovisual services with higher picture quality and video capabilities is now under way. 3G networks can therefore be said to offer "Mobile Multimedia services". Future mobile networks will be based on Internet protocol (IP) technology to form "All-IP" structured networks, allow-

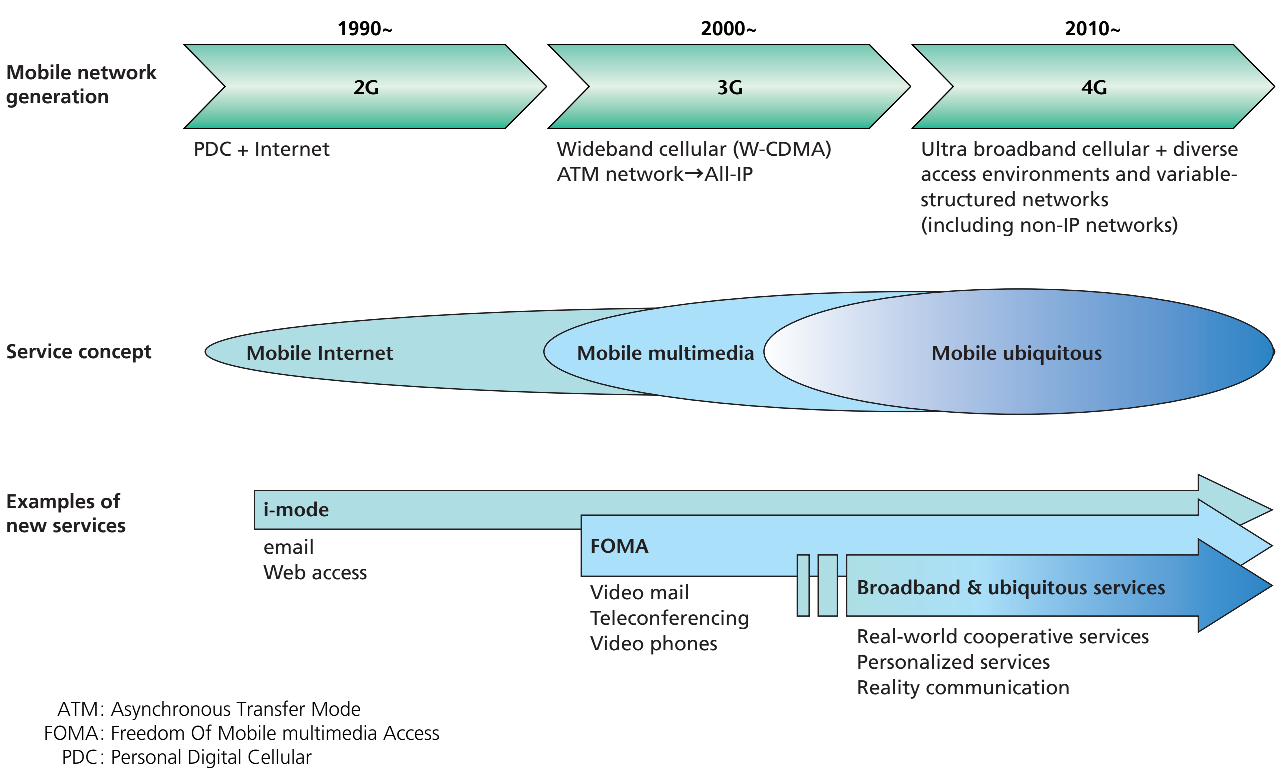



**Figure 1  Development of mobile services and networks**

ing them to operate more economically and develop a more flexible range of services.

So when 4G services arrive, what form will they take, and what sort of network architecture will be needed to support them? If we assume that each generation of network technology lasts for 10 years or so (as they have so far), then we can expect 4G technology to arrive some time between 2010 and 2015. In this generation, it is expected that communications between humans will be implemented with enhanced reality that surpasses what has so far been achieved with audio and video communications. For example, it might become possible to implement 3D audio-visual communication services that provide users with convincing 3D images and 3D sound fields that allow them to tell which direction sounds are coming from. It is also thought that new modes of communication will appear, such as "alter-ego communications" in which robots and the like are used to convey tactile and motor information in addition to audio-visual data with the aim of conveying atmosphere and emotion. Such services impose new requirements on mobile networks. Broadband technology will be required to allow multidimensional data to be transferred in real time, and minimal stable transmission delays are essential to convey subtle changes such as tactile feedback.

Another driving force behind 4G services is the remarkable development of micro-device technologies such as ultra-miniature computing chips, sensors and radio tags. This is likely to result in the appearance of new types of service in which a number of micro devices embedded in real space will interact with humans to support everyday activities. This will lead to a fusion between real-world information and virtual space information and services, and allow users to freely access whatever services they need, only where and when they need them via an appropriate means. We call such services "Ubiquitous Services". The basic requirement of a network that supports ubiquitous services is that it should provide connectivity with a huge number of devices which have a wide variety of characteristics. These devices (we call them Ubiquitous Devices) range from multi-functional terminals such as information appliances to miniature devices embedded in the environment. Ubiquitous devices are characterized in that a) they usually have very limited communication abilities (such as radio tags and sensors), and b) they only operate within a limited range of space and time, and in some cases the network that connects these devices may itself have a mutable and temporary (i.e., ad hoc) configuration. And unlike ordinary public networks, the owner of the network may not be unique and management of these devices need not be performed centrally by a telecommunication carrier. This ability of ubiquitous connectivity for limitless information reachability can be thought of as another new characteristic of next-generation networks alongside the ability of mobile networks to provide broadband and delay-sensitive communications.

We use the term "Mobile Ubiquitous" to refer to the concept of new services and networking, which are created by the combination of broadband capability and ubiquitous connectivity. In the following, we discuss the networking technology needed to realize this concept.

## 3. A New Mobile Network Structure

### 3.1 The Concept of a Mobile Ubiquitous Network

The realization of ubiquitous communications will impose new requirements on networks. However, it is difficult to say now precisely what these requirements will be because the concept still needs to be concretely defined and there are still many unknown issues to contend with. On the other hand, greater broadband capacity will be needed for networks to support multimedia and enhanced-reality communications. We believe that this can be achieved by extrapolating the existing efforts to increase the speed and efficiency of 3G cellular networks, and in a narrow sense this target has already been clarified for research into 4G radio access technology [2]. The 4G mobile cellular network with broadband capability will form the basis of carrier network development, and will play an essential role at the core of networks even in the mobile ubiquitous era. The advanced mobile terminals (4G terminals) that exhibit this broadband performance will provide multimedia and enhanced-reality communications between people on 4G mobile networks. We will therefore consider how to build a next generation network for carrier services under a broad definition of 4G networks that includes broadband mobile capability and the abovementioned ubiquitous attributes, which we refer to as a "4G+" network.

### 3.2 4G Mobile Networks

Here we discuss 4G networks in the narrow sense, which means broadband mobile networks as the core of mobile ubiquitous networking. This discussion is directly related to the studies on "Systems Beyond 3G" which are already in progress at research forums and standardization bodies throughout the world, such as the Wireless World Research Forum (WWRF) and the International Telecommunication Union (ITU). Some specific proposals are starting to be made for broadband wireless access and network systems.

- Broadband wireless access system: A promising modulation scheme called Variable Spreading Factor-Orthogonal Frequency and Code Division Multiplexing (VSF-OFCDM) has been proposed for 4G access systems [2]. This scheme combines Orthogonal Frequency Division Multiplexing (OFDM) (which allows greater speeds in isolated cell environments) with CDMA (which has superior performance in multicell environments), and is able to work in diverse environments by varying the spreading factor according to the wireless environment. This new scheme allows the same air interface to be used in an efficient manner for broadband communications in both outdoor cellular environments and indoor isolated cells. At DoCoMo in 2003, we successfully conducted outdoor trials of 100 Mbit/s class video transmission using this scheme in a mobile environment [3].
- Network schemes: 3G network designs adopt an architecture in which the circuit and packet switching are performed separately. In the future, however, the bulk of traffic will be generated by non-voice services via Internet connections, and even voice services will be supported by IP technology such as Voice over Internet Protocol (VoIP) instead of using circuit switching. In line with this trend, mobile carriers and vendors discovered in the early stages of their next generation network studies that the introduction of "All-IP" networks that make comprehensive use of IP technology was an effective way to improve efficiency and rapidly create new services. In Japan, full-scale studies of All-IP solutions were initiated as far back as 2000, including studies and evaluations with test systems based on commercial IP equipment [4]. The requirements of these system differ significantly from those of fixed Internet technology in that it must be possible to guarantee IP reachability for mobile hosts. Although mobile IP technology has been developed to allow terminals to move around while connected to the Internet [5], it does not perform well enough for high-speed hand-overs while tracking terminals moving at high speed in a carrier network. There is also a need for multiple wireless systems (including existing systems such as 3G and Wireless Local Area Network (WLAN)) to be flexibly accommodated and for the support of seamless mobility of terminals among these systems. A new mobility control technique should be developed to meet these requirements. New studies of All-IP networking are being undertaken to improve upon and implement these issues in order to ensure the reliability, security and quality of service required by telecommunication carriers [6].

### 3.3 Achieving New Value with a 4G+ Network

A ubiquitous network might be defined as an environment in which all kinds of objects and equipment are networked together so that terminals, networks and content can be used safely and with peace of mind wherever one happens to be. Networked ubiquitous devices cover a diverse range from miniature environment-embedded devices to information appliances with powerful processing capabilities. By using these devices to gain an understanding of the user's context by acquiring environmental and personal information, it should be possible to create new services with greater value.

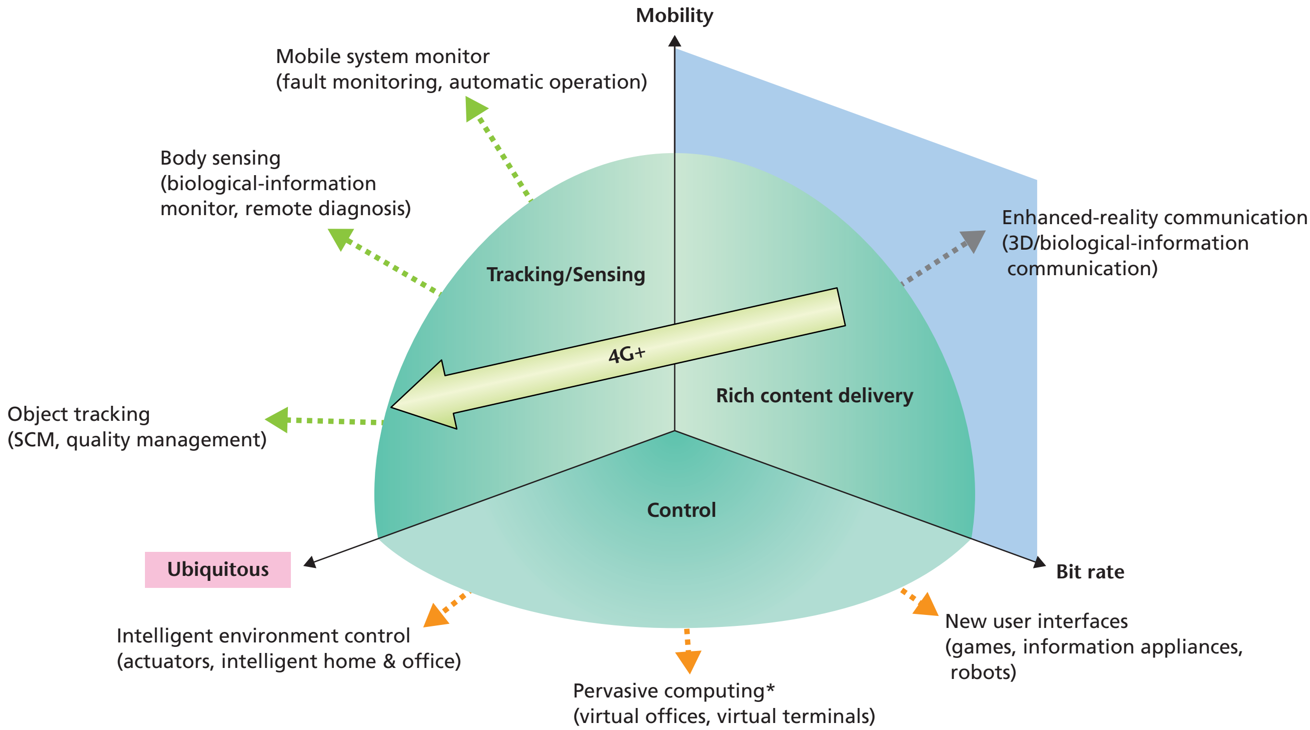
In addition to the existing mobile network development strategy towards broadband communications, in the 4G+ world of networking via ubiquitous devices it is expected that a new type of service will be created by combining real-world functions such as tracking, sensing and control functions with cyberspace services (**Figure 2**). We use the term "Mobile Ubiquitous" to describe the concept whereby the development and growth of such services is promoted by linking mobile and ubiquitous technologies.

1) The Added Value of Mobile Ubiquitous Technology

a) Expansion of the scope of communications

The earliest forms of communication such as the telephone were used for person-to-person conversations, in which humans were the primary subject of the communication and the telephone equipment was the primary means by which the communication was carried out. Subsequently, the development of computer technology made it possible to digitize all kinds of information and store it electronically. With the arrival of the Internet, it became possible for people to access this electronic information with ease, thereby making humans and computers the primary subjects of the communication, and the computer equipment that handles this information (such as PCs and servers) is gradually becoming the primary means of communication.

In a mobile ubiquitous environment, in addition to person-to-person and person-to-computer communication, a new com-




SCM: Supply Chain Management

* Pervasive computing: An environment in which devices such as information appliances, mobile terminals and in-car TVs are connected to a network, allowing information to be accessed from anywhere at any time.

**Figure 2 The creation of mobile ubiquitous services**

munication role is played by all kinds of objects situated in the real environment. The information handled in such an environment is obtained via ubiquitous devices such as sensors, and corresponds to context information which describes the status of the real world including humans.

This transition to an ubiquitous world will expand the scope of communication to encompass all objects in the real world, and a new information space will be created by linking real-world information with cyber information on the network.

b) Structural expansion of the network infrastructure

Ubiquitous devices located in all sorts of places will be connected to the devices around them and will gather and distribute information according to their needs. As shown in **Figure 3**, the local ubiquitous network groups formed by this type of local networking will be connected to the mobile terminals of 4G wireless access, and thus the 4G mobile network will reach out into the ubiquitous real world and expand its communicating capability beyond its mobile terminals.

By linking mobile networks and local ubiquitous networks in this way, network connectivity and information reachability will extend to all kinds of objects. Due to diversification of the ownership and management of each local ubiquitous network and of the types of network protocol used within it, a mobile ubiquitous network formed in this way will be able to offer a substantially greater range of services over a substantially larger area.

c) Expansion of business

When mobile networks were linked to the Internet, it became possible to access Internet services via mobile phones at any time and place, and mobile Internet business flourished as a result.

It is now very likely that cooperation between mobile and ubiquitous environments will create new businesses in which the real world is linked together with the cyber world. Once sensors and tags on all objects are connected to the mobile network and the Internet via local ubiquitous networks, it is likely that new service providers will deal with real-world information as content for new services. The ability of interconnecting mobile terminals with information appliances and home networks via ubiquitous networking may also expand their usability and lead to the creation of new networking businesses.

2) Examples and Effects of Linking Mobile and Ubiquitous Systems

**Figure 4** shows an example of cooperation between a

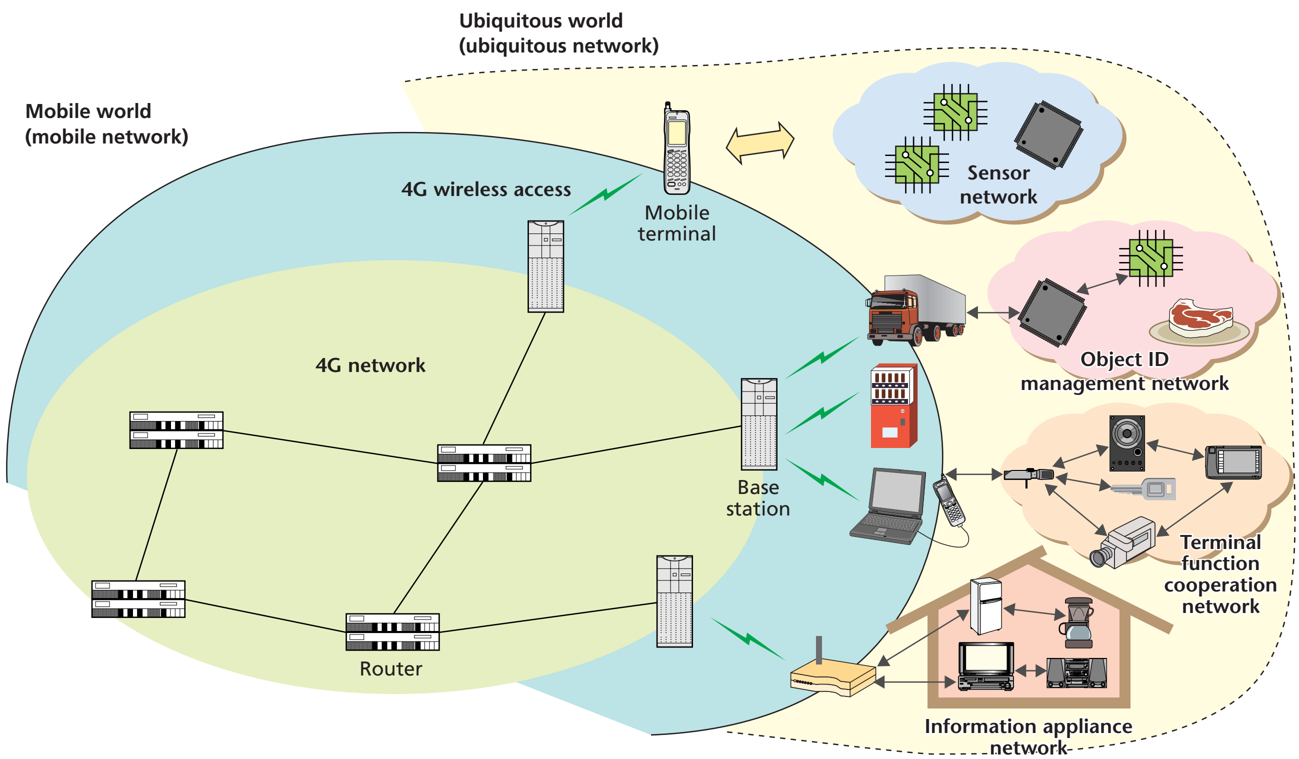
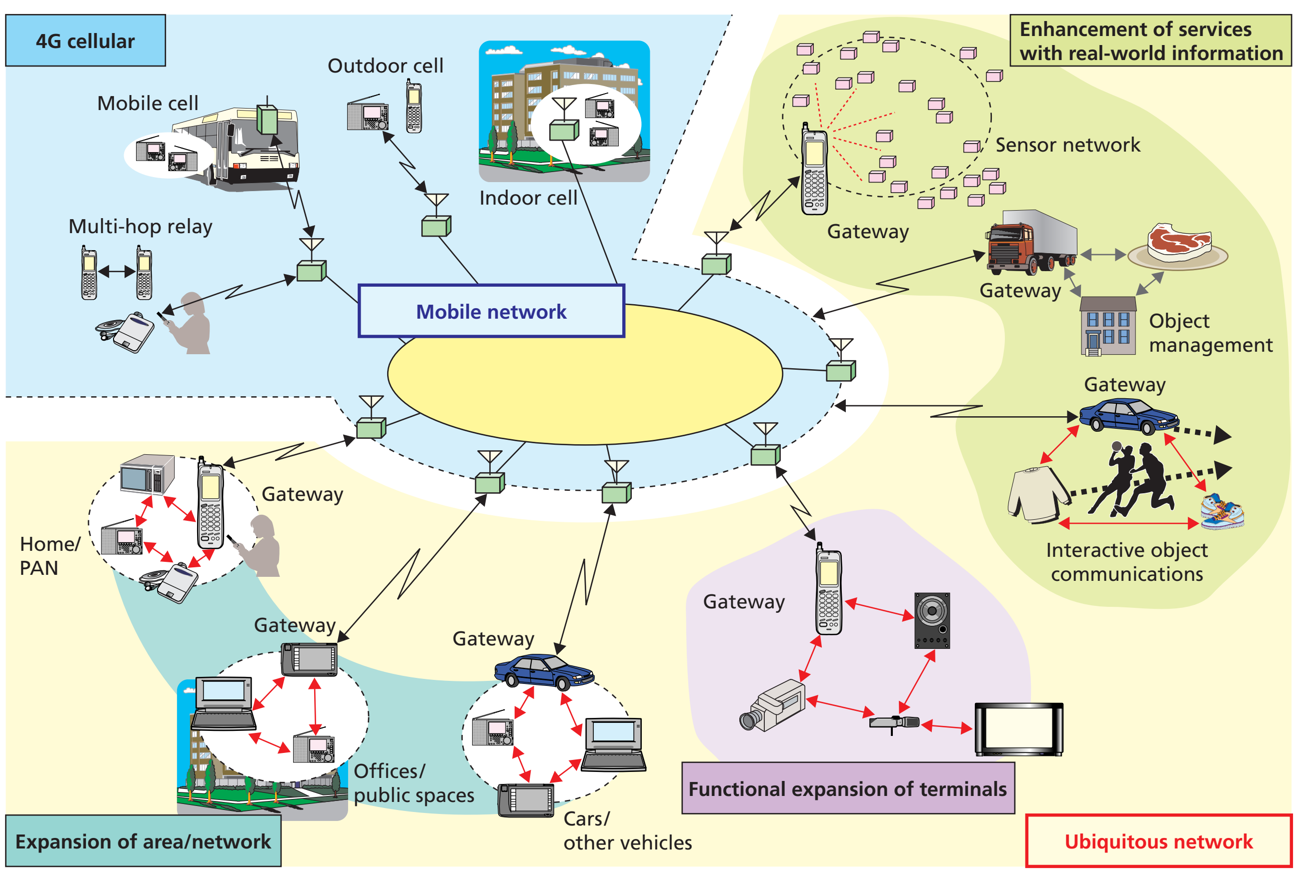



**Figure 3  Structural growth of the network infrastructure**




PAN: Personal Area Network

**Figure 4  Cooperation between mobile networks and ubiquitous networks**

mobile network and a ubiquitous network, in which the terminals (or devices that possess the functions of terminals) in the 4G cellular network act as constituent elements of the ubiquitous network. Broadly speaking, this cooperation between the ubiquitous network and mobile network will bring about the following three merits (i.e., new values).

a) Area and network expansion

In daily life, people move about between various living spaces, such as homes, offices, public spaces, and mobile environments. In the future, it may become possible to use ad hoc networks in each space, resulting in the appearance of various information spaces that differ in terms of their quality, density and reliability. Connections between mobile networks and ad hoc networks resulting from mutual communications between ubiquitous devices generate benefits for both types of network.

From the viewpoint of mobile networks, ad hoc networking can extend the reachability of communications by using hop-by-hop connections with ubiquitous devices into spaces where conventional cellular signals cannot reach.

Conversely, from the viewpoint of ubiquitous networks, the local ubiquitous network can be supported in many ways from the mobile network, which is more powerful and has carrier-grade reliability[*1]. Typical examples are support for global connections to information servers on the Internet and interconnections between multiple distributed local ubiquitous networks. Furthermore, the mobile network can provide alternative routes to compensate for the structural fragility of ubiquitous networks that arises from frequent changes of constituent devices in time and space. Ubiquitous devices with limited capabilities can also be supported by temporarily providing them with additional (or replacement) processing power and memory functions from nodes in the mobile network.

b) Functional enhancement of terminal systems

A virtual device with advanced functions can be formed anywhere by mutual communication between simple-function devices to combine their functions. This results in the creation of new terminal capabilities around an existing mobile terminal, thereby expanding and strengthening the mobile terminal functions.

For example, in a room that happens to contain a video camera, a microphone, speakers and a large-screen display, the mobile terminal might communicate with these devices to implement impromptu video conferencing, thereby providing the user with a more realistic and comfortable video conferencing environment than would have been possible with the mobile terminal alone.

Using nearby input and output devices to create ad hoc virtual terminals and virtual office spaces in this way will make the services more attractive and increase the opportunities for users to access mobile networks.

c) Expansion of services by the use of real-world information

By providing objects with communication functions and allowing them to exchange various kinds of information, a variety of services that use real-world information will appear and develop. Three examples of how this might occur are as follows:

- Sensor network service: Sensors and Radio Frequency IDentification (RFID) tags are used in a ubiquitous environment to measure real space data and ID information from objects surrounding a mobile user. This information is gathered at a gateway on a mobile terminal. The key point is that the gateway does not simply gather information, but has advanced reader functions that filter out only the significant information from the very large amount of information available. The sensor information collected via the mobile terminal is analyzed as context data for the user and is associated with related services over the mobile network. Suitable services are provided according to the status of the environment at each moment in time.
- Object management service: A service for managing objects and artifacts that are produced, circulated and disposed of in the real world. RFIDs are used not just as a means of identifying objects, but as a source of information which is fed back to a server via the mobile network, thereby facilitating advanced management functions such as real-time tracing of objects over a wide area.
- Interactive object communication: An intelligent object communication service in which objects themselves are able to exchange information with and exert an influence on neighboring objects. For example, when an emergency situation is judged to have arisen, the objects might sound an alarm, implement danger avoidance control measures, and inform the appropriate emergency authorities via the mobile network. The mobile network provides functions for judging the significance of and relationships between objects in real time.

*1 Carrier grade: A term expressing the quality and reliability that can be provided for a communication network

In this way, collaboration between the mobile network and local ubiquitous networks creates ubiquitous services that use all kinds of real-space information and go beyond the conventional locational information services offered by a mobile network.

## 4. Method for the Implementation of Mobile Ubiquitous Technology

The ability of ubiquitous services to handle real-world and real-environment information that is closely associated with the current time and location is a new characteristic. Ubiquitous devices are placed everywhere, and ad hoc networking among these multiple ubiquitous devices will be achieved using short-range wireless communications technologies such as infra-red or Bluetooth[*2]. A network of this type is referred to as a Ubiquitous Local Network (ULN).

A conventional mobile network, on the other hand, is destined to interconnect people through mobile terminals wherever they are. The mobile network will support a virtual world collaborating with the Internet. Once ULNs are interconnected with the mobile network, this will facilitate the creation of a global network among ULNs which are able to move around in time and space. Accordingly, it is possible to expect the appearance of a new ubiquitous (global) network that encompasses the real world and goes beyond the conventional concept of the Internet (which basically provides a virtual world).

We would like to propose that these connections are made by gateways situated at the "edges" of the mobile network. Here it is important to bear in mind that the edges are not always on network nodes, but are envisaged as the mobile terminals that people carry at all times. According to this concept, the growth of ubiquitous networks will be centered around people with mobile terminals acting as gateways between mobile and ubiquitous networks. **Figure 5** shows the structure of a mobile ubiquitous network (4G+) in which a mobile terminal acts as a Ubiquitous Gateway (UbG). A UbG possesses both cellular and local ubiquitous networking functions corresponding to both networks.

However, connecting to and controlling devices such as information appliances in the home does not necessarily require a mobile terminal to act as a gateway. In such cases, the gateway functions should instead be modularized and set up in various locations rather than in mobile terminals.

## 5. Technical Challenges in Mobile Ubiquitous Architecture

In this section we discuss the characteristic issues of mobile ubiquitous architecture in which a mobile network and ULNs collaborate together. **Figure 6** summarizes the constituent elements of this architecture and the topics that need to be studied.

In addition to the abovementioned ULN and UbG, there are three main elements that constitute the mobile ubiquitous architecture: an IP backbone for a simple and efficient mobile network, a network control platform for effective collaboration between the mobile and ubiquitous transport layers, and a ser-

*2 Bluetooth is a registered trademark of Bluetooth SIG, Inc.

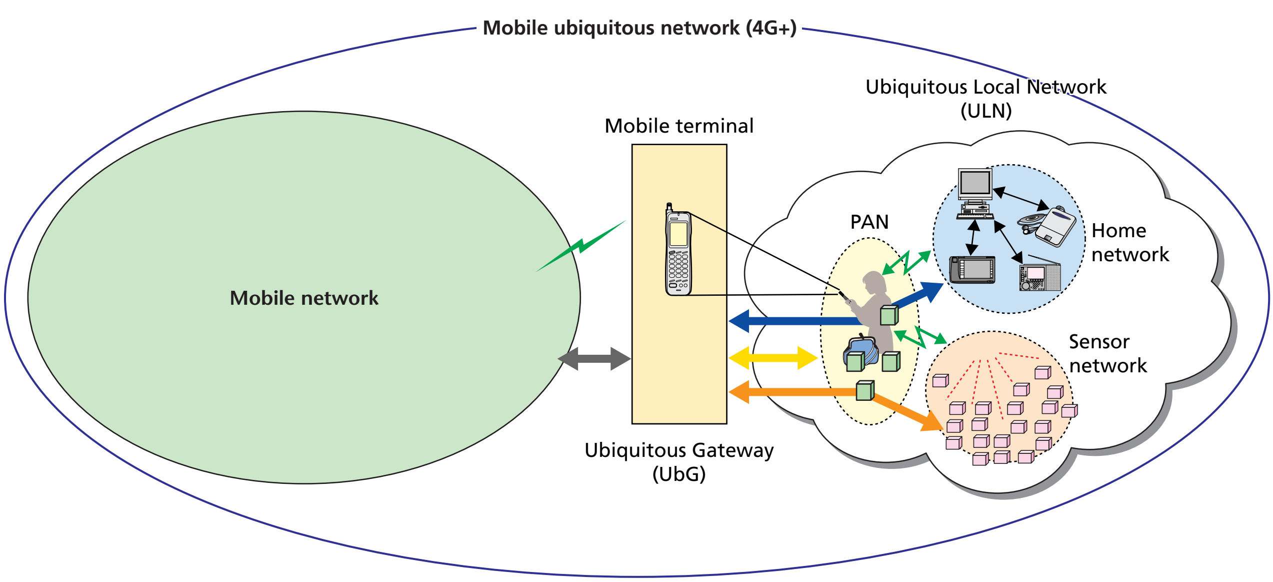
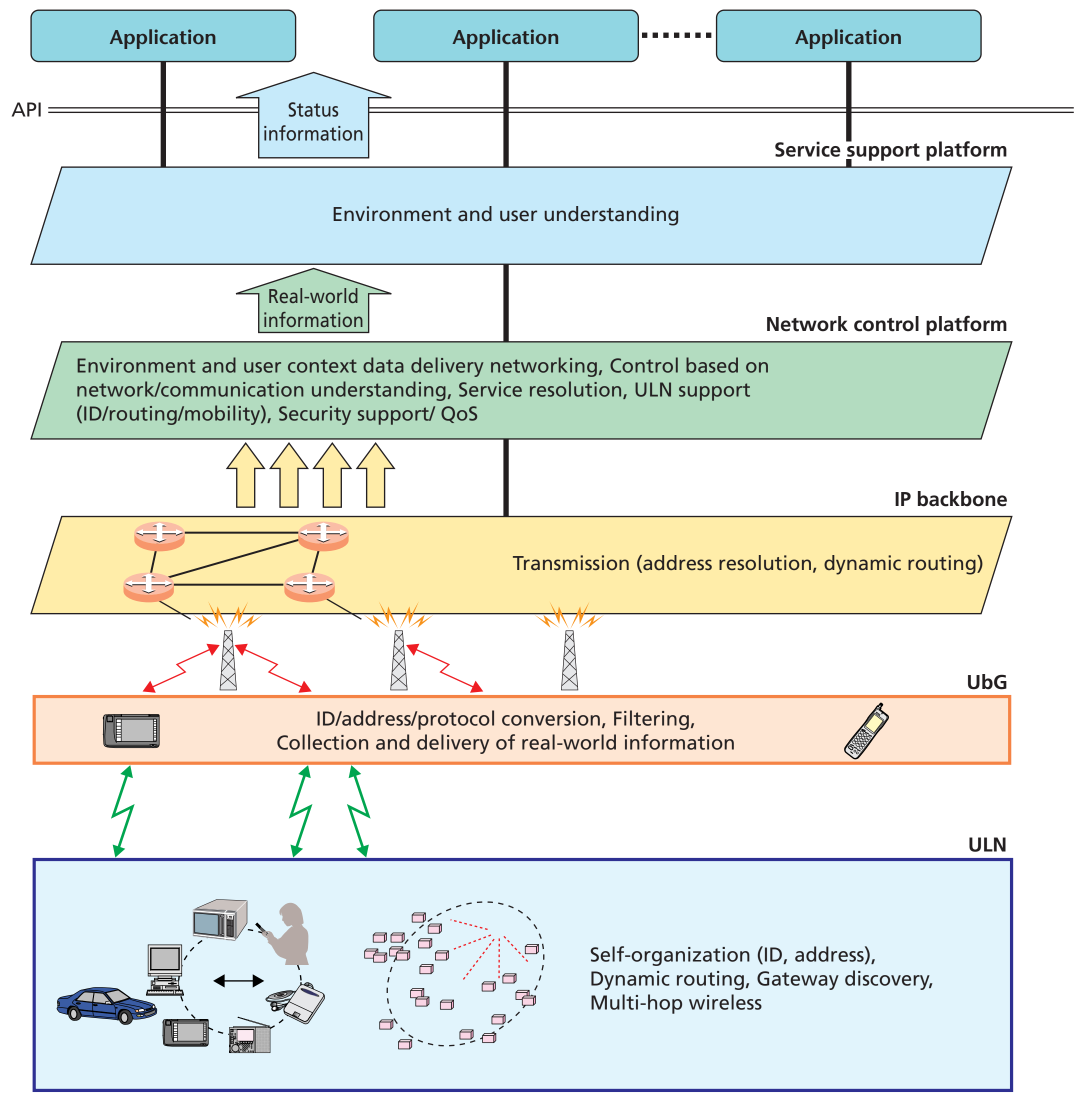



**Figure 5 A mobile ubiquitous network with mobile terminals as gateways**




QoS: Quality of Service

**Figure 6 Constituent elements and research issues of mobile ubiquitous environments**

vice support middleware platform for ubiquitous service provisioning.

### 5.1 ULN

A ULN consisting of ubiquitous devices has the following characteristics:

1) Self-organizing Network and Dynamic Mobility Control

a) The connection status between devices (i.e., the network configuration) changes with the movement, on/off status and wireless conditions of each ubiquitous device.

b) The constituent elements of a ULN centered on a gateway change with the movement of users who carry UbGs even when the respective ubiquitous devices stay where they are.

Characteristic a) is shared by so-called ad hoc networking studies. It is essential to study how to implement self-organization to accommodate changes in the constituent elements in situations where very large numbers of ubiquitous devices form a ubiquitous local network. To adapt optimally to dynamic changes of configuration and status of each wireless link, it is essential to study how to implement dynamic routing to set and maintain local communications, as well as efficient resource control for multi-hop wireless communications.

Characteristic b) means that the ULN's network boundaries move as the UbGs move, which is a new form of mobility not found in conventional mobile networks. As a UbG moves, some of its constituent ubiquitous devices may end up belonging to multiple ULNs, which make routing control more complicated. The conventional ad hoc network control mechanism does not work well in this situation, so this must be resolved by developing completely new mobility control capabilities such as route control and host movement management that work by cooperating with the mobile network (**Figure 7**).

2) Communication Protocols

The constituent devices of a ULN can vary widely in many respects including their communication performance. For example, a sensor only needs to transmit a certain piece of information, and thus even IP might be too much for handling such a limited flow of information. It may not be appropriate to require that all ULNs communicate using the same advanced IP technology. This would make it necessary to design a new, simple protocol suitable for one-way low-volume data transmission from devices such as sensors and RFIDs.

3) IDs and Addressing

Although a lot of work has already been put into specifying IDs for object recognition, there are still aspects of networking for which the use of IDs remains unclear, such as what sort of IDs should be used and how the routing addresses should be set. There are still many issues to be resolved such as what sort of scheme should be used to manage these IDs. Specifically, the IP reachability that is naturally guaranteed in an All-IP mobile network is not guaranteed as far as the ULNs extended in a ubiquitous space. It is therefore necessary to resolve the issue of how to reach devices that cannot be reached by IP, while accommodating a sufficient level of diversity in communications requirements. There may also be some cases where individual devices are loosely coupled with IDs or addresses. Since there may be countless ULNs whose ownership varies, the problem of how to connect them (whether temporarily or otherwise) must be resolved not just by technical consideration but also by considering the operational problems (rules).

### 5.2 UbG

Following functions are important for UbGs:

a) The efficient collection of real-world information measured in ULN environments, and conversely the distribution of necessary information to ULN environments.

b) Management of the IDs/addresses of ubiquitous devices in ULN environments, and conversion of necessary communication protocols between the ULNs and the mobile network.

Further study is needed to implement efficient security for mobile networks without having to manage large numbers of ubiquitous devices or uploading their information to the global network any more than is necessary.

It is also very important to define and standardize the access interfaces to ubiquitous devices and Application Programming Interfaces (APIs) to ubiquitous middleware so that these inter-

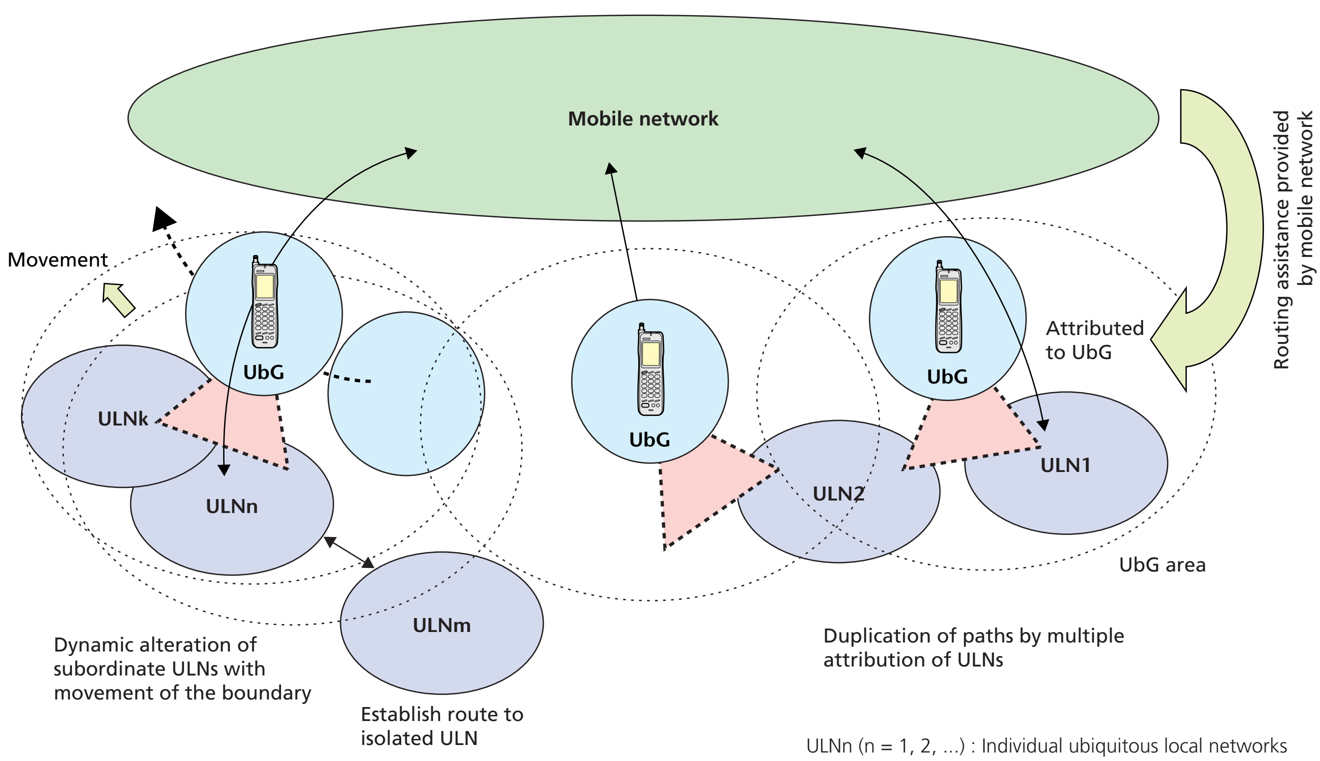



**Figure 7  New problems with mobility and routing**

faces can be applied to all kinds of ubiquitous devices and services. It is also necessary to determine how intelligence should be shared between the network and the UbGs so that the UbGs can cope with the limited power consumption and processing power available in mobile terminals.

### 5.3 Transport Network Control

It is thought that effective network control can be achieved by providing a control platform on the core mobile network in a form where it is separate from the transport layer. This is because concentrating the control processing mechanisms separately from the transport functions allows improvements to the functionality, reliability and the like to be implemented with greater ease and flexibility. This control platform performs tasks such as address resolution and the provision of services for establishing connections and managing the quality and security of the overall network. Commands from this platform are delivered as signals via the UbGs to the ULNs that require them. On the other hand, the network status of various types of ULN (e.g., their connection state and routing management) is basically administered by autonomous distributed management, but for operations involving global connections or cooperation with the mobile network, control information may be managed by the control platform of the core mobile network. In situations where the ULNs transform from time to time and the mobile network is expanding accordingly, it is important to construct a mechanism that performs this sort of function sharing between the ULNs and the core network in a flexible manner in order to manage the whole network in stable way.

### 5.4 Service Provision

Mobile ubiquitous networking is a mechanism for information sharing that forms the basis of the provision of ubiquitous services, and is only meaningful when connected with service provisioning mechanisms. The ubiquitous service applications themselves come in many different types, but the mechanisms used to provide them are basically composed of the following elements: a) acquiring user/environment information, b) interpreting/understanding the significance of this information, c) determining/selecting services, and d) service provision and control. For example, many research issues must be addressed to realize the respective elements of a real-time processing sequence that selects and provides an optimal service based on an understanding of a person or environment gained using real-world information or context information [7]. Trial-and-error verification is needed to find out how information can be extracted effectively from real spaces. There are some areas in which wide-ranging technology is needed to respond to the need for advanced intelligence and privacy management. An environment for the provision of mobile ubiquitous services is to be implemented by forming this mechanism as a service support platform on the mobile ubiquitous network. Research towards this aim needs to be accelerated from now on.

## 6. Conclusion

For the future of mobile services, we have discussed the idea of developing a "mobile ubiquitous" world by promoting a transition to ubiquitous technology whereby all kinds of objects in real space are connected via broadband mobile networks, allowing real spaces to be connected with virtual spaces on the mobile core. As a next-generation system for the implementation of this goal, we have described a "4G+" mobile network in which mobile terminals are used as gateways for the expansion of the network into ubiquitous environments. This system is centered around introducing All-IP technology into existing (≤3G) cellular mobile networks while increasing their speed and bandwidth. In this 4G+ network architecture, networking is performed by the three main constituent elements of terminals, networks and service support platforms. It is thought to be essential to achieve smooth interconnections between these main constituent elements. It is also essential to have new wireless network technology that can efficiently accommodate and control many ubiquitous devices with efficient wireless resource control. In today's Internet these constituent technologies are developing separately, and techniques to link them together are also being separately developed for each individual service that requires them. In the world of mobile ubiquitous networking, it is envisaged that it will be possible for telecommunication carriers to create new markets by providing a place where they can coordinate these technologies to facilitate the prompt provision of services.

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## Abbreviations

API: Application Programming Interface
ATM: Asynchronous Transfer Mode
FOMA: Freedom Of Mobile multimedia Access
IP: Internet Protocol
ITU: International Telecommunication Union
OFDM: Orthogonal Frequency Division Multiplexing
PAN: Personal Area Network
PDC: Personal Digital Cellular
QoS: Quality of Service
RFID: Radio Frequency IDentification
SCM: Supply Chain Management
UbG: Ubiquitous Gateway
ULN: Ubiquitous Local Network
VoIP: Voice over Internet Protocol
VSF-OFCDM: Variable Spreading Factor-Orthogonal Frequency and Code Division Multiplexing
W-CDMA: Wideband Code Division Multiple Access
WLAN: Wireless Local Area Network
WWRF: Wireless World Research Forum