2012/3/28

# The Multimedia Mobile Access Communication Systems Forum (MMAC Forum)
# Wide-area Ubiquitous NW-WG
# Report Ver. 1.2

# Introduction

This working group has studied a wireless network providing stable machine-to-machine (M2M) communications over wide areas, called the wide-area ubiquitous network (WAUN), as well as a wireless access system for this network, called the wide-area ubiquitous wireless system (WAUWS).

The WAUWS enables achievement of a ubiquitous network society with a large number of objects connected to the network, and it improves convenience and efficiency in our lives. The WAUWS provides communication service, anytime and anywhere, to any object, based on an autonomous information flow (specifically, using the retrieved information according to the application and controlling devices remotely). The WAUWS also provides a platform for creating new applications of M2M communications, including being widely dispersed, scalable, secure, and supporting low-power terminals.

The WAUWS should be a reliable, stable and flexible wireless system, to enable an infrastructure to be built for a richer, safer and more secure ubiquitous information society.

In this report, we describe the technical requirements for this WAUWS, as compiled by the Wide-area Ubiquitous Networking Working Group (WAUN-WG) in the Multimedia Mobile Access Communication system (MMAC) Forum.

This document is composed of three parts.

Part 1: System Concept

Part 2: Technical Requirements

Part 1 summarizes the concept of this system, while Part 2 summarizes the technical requirements.

Part1: System Concept



Part2: Technical Requirements

# Part 1: System Concept

## 1. Scope of Study

The basic approach taken by the Wide-area Ubiquitous Networking Working Group (WAUN-WG) is to standardize, for the wide-area ubiquitous network (WAUN), a wireless access system called the wide-area ubiquitous wireless system (WAUWS).

The scope of the study is to define system requirements for WAUWS:

- Technical requirements focusing on standard specifications, and
- Frequency sharing requirements focusing on frequency assignment.

## 2. Ubiquitous Sensor Networks

### 2.1. Context for Ubiquitous Sensor Networks

The requirements of a ubiquitous network are to provide communication services to any object and any person for any information, anytime and anywhere. The requirement “any object” is the most important point to consider in developing new applications because it will dramatically expand communication needs.

Advances in wireless technology are enabling all kinds of objects to be connected to networks, and this is making it possible to incorporate information from real-space entities, such as products (e.g., product IDs), locations, health (e.g., blood pressure, body temperature, pulse), the environment (e.g., temperature, humidity), or events (e.g., avalanches), rather than just human-generated, imaginary-space information (e.g., documents, images, video, etc.).

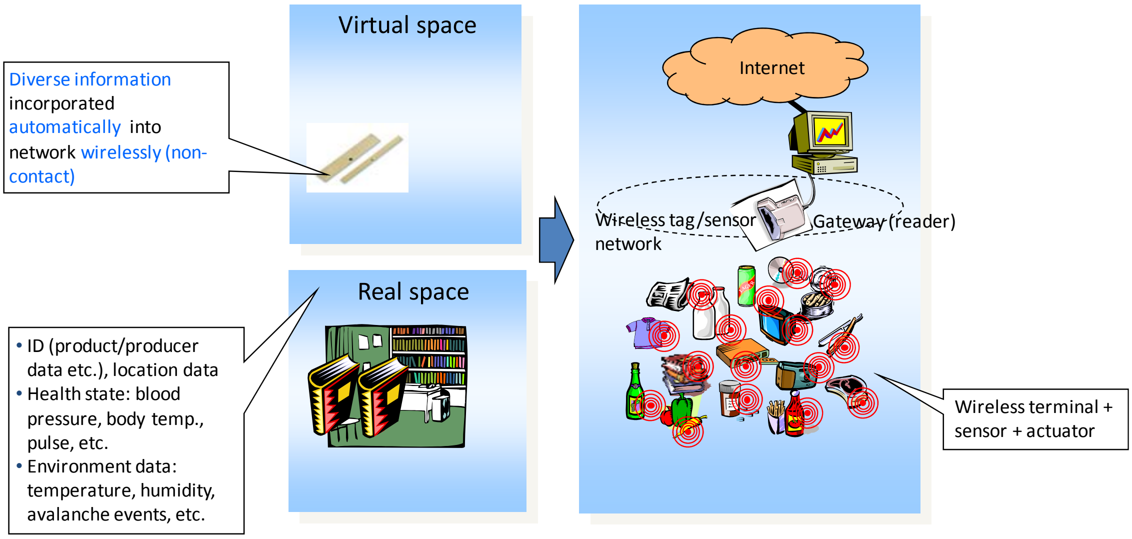



**Figure 2.1-1 Networking of imaginary-space (human) information and real-space (object) information**

## 2.2. Creating Markets with Ubiquitous Sensor Networks

Ubiquitous sensor networks enable creation of new services through communication with objects, and hold the potential for a social paradigm shift similar to those brought by voice communication using mobile phones and mobile data communication using i-mode. The Radio Policy Panel of the Ministry of Internal Affairs and Communications (as of July 2009) has projected that newly created services will affect markets on the order of 22.2 trillion yen by the year 2020.

## 2.3. Contribution of Ubiquitous Sensor Networks to Society

Ubiquitous sensor networks are expected to enable ICT services, such as more efficient task management (e.g., automatic meter reading), disaster prevention and response (e.g., earthquake monitoring), and environmental preservation (e.g., CO2 concentration measurement). They are also expected to contribute to building infrastructure for a "ubiquitous society," with improved safety and security, reduced environmental impact, and more comfortable and convenient lifestyles.

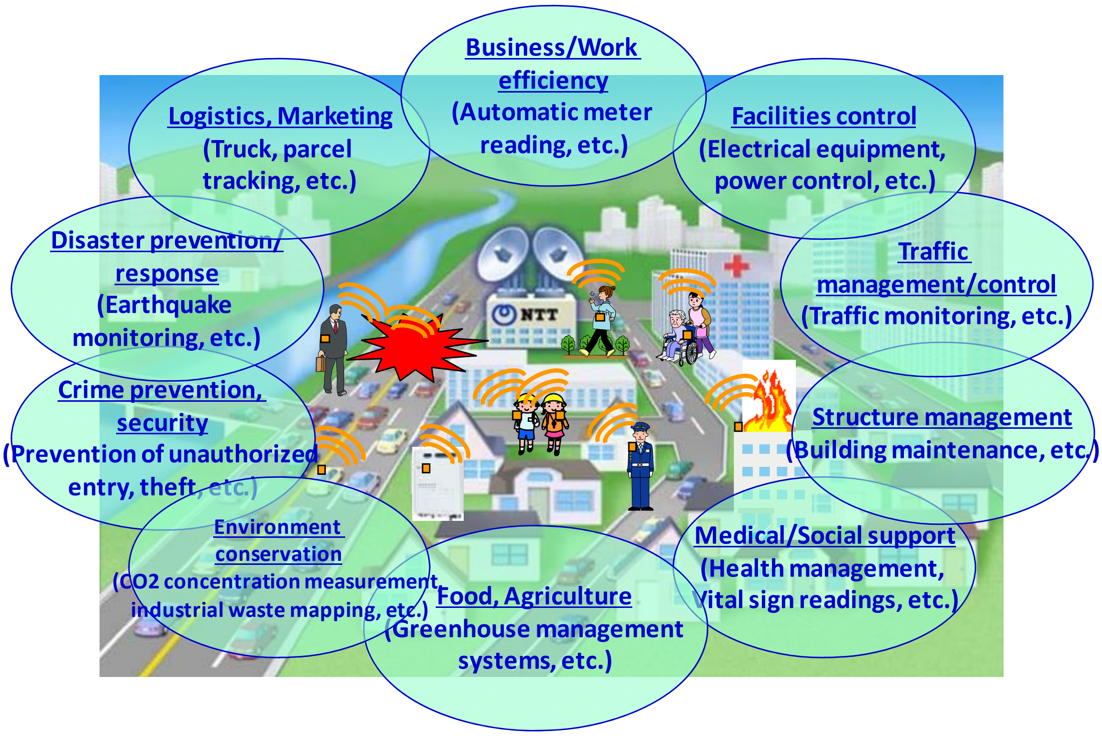



**Figure 2.3-1 Contributions of infrastructure to ubiquitous networked society**

## 2.4. Expansion of Networking Domain

The networking domain continues to expand, from narrow-band to broadband, from broadband to mobile, and with ubiquitous sensor networks, to include objects as well. Networks are gradually expanding from human communication, in which portable wireless terminals are used, to communication with objects, i.e., embedded wireless terminals incorporated into the environment. Short-range wireless systems such as radio frequency identification (RFID) are already being used to implement various applications and services, particularly within independently operated, closed (internal) areas.

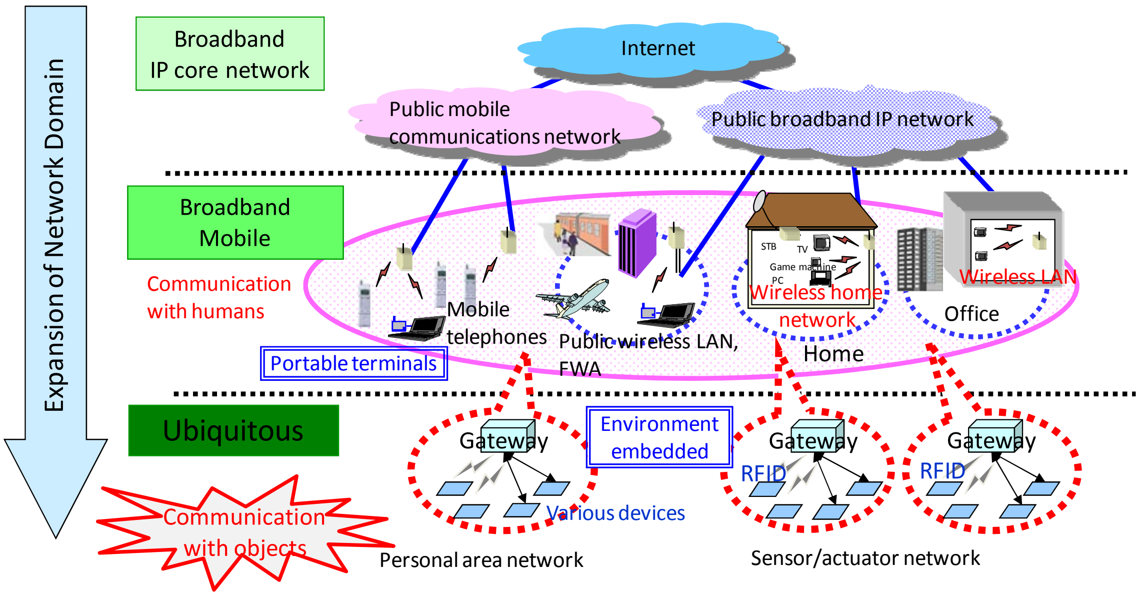



**Figure 2.4-1 Expansion of network domain**

## 2.5. Scope of Application for Ubiquitous Sensor Networks

Examples of practical applications expected to use communication with objects on ubiquitous sensor networks are described below.

(1) Health monitoring (body temperature, heart rate, blood pressure, etc.)

(2) Home monitoring, security (state of door locks, toilets, baths, etc.)

(3) Factory monitoring (furnace/oven temperatures, fault monitoring, waste materials, etc.)

(4) Environmental monitoring (CO2 concentrations, water levels, temperatures, etc.)

(5) Vehicle monitoring (component monitoring, running state, etc.)

(6) Traffic monitoring (traffic volume, accidents, etc.)

(7) Facilities control (abnormality monitoring, settings, switching on and off, etc.)

(8) Meter reading (gas, water, and electricity meters)

(9) Agricultural monitoring and control (cultivation records, environment optimization, etc.)

Applications are not limited to closed or internal areas, such as the home, buildings or factories. Applications and needs can also be found in wide areas, such as on roadways, waterways and outside of buildings. Thus, it is desirable to expand the application area for ubiquitous sensor networks beyond closed, privately operated areas to include wider, public areas. In the following sections, how this expansion can be brought about is described.

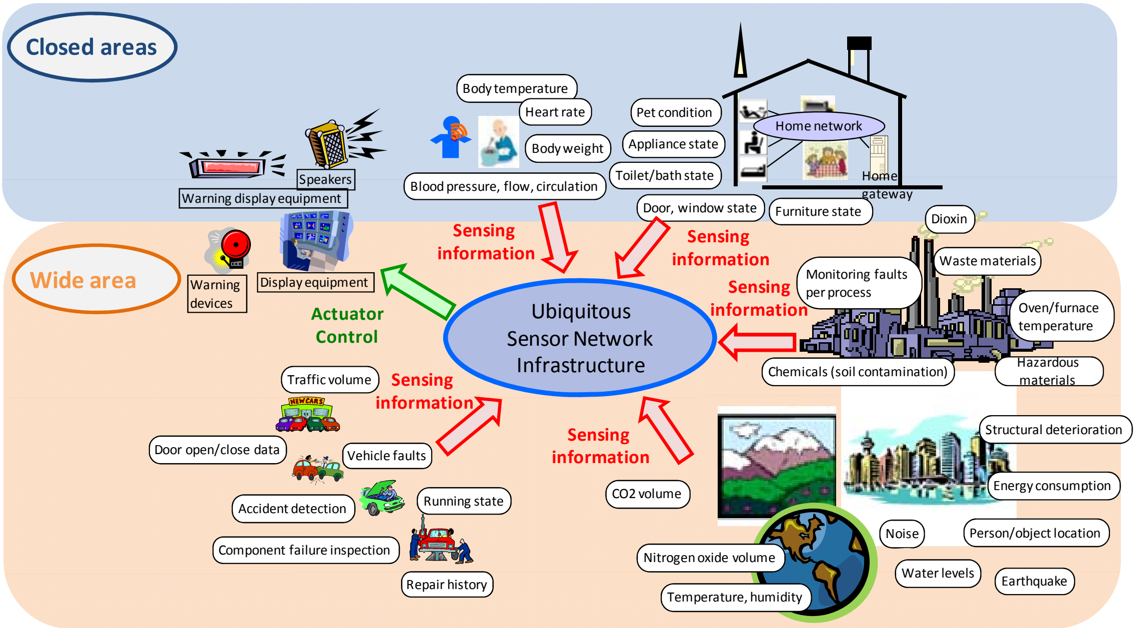



**Figure 2.5-1 Example applications of communication with objects**

## 3. System Architecture of Ubiquitous Sensor Network

### 3.1. What is Communication with Objects?

All types of “objects” have some information without direct human involvement. These objects can range from the simplest device, which only bears each identifier (ID) indicating its existence, to one that accumulates a variety of sensing data or a log. Communication with such objects, usually without human intervention, differs greatly from communication with humans, and it has the following features.

(1) Generally, neither an electric power supply for operation of the objects nor battery charge can be assumed.

(2) The object cannot be expected to process Internet protocol (IP) communications.

(3) There is usually a large number, and often a variety, of objects.

(4) The objects can exist anywhere and everywhere, and can also be mobile.

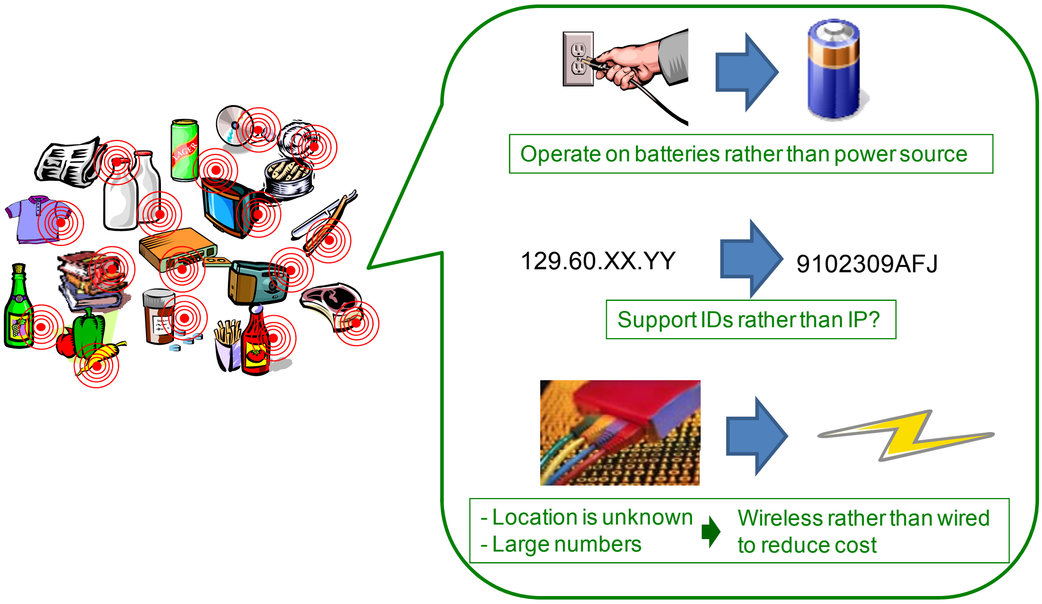



**Figure 3.1-1 Object characteristics**

To fulfill these features, communication with objects has the following requirements.

(1) Low power consumption (for long periods of operation on battery or environmental energy)

(2) Support for non-IP networking (objects have constraints on computing resources and communications functionality)

(3) Support for widespread distribution (wider service area than communication with humans)

(4) Low cost (less expenditure for both equipment and operation is necessary, providing capable communication with a large number of objects)

## 3.2. Example of System Architecture

Considering the various requirements for communication with objects, and requirement (2) in particular, the architecture of a communication system should preferably accommodate such objects within a local IP or non-IP network and should provide a connection to the backbone IP network through a gateway (GW). Comprehensively, the most promising way to provide such local IP or non-IP networks, capable of low power consumption and wide distribution, is possibly based on a wireless system.

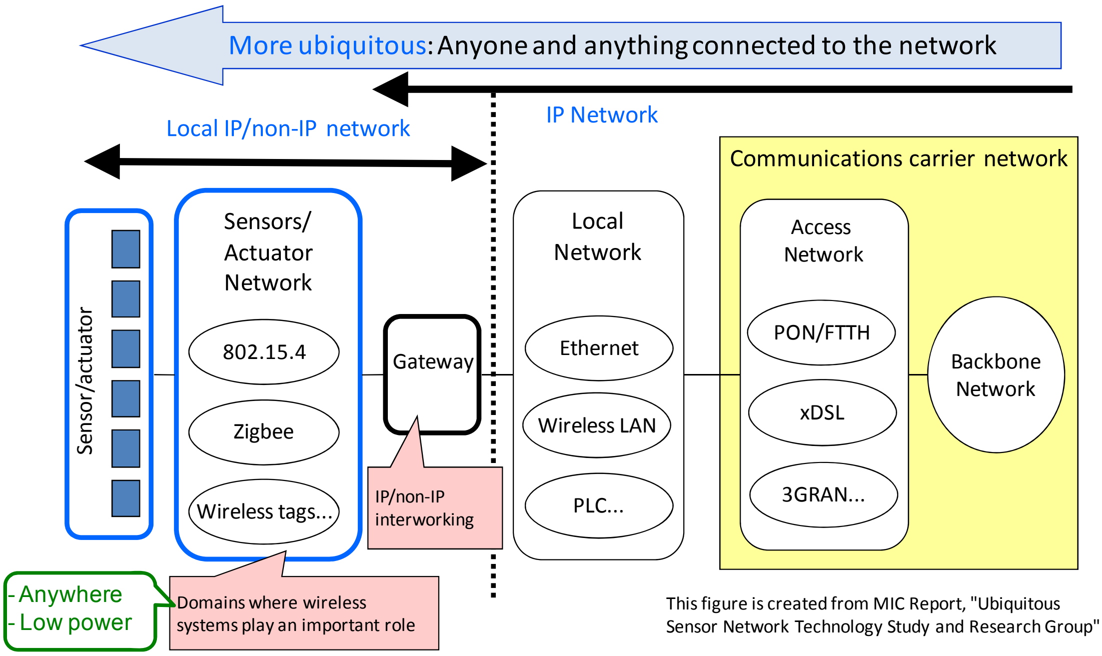



**Figure 3.2-1 Example network architecture**

## 3.3. Topologies for Accommodating Terminals

The three cases of topologies for accommodating terminals are described below.

- Case 1: Direct connection to a dedicated network infrastructure. Objects must have a unique, global, non-IP network address. This enables mobility over a wide area, and communication with the backbone IP network is assumed through dedicated base stations.
- Case 2: Objects are accommodated in a local area network routed through a gateway. The communication range (possibly mobile) is limited within the local area but can connect to IP network infrastructure through a gateway.

Case 3: Objects are accommodated in a local area network routed through a gateway, and areas are expanded by using a wireless multi-hop function. Higher reliability can be achieved by detouring around deficient paths. As with Case 2, connection with the IP network infrastructure is assumed through a gateway.

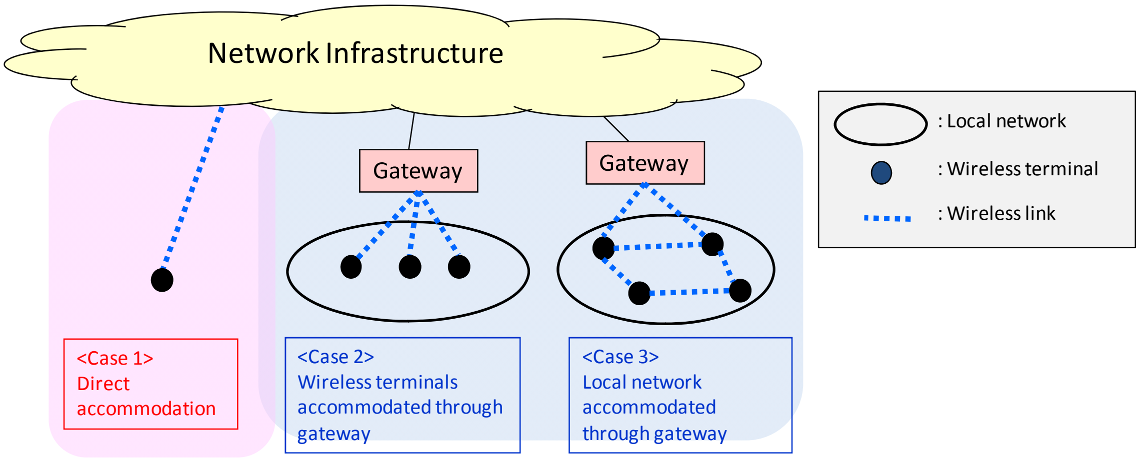



**Figure 3.3-1 Topologies for accommodating wireless terminals**

The features of these topologies are shown below.

In the case of direct accommodation, terminals connect to only a public wireless WAN, while gateway topologies combine public wired or wireless WAN with a private wireless system.

**Table 3.3-1 Features of accommodation topologies**

| Topology | Example of gateway | Example of wireless gateway | Example of terminal | Application example | Features |
|---|---|---|---|---|---|
| **Direct accommodation** | None (Case 1) | Cellular phone | Household devices Surveillance cameras Various sensors | Remote control Remote monitoring Gathering sensor information | Independence |
| **Gateway topologies** | Cellular phone (Case 2) | Cellular phone + ZigBee, | Wearable sensors, Headsets | Gathering sensor information Content transmission | Portable Mobility Low power consumption Compact |

| | | | | | |
|---|---|---|---|---|---|
| | | Bluetooth, RFID | | | |
| | Car navigation Mobile router (Case 3) | Cellular phone + Wireless LAN/PAN | Vehicle mounted sensors Vehicle mounted DVD | Gathering sensor information Content transmission | Portable Mobility |
| | Home gateway PC (Case 3) | ADSL, FTTH + Wireless LAN/PAN | Home AV devices | Remote maintenance Content transfer | Fixed (limited movement) High bit-rate |

For the case of gateway topologies, examples of wireless networks connecting to the gateway are described in Table 3.3-2. Each of these transmission distances is up to about 100 m, so a multi-hop function would need to be implemented to support requirement (3), i.e., widely dispersed objects.

**Table 3.3-2 Examples of wireless system for gateway topologies**

| **Wireless system** | **Wireless LAN** | **Bluetooth** | **Low-speed wireless PAN** | **UWB** |
|---|---|---|---|---|
| **Frequency band** | 2, 4 GHz<br>5 GHz | 2.4 GHz | 950 MHz<br>2.4 GHz | 3.1 to 10.6 GHz |
| **Transmission rate** | 11 Mbit/s<br>54 Mbit/s<br>⇒ 500 Mbit/s | 1 Mbit/s | 20 kbit/s<br>40 kbit/s<br>250 kbit/s | 100 to 500 Mbit/s |
| **Communication distances** | 100 m<br>50 m | 10 m | 10 to several 100 m | < 10 m |
| **Power consumption** | High | Medium | Very low | Low |

Based on the above, the system characteristics of Case-3 gateway topology using multi-hop transmission to expand the communication area are summarized below.

◆ Expanding communication area for indoor applications

- Number of relay points is relatively small.
- Inside a building, electric power supply to the relay terminals can be comparatively easier.
- Deployment and operation of the network can be handled by individuals or private companies.

◆ Expanding communication area for outdoor applications

- If a short-range wireless system is used, many relay points are required.
- When dispersed over a wide outdoor area, securing a power supply and maintenance for each relay terminal is difficult.
- If terminals move around a wide area, sophisticated functions, such as detection of mobile terminals and routing control, have to be equipped on each relay terminal.
- Responsibility for deployment, operation and maintenance of the network including each relay terminal is apt to be unclear.

### 3.4. Application of Communication with Objects in Public, Wide-area Networks

As described above, applying a gateway topology with a multi-hop function to outdoor public service areas is difficult because of the problems of stability and maintainability. Thus, there is new demand for ubiquitous sensor networks with the direct accommodation topology, which are able to handle the demands of public services economically over a wide area.

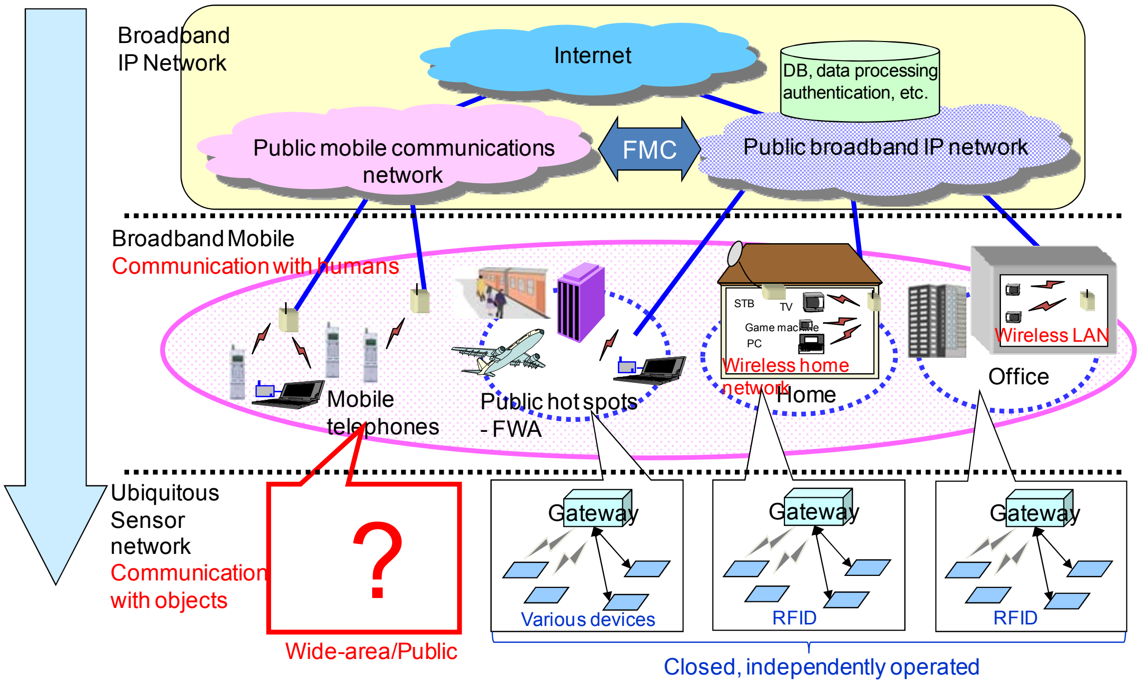



**Figure 3.4-1 Public, wide-area communication with objects**

Expanding communication with objects in wide, public areas is a domain that has not been explored yet. In the same way that a new ICT society has been created due to the expansion of communication with humans in the public network topology and private network topology, the expansion of communication with objects into public, wide-area services will reveal new possibilities for societal life, depending on innovativeness and market expandability of communication with objects.

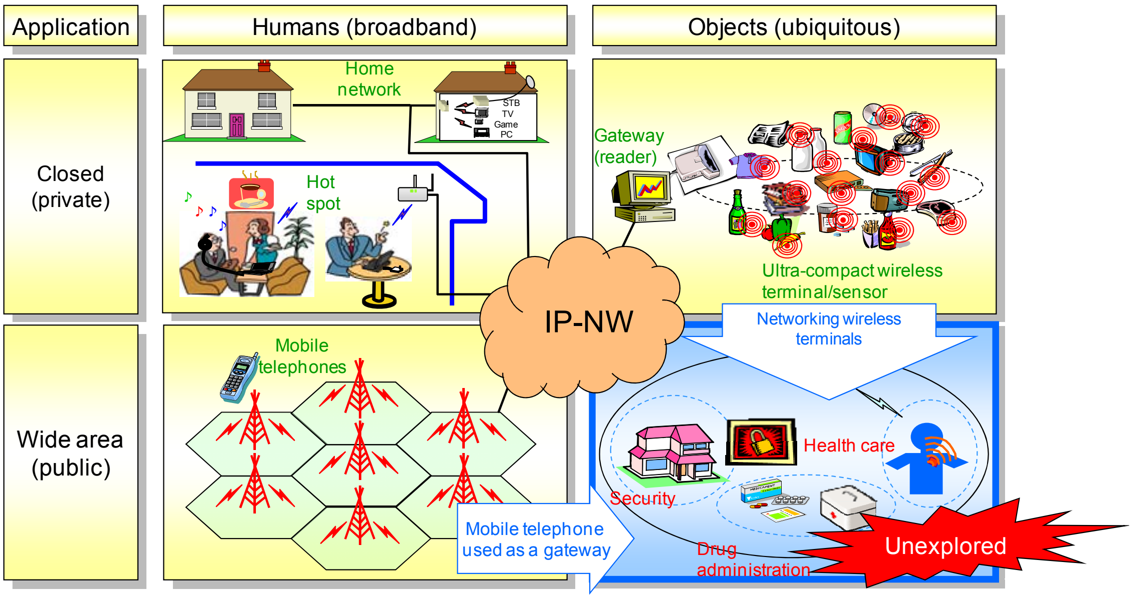



**Figure 3.4-2 Communication applications and areas**

As is the case for communication with humans, it is desirable that the topology of infrastructure for communication with objects is composed of both closed (internal) networks and public networks, which can be independently operated and complement each other. Thus, implementing an optimal wireless communications infrastructure for the unexplored domain of wide-area public services is much anticipated.

**Table 3.4-1 Complementary relationships between wide-area, public and private, closed (internal) communications**

| | **Purpose** | **Wide-area/Public** | **Closed (internal)/ Private** | **Notes** |
|---|---|---|---|---|
| **Wireless communication with humans** | Broadband wireless access of the same class as wired networks | Mobile telephone | Wireless LAN | "Anytime, anywhere" communication achieved by having each complementing the other. |

| | | | | |
|---|---|---|---|---|
| **Wireless communication with objects** | Extremely small terminals attached to anything and highly multiplexed wireless access | Unexplored domain | RFID, Low-speed wireless PAN | |

# 4. Wide-area Ubiquitous Network and its Target Areas

## 4.1. Requirements for System

As mentionend earlier, connecting not only humans, but also sensors and other objects, to networks will reveal the potential for creating new markets for services. Furthermore, expansion of a network to accommodate such objects is anticipated. The WAUN being studied by this working group has the characteristics shown below.

<Aim of WAUN System>

(1) A direct-accommodation topology object-communications network that achieves stable, economical, wide-area, public ubiquitous services.

(2) Low quantity of information (per terminal) but inexpensive object communication services implemented at greatly reduced wireless access costs (reduced number of base stations), which is difficult to achieve with a cellular phone system aimed at broadband communications.

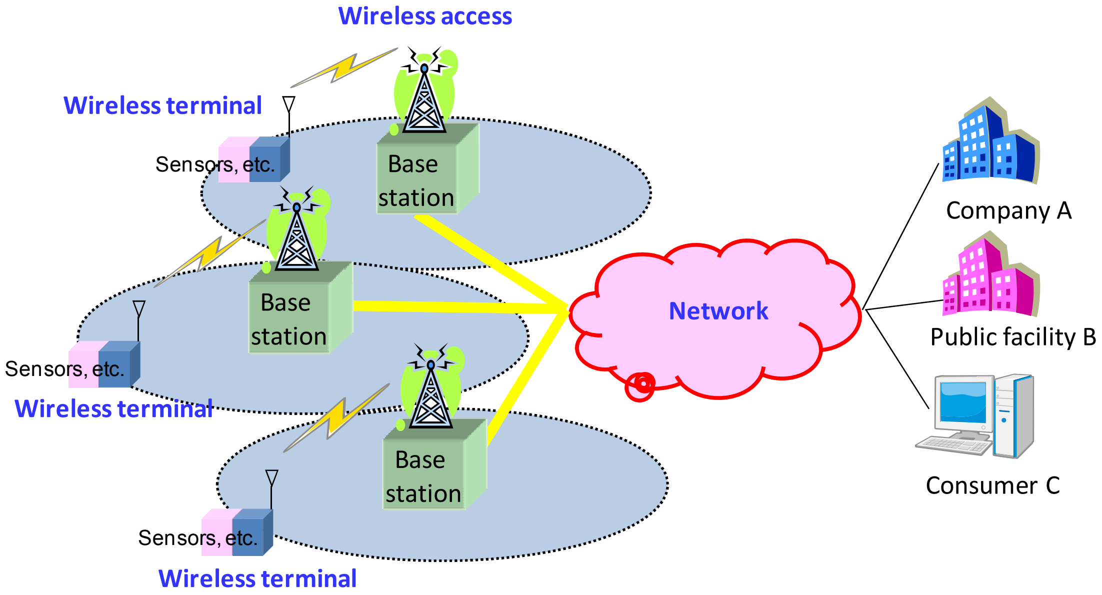



**Figure 4.1-1 Wide-area ubiquitous network (WAUN)**

The goal is to provide a wide-area public ubiquitous sensor network while keeping the costs as low as possible.

Cost reduction for both the infrastructure and user will be considered. The implementation will be based on the following methods.

◆ Cost reduction for communications infrastructure

To cover a wide public area, a wireless cellular system network must be built. However, such cellular systems need many base stations to cover the whole area, and the infrastructure costs depend strongly on the number of base stations. Therefore, it is necessary to increase the radio propagation distance as much as possible for the WAUN. This increases the cell radius, reducing the number of base stations per unit area, and therefore, infrastructure costs.

◆ Cost reduction for user equipment and management

Wireless terminals will be attached to objects, resulting in diffusion of a greatly increasing number of wireless terminals. The workload and costs of maintaining and managing each of the wireless terminals attached to these objects will be very high. In addition, in many cases, sensors and actuators attached to wireless terminals will be placed in environments where it is difficult for people to maintain and manage them. This will increase management costs. To reduce such administrative costs, the wireless terminals implemented will be as maintenance-free as possible, by using long-life batteries to avoid frequent exchange or recharge of the batteries.

## 4.2. Target Areas

Next we describe target areas for this network.

◆ Target area 1: Cost rather than transmission rate

In the WAN domain, speed and capacity have continued to increase, meeting the needs of human communication, with technologies including International Mobile Telecommunication (IMT) 2000, High Speed Packet Access (HSPA), and Long Term Evolutuon (LTE). The needs of human communication through Internet connections have also increased in the LAN domain, leading to increased speed and capacity as with the WAN domain. However, when we use these systems for low-speed communication with throughput of several kbits/s, the networking costs are high relative to the traffic volume for low-speed communication with throughput of several kbits/s, when done in the WAN and LAN domains. There has also not been a clear need for low-throughput applications in the area of human communications.

In contrast, in the short-range wireless domain, various wireless communications technologies are available depending on applications. Such technologies, like RFID and ZigBee, have also been studied for sensor networks communicating with objects. However, the range of applications that can use those technologies is often limited because of short transmission ranges.

We set targets of transmission rates similar to RFID, and of keeping wireless terminals compact, low cost and low power as with RFID, while using more sophisticated base stations to expand the cell radius. Thus, we placed higher priority on cost than on bandwidth.

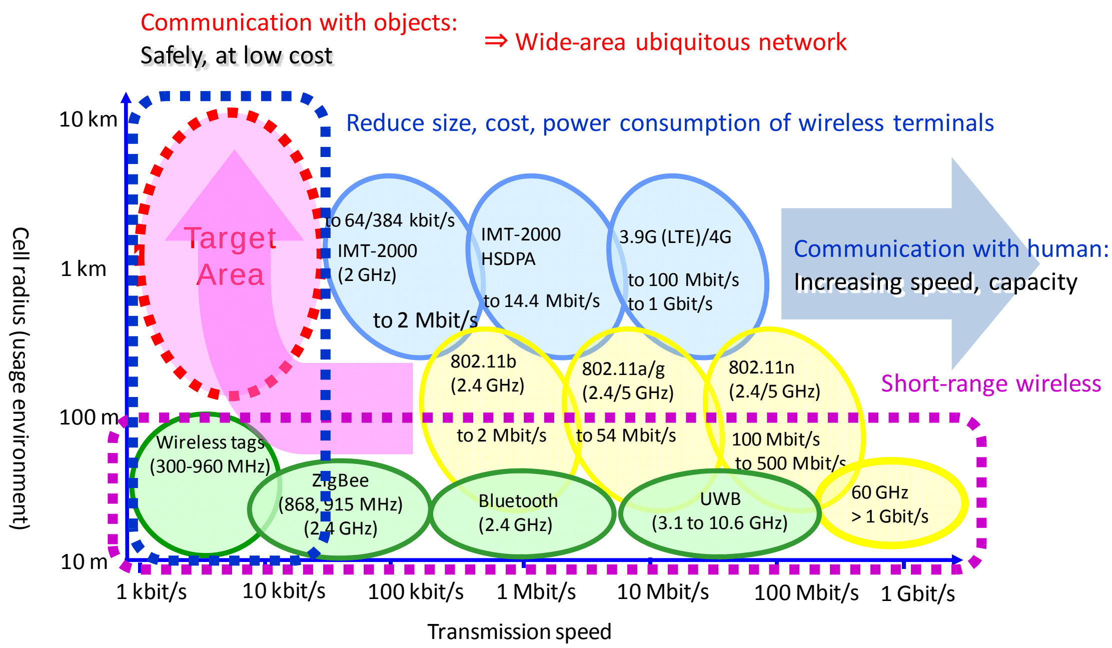



**Figure 4.2-1 Target area 1 (large cell radius and low transmission rate)**

◆ Target area 2: Low-volume data and non-real-time

Most data for communication with humans are high volume and delay sensitive. Cellular systems have continued to increase capacity and speed to support transmission of this sort of data. In contrast, communication with objects such as sensors and actuators does not usually require high volumes and low latency.

The WAUN targets communication with objects, in particular services that require only low data volume and are delay tolerant. This allows us to reduce base station costs by increasing transmission distance and cell size, enabling maintenance-free operation of wireless terminals for a long period with only a battery, even in an environment where a power supply is not available.

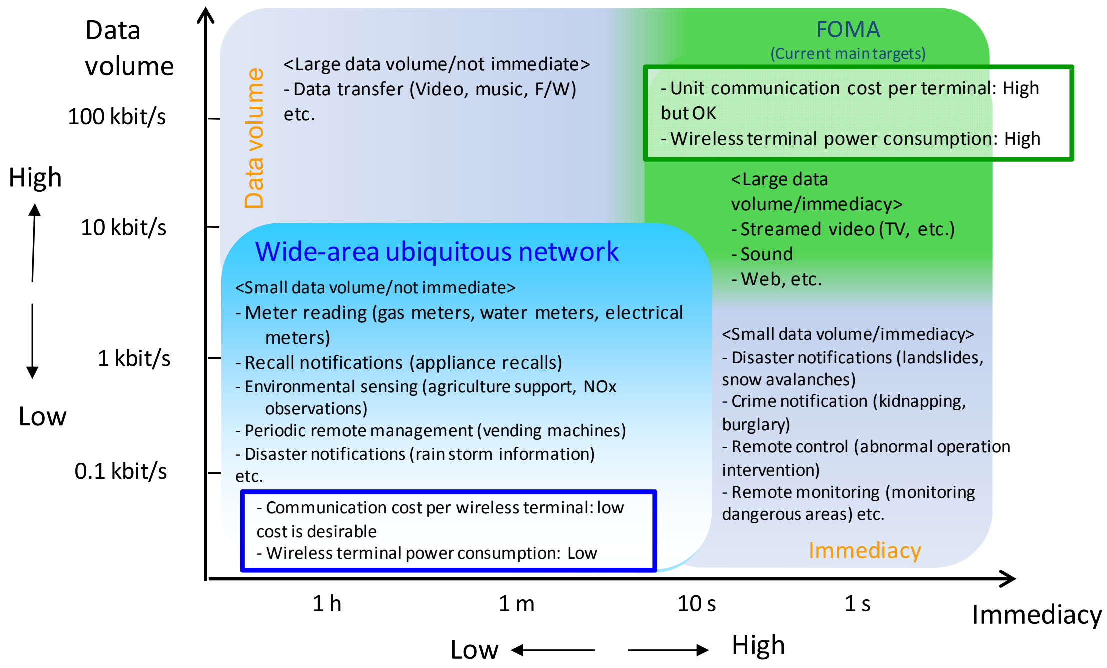



**Figure 4.2-2 Target area 2 (low-volume data and non-real-time)**

## 4.3. Target Applications

◆ Relationship between commercial feasibility and cell radius

Since this system is for providing public services, building the communication infrastructure must be commercially feasible. We thus increase the cell size and reduce the number of cells. The cost of a base station serving one wireless terminal is reduced by increasing the number of wireless terminals served by one base station. From this perspective, we can estimate roughly the number of wireless terminals that must be served by one base station, as well as the required cell radius, to obtain a picture of a commercially feasible system.

Figure 4.3-1 shows the relationships between the number of wireless terminals per base station/cell, the total terminal cost served in the cell, and the revenue, assuming that the subscrition cost is approximately 100 yen/month/wireless terminal and a wireless terminal costs several thousand yen. The difference between revenue and total wireless terminal cost includes infrastructure cost and profit. As shown in Figure 4.3-1, if a base station can serve tens of thousands of wireless terminals, this system will be commercially feasible.

Figure 4.3-2 shows the relationship between cell radius and the number of wireless terminals in the cell. Note that we assume that one household has one wireless terminal. According to Fig. 4.3-2, a feasible condition for commercialization is when a cell radius is larger than a few kilometers for serving a few tens of thousands of wireless terminals per base station.

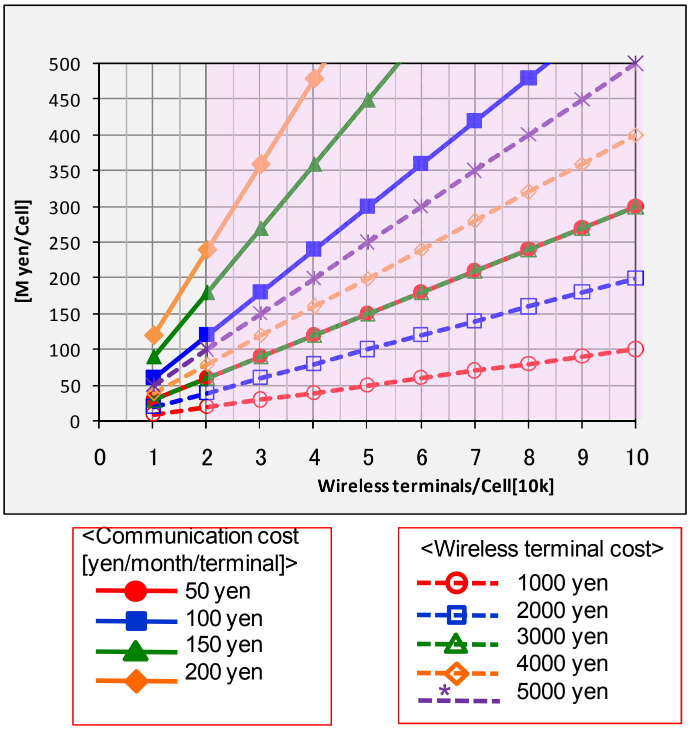
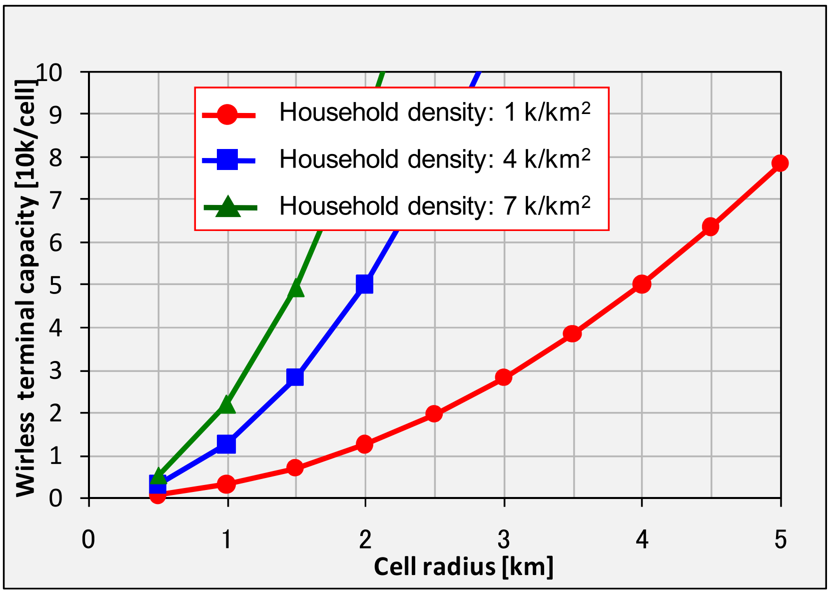



**Figure 4.3-1 Terminals/cell vs. cost/revenue**




| Household density [10,000/km$^2$] | Area examples |
|---|---|
| 0.1 | Kawagoe City, Yotsukaido City, etc. |
| 0.4 | Yokohama City, Kawaguchi City, Ichikawa City, etc. |
| 0.7 | Average of 23 Wards of Tokyo |

Note: Chiba City: 1.5 k/km$^2$

**Figure 4.3-2 Cell radius vs. terminals/cell**

◆ Wireless terminal capacity and throughput

Here we consider the relationship between the number of wireless terminals served in a cell and the throughput of one single wireless terminal. Figure 4.3-3 shows the relationship between cell radius and throughput per wireless terminal. Note that we assume the wireless terminal density is the same as for Fig. 4.3-2, which is one wireless terminal per household. We also assume that the per-channel transmission rate is 9600 bits/s and the transmission efficiency is 20%. Figure 4.3-3 shows that the single wireless terminal throughput is described as follows:

A cell radius of 2.5 to 3.5 km yields approximately 4.6 to 9 kbytes/month, when two channels are used in a cell.

This allows, for example, a few pages typed text messages to be transmitted each month.

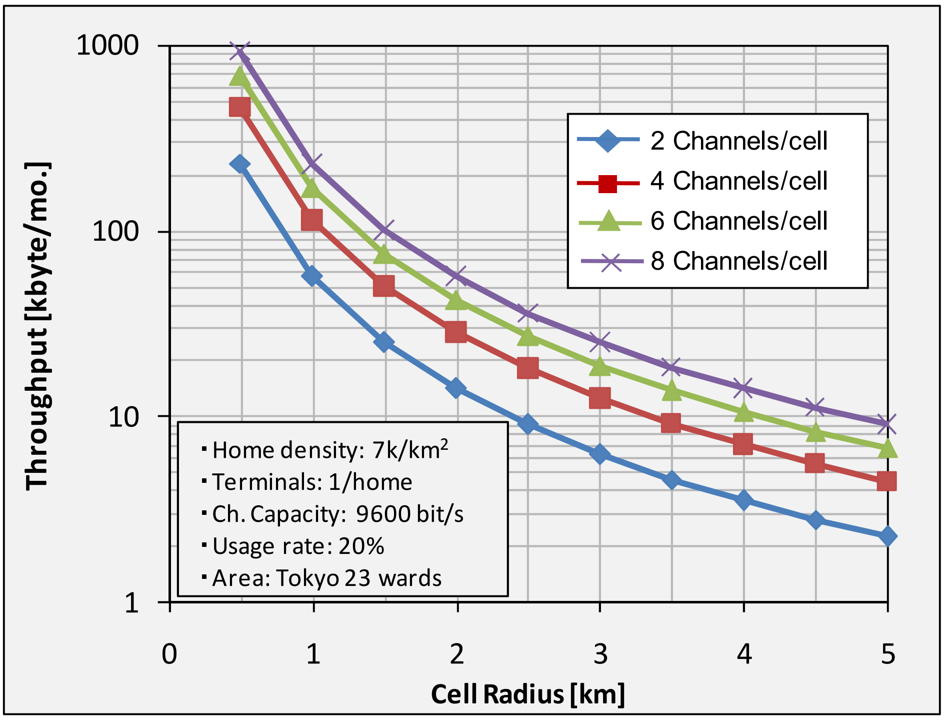



**Figure 4.3-3 Cell radius vs. throughput/terminal (Amount of transmission data allowed from one single terminal per month)**

<Examples corresponding to data volume>

1 Mbyte: Short novel or one 3.5-inch floppy disk

200 kbyte: One box of punch cards

100 kbyte: One low-quality photograph

50 kbyte: One compressed document image

10 kbyte: One page of an encyclopedia

2 kbyte: One page of typed text

1 kbyte: A very short conversation

100 byte: A single text message or a punch card

10 byte: One word

1 byte: One character

◆ Examples of target applications

On the basis of the above, applications targeted for this system should be developed under the following conditions:

- Throughput per terminal is several kilobytes per month.
- Wireless terminal density (“Object” density) is approximately one terminal per

household.

Examples of such applications are as follows.

<Examples of target applications>

- Low-frequency regular data notification: Automated meter reading, etc.
  Tele-metering of gas and water meter reading in wide areas, especially in the areas where on-site reading is difficult.
- Emergency information notification: Product recall notifications, etc.
  Product recall notifications for home appliances, remote monitoring of plant facilities for malfunction alerts, remote monitoring of security areas for preventing unauthorized entry.
- Remote machinery control: Switching (ON/OFF) control, parameter setting, etc.

Control of switches and parameter settings for indoor equipment remotely from the outdoor environment, e.g., switching electricity ON/OFF and changing temperature setting of air conditioner.

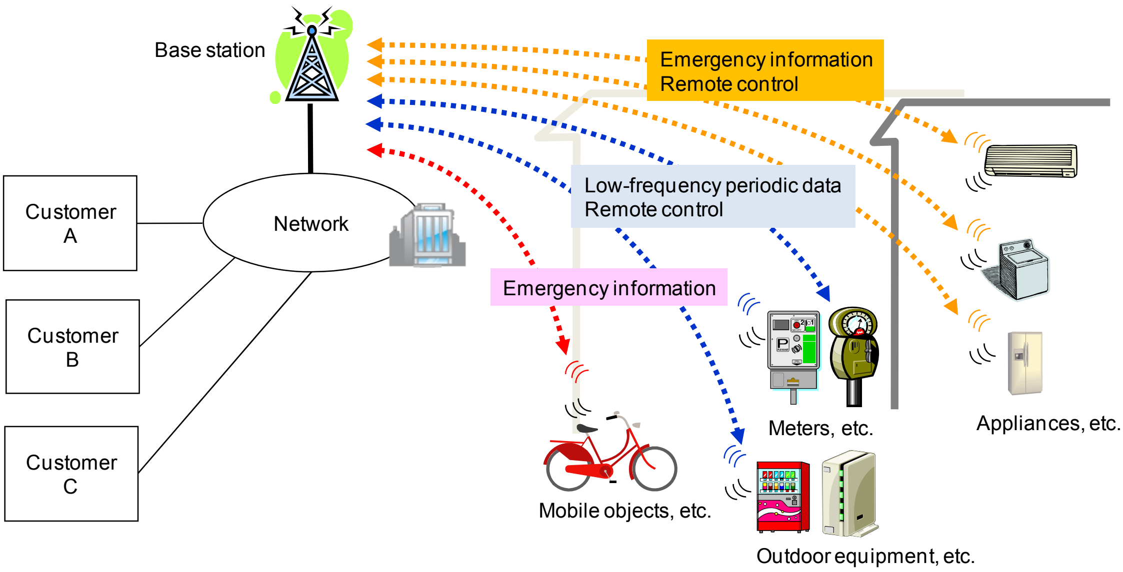



**Figure 4.3-4 Examples of target applications**

## 4.4. System Requirements

We now summarize the system requirements resulting from the above discussion, including (1) large cell radius, (2) accommodation of large numbers of wireless terminals, (3) wireless terminals that are compact, low cost, and low power, and (4) system stability.

<System Requirements>

(1) Large cell radius

A cell radius with wireless terminal transmission power of ten to several hundreds of milliwatts should be a few kilometres.

(2) Accommodation for large numbers of wireless terminals

The system should accommodate numbers of wireless terminals on the order of or greater than the population, with one to five terminals per household.

(3) Wireless terminals should be compact, low cost, and low power

Wireless terminals should be battery-operated, maintenance-free, and be able to operate for several years or more.

(4) System stability

The system must be stable enough to offer public services, and must have strong security.

## 4.5. Advantages over Other Wireless Systems

We summarize the advantages of the WAUN over other wireless systems below.

(1) Comparison with existing cellular phone networks

The WAUN is better than existing cellular phone networks from a cost perspective, with lower wireless terminal and base station costs as follows.

- Wireless terminal cost: low power consumption results in long battery life, so battery and maintenance costs are low. Transmission power is also low, so circuits can be simplified.
- Base station cost: cell radius is large, so fewer base stations are needed.

(2) Comparison with RFID

Compared to RFID and other privately operated systems, this system covers a wider area and enables a stable, direct-access network to be built.

**Table 4.5-1 Comparison with other wireless systems**

| Wireless | Wide-area | | PHS | ZigBee | RFID |
|---|---|---|---|---|---|

| system | ubiquitous network | Cellular phone | | (IEEE802.15.4) | (ISO-18000-7) |
|---|---|---|---|---|---|
| **Transmission rate** | Approx. 9.6 kbits/s | Up to several tens of Mbits/s | Up to several hundreds of kbits/s | 250 kbits/s | Up to 27.7 kbits/s |
| **Wireless terminal output power** | 10 to several hundred mW | Up to 250 mW | 10 mW | Up to 1 mW | up to 4 mW |
| **Transmission distance** | Several km | 1.5 km | Several hundred m | 1 to 100 m | 30 m or more |
| **Battery life** | Several years | Several weeks | Approx. one month | Up to 2 years | Several years |

## 4.6. System Overview

To summarize, an overview of the network system is shown in Fig. 4.6-1.

<Targeted communication with objects>

- Communication with many, widely dispersed objects.
- Data volume per terminal is low, and low-cost communication with objects is desired.
- Communication with objects operating maintenance-free for long periods on batteries.

<Usage scenarios>

- Indoor devices: Gas meters, water meters, home appliances, etc. (readings, recall notices, etc.)
- Outdoor devices: Vending machines, outdoor equipment, etc. (remote maintenance, etc.)
- Mobile devices: Bicycles, automobiles, mobile devices, etc. (managing mobile items, etc.)

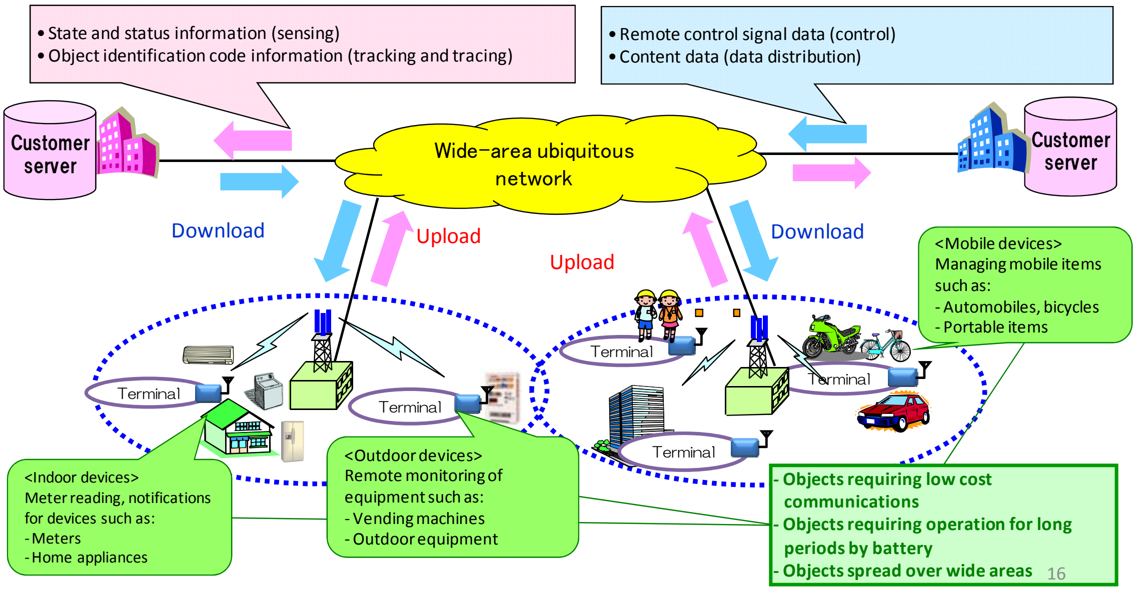



**Figure 4.6-1 System overview**

# Part 2: Technical Requirements

The technical requirements for the wide-area ubiquitous wireless system, which provides stable M2M communication over a wide area, are described below.

(1) Large cell size

- A cell radius of 3.5 km and greater can be achieved with wireless terminal transmission power of 10 mW where man-made noise is negligible.

(2) Accommodation of a large number of wireless terminals

- The system can accommodate one to five wireless terminals per household, as many as in the population.

(3) Wireless terminals

- Wireless terminals should be simple, small, and inexpensive.
- Wireless terminals should have low power consumption, so that their battery life can be for several years.

(4) Security

- The system should provide the security features appropriate for the sensor and/or actuator network system over wide-area public communication services.

## 1. General Conditions

### 1.1. System Structure

The system consists of the following equipment.

- Base station (BS): A base station refers to radio equipment that provides public cellular networks in wide areas.
- Wireless terminal (WT): A wireless terminal refers to radio equipment that is connected to the sensor and/or actuator.
- Compact base station(compact BS): A compact base station refers to radio equipment that is used as an extensional base station, a repeater, or a portable access point.

### 1.2. Frequency Band

The 280 MHz band is suitable , though it has not been allocated yet.

- This band has a favourable balance of propagation path characteristics, man-made noise characteristics, and the allowable carrier frequency offset for demodulation.

## 1.3. Channel Spacing

The basic channel spacing is 25 kHz. The channel spacing means the interval between the center frequencies of each channel. The 12.5 kHz is optional, in the case of the interleave channel arrangement in which a portion of each signal bandwidth is allowed to overlap each other.

## 1.4. Duplex Method

- Public band: Time division duplex (TDD).
- Private band: To be discussed (TBD).

## 1.5. Channel Arrangement

(1) Public frequency band:

- Bandwidth: 3.3 [MHz].

  The cluster size is assumed to be 16.

  Eight channels can be allocated to a cell when channel spacing is 25 kHz.

  Sixteen channels can be allocated to a cell when channel spacing is 12.5 kHz.

  Note: Guard bands are excluded.

- Channel allocation: Fixed channel allocation (FCA).

(2) Sharing frequency band:

- Bandwidth: 1 [MHz].

  Note: Guard bands are excluded.

- Channel allocation: Dynamic channel allocation (DCA).

**Note: The following provisions apply to only the public frequency band.**

**Note: The requirements of sharing a frequency band are TBD.**

## 1.6. Channel Selectivity

The communication channel should be advertised to all WTs through the control channel transmitted from a BS or compact BS.

## 1.7. Transmission Rate

For the transmission rate on the downlink, 9.6 kbits/s/s and 4.8 kbits/s/s should be set for basic mode. Here, 4.8 kbits/s may be used for control information, such as a broadcast packet, which requires higher reliability than data information. Moreover, 14.4 kbits/s, 19.2 kbits/s, and 28.8 kbits/s may be used for optional mode.

Transmission rates of 0.6 kbits/s, 1.2 kbits/s, 2.4 kbits/s, 4.8 kbits/s, and 9.6 kbits/s should be used on the uplink. Each rate may be selected according to the propagation condition and required delay performance.

● Downlink

- 9.6 kbits/s (data).
- 4.8 kbits/s (control).

The symbol rate is fixed for both of these, and the modulation schemes and coding rates are different.

The three optional modes are as follows:

- 14.4 kbits/s (data).
- 19.2 kbits/s (data).
- 28.8 kbits/s (data).

The same as in the basic mode, the symbol rate is fixed, and the modulation methods and coding rates are different.

● Uplink

- 0.6 kbits/s, 1.2 kbits/s, 2.4 kbits/s, 4.8 kbits/s, 9.6 kbits/s (data, control).

The symbol rates are different, and the modulation scheme and coding rate are the same.

## 1.8. Modulation/Demodulation Method (Downlink)

The modulation and demodulation schemes should be designed to use frequencies efficiently and to simplify demodulation on the WTs.

● Modulation methods

- π/4-shift Differential Quadrature Phase Shit Keying (DQPSK) (data).
    - 9.6 kbits/s (coding rate: 1/2)
    - 14.4 kbits/s (coding rate 3/4): Optional mode
- π/2-shift Differential Binary Phase Shit Keying (DBPSK) (control).
    - 4.8 kbits/s (coding rate: 1/2)

Using 16 Quadrature Amplitude Modulation (QAM) is also optional.

- 16QAM (data).
  19.2 kbits/s (coding rate 1/2): Optional mode
  28.8 kbits/s (coding rate 3/4): Optional mode

● Demodulation methods
- Differential detection is used for π/4-shift DQPSK and π/2-shift DBPSK.
- Coherent detection is used for 16QAM.

### 1.9. Modulation/Demodulation Methods (Uplink)

The modulation and demodulation methods should be designed to use frequencies efficiently, and to have low power consumption in the WTs.

● Modulation schemes
  - π/4-shift QPSK (all transmission modes).

● Demodulation schemes
  - Coherent detection.

### 1.10. Multiple-Access Methods

The Time Division Multiple Access (TDMA) scheme should be used for a multiple access method to accommodate several tens to several hundreds of thousands of WTs, since it is a central control scheme, and so it can stably allocate channels to the WTs. In the uplink, multiple subcarriers (sub-channels) are established within the 25 kHz bandwidth, providing a total transmission rate of 9.6 kbits/s. The Frequency Division Multiple Access (FDMA) scheme should also be used as a multiple access scheme for the inter-sub-channels.

<Downlink>
- 9.6 kbits/s, 4.8 kbits/s: TDMA scheme controlled centrally at the BS.

<Uplink>
- 9.6 kbits/s: TDMA scheme controlled centrally at the BS.
- 0.6 kbits/s, 1.2 kbits/s, 2.4 kbits/s, and 4.8 kbits/s: TDMA-FDMA scheme controlled centrally at the BS.

  Subcarriers are established at equal intervals within the 25 kHz bandwidth, with one of the following multiplicities. The WTs connect at the same time, each using a single, different subcarrier.
  0.6 kbits/s: 16 sub-carriers (1.5625 kHz carrier interval)
  1.2 kbits/s: 8 sub-carriers (3.125 kHz carrier interval)

2.4 kbits/s: 4 sub-carriers (6.25 kHz carrier interval)
4.8 kbits/s: 2 sub-carriers (12.5 kHz carrier interval)

# 2. Wireless Equipment Technical Requirements

## 2.1. Transmitter Equipment

### 2.1.1. Antenna Power

#### 2.1.1.1. Antenna power (BS)

The antenna power of the BSs should be as follows.

Max. 46 dBm

- Transmission power: Max. 4 W (measured at point connected with antenna).
- Antenna gain: Max. 10 dBi.

#### 2.1.1.2. Antenna power (WT)

The antenna power of the WTs should be as follows.

Max. 30 dBm

- Transmission power: Max. 1 W (measured at point connected with antenna).
- Antenna gain: Max. 0 dBi.

Note: It is desired that the antenna power is limited to the permitted range of licence-free power under the Radio Law in Japan.

#### 2.1.1.3. Antenna power (compact BS)

Antenna power of the compact BSs should be as follows.

Max. 35 dBm

- Transmission power: Max. 1 W (measured at point connected with antenna).
- Antenna gain: Max. 5 dBi.

### 2.1.2. Occupied Bandwidth

Occupied bandwidth is a measure of the bandwidth containing 99% of the total integrated power for the transmitted spectrum and is centered on the assigned channel frequency. The occupied bandwidth should be as follows. Note that a roll-off filter with a roll-off factor of 0.2 is assumed to be used as the base-band filter.

● Downlink

- 11.52 kHz or less.

● Uplink
- 11.52 kHz or less (9.6 kbits/s).
- 5.76 kHz or less (4.8 kbits/s).
- 2.88 kHz or less (2.4 kbits/s).
- 1.44 kHz or less (1.2 kbits/s).
- 0.72 kHz or less (0.6 kbits/s).

### 2.1.3. Frequency Tolerance

The frequency tolerances should be as follows.
- BS: 1 ppm or less when channel spacing is 25 kHz, 0.05 ppm or less when channel spacing is 12.5 kHz as an optional model.
- WT: 15 ppm or less.
- Compact BS: 1 ppm or less.

### 2.1.4. Adjacent Channel Leakage Power (BS, Compact BS)

Adjacent channel leakage power is defined as leakage of the power radiated into the ±5.76 kHz band of the frequency 25 kHz distant from the center frequency. Adjacent channel leakage power should be as follows.
- BS: -52 dB or less relative to carrier power at any transmission rate.
- Compact BS: -40 dB or less relative to carrier power at any transmission rate.

### 2.1.5. Adjacent Channel/Sub-channel Leakage Power (WT)

Adjacent channel leakage power at 9.6 kbits/s and adjacent sub-channel leakage power at 4.8 kbits/s, 2.4 kbits/s, 1.2 kbits/s, and 0.6 kbits/s should be as follows.

<Offset frequency and occupied bandwidth of adjacent channel/sub-channel leakage power>

| Transmission rate (kbits/s) | Offset frequency (kHz) | Occupied bandwidth (kHz) |
|---|---|---|
| 9.6 | 25 | ±5.76 |
| 4.8 | 12.5 | ±2.88 |
| 2.4 | 6.25 | ±1.44 |
| 1.2 | 3.125 | ±0.72 |
| 0.6 | 1.5625 | ±0.36 |

- Adjacent sub-channel leakage power:

-38 dB or less relative to carrier power when transmission power is 300 mW or less

-40 dB or less relative to carrier power when transmission power is greater than 300 mW.

The 2nd and 3rd adjacent channel leakage power and the 2nd and 3rd adjacent sub-channel leakage power should be as follows.

<Offset frequency and occupied bandwidth of 2nd adjacent channel/sub-channel leakage power>

| **Transmission rate (kbits/s)** | **Offset frequency (kHz)** | **Occupied bandwidth (kHz)** |
|---|---|---|
| 9.6 | 50 | ±5.76 |
| 4.8 | 25 | ±2.88 |
| 2.4 | 12.5 | ±1.44 |
| 1.2 | 6.25 | ±0.72 |
| 0.6 | 3.125 | ±0.36 |

<Offset frequency and occupied bandwidth of 3rd adjacent channel/sub-channel leakage power>

| **Transmission rate (kbits/s)** | **Offset frequency (kHz)** | **Occupied bandwidth (kHz)** |
|---|---|---|
| 9.6 | 75 | ±5.76 |
| 4.8 | 37.5 | ±2.88 |
| 2.4 | 18.75 | ±1.44 |
| 1.2 | 9.375 | ±0.72 |
| 0.6 | 4.6875 | ±0.36 |

- 2nd adjacent channel/sub-channel leakage power:
  -45 dB or less relative to carrier power.

- 3rd adjacent channel/sub-channel leakage power:
  -50 dB or less relative to carrier power.

## 2.1.6. Transmission Spurious Emission

Transmission spurious emission should be as follows.

- BS: 25 μW/100 kHz or less.
- WT: 50 μW/100 kHz or less, and -50 dB/channel bandwidth or less relative to carrier power.
- Compact BS: 50 μW/100 kHz or less.

These values are specified as measuring equivalent isotropically radiated power (EIRP) in a spurious domain.

Measurement methods for when multiple carriers are transmitted from a BS or a compact BS are TBD.

Note that this clause may be modified according to the examination of coexistence with other wireless systems.

### 2.1.7. Carrier-off Time Leakage Power

Carrier-off time leakage power should be as follows.

- BS: No stipulation.
- WT: 1 nW/ 11.52 kHz or less.
- Compact BS: No stipulation.

Note that a transition period of burst transmission is not included in these figures.

### 2.1.8. Transient Response of Burst Transmission (Ramp Symbol Length)

Transient response of burst transmission (ramp symbol length) should be as follows.

- BS: Four symbols at both start and end points of burst transmission at any transmission rate. Its absolute time is 4/9600 sec.
- WT: Four symbols at both start and end points of burst transmission at any transmission rate. The absolute time at each transmission rate differs as follows:

  9.6 kbits/s: 4/9600 sec.
  4.8 kbits/s: 4/4800 sec.
  2.4 kbits/s: 4/2400 sec.
  1.2 kbits/s: 4/1200 sec.
  0.6 kbits/s: 4/600 sec.
- Compact BS: Four symbols at both start and end points of burst transmission at any transmission rate. Its absolute time is 4/9600 sec.

## 2.1.9. Intermodulation

### 2.1.9.1. Intermodulation (BS, compact BS)

Intermodulation emission generated by mixing a desired signal within a regulated power and interfering signal at the first, 2nd, and 3rd adjacent channel offset from the desired signal with powers of -30 dB less than that of the desired signal should be less than the permissible level of the spurious emission and adjacent channel leakage power.

<Adjacent channels>

- BS: -52 dB/11.52 kHz or less relative to desired signal level.
- Compact BS: -40 dB/11.52 kHz or less relative to desired signal level.

<2nd/3rd adjacent channels>

- BS: 25 μW/100 kHz or less.
- Compact BS: 50 μW/100 kHz or less

In addition, measurement frequencies for intermodulation are as follows.

- Measurement frequency: 2 x (interfering signal frequency) - (desired signal frequency).

### 2.1.9.2. Intermodulation (WT)

Intermodulation emission generated by mixing a desirable emission within a regulated power and disturbing waves at the first, 2nd, and 3rd adjacent channel offset, in the case of a 9.6 kbits/s transmission rate, and at the first, 2nd, and 3rd adjacent sub-channel offset, in the case of 4.8 kbits/s, 2.4 kbits/s, 1.2 kbits/s, and 0.6 kbits/s transmission rates, from the desired emission with power of 30 dB less than the desirable emission should be less than the permissible level of the spurious emission and adjacent channel leakage power.

<Adjacent channels>

- -45 dB/channel bandwidth or less relative to desired signal level.

<2nd/3rd adjacent channels>

- 50 μW/100 kHz or less and -50 dB/channel bandwidth or less relative to desired signal level.

Measurement frequencies for intermodulation signal level are as follows.

- Measurement frequency: 2 x (frequency of disturbing wave) - (signal frequency).

## 2.2. Receiver Equipment

### 2.2.1. Reception Sensitivity

The reception sensitivity is defined as the minimum input power (dBm) of the radio receiver component that yields a packet error rate (PER) of 1.0E-2 when packets with a length of X bits are received (the packet length, X, is TBD.) Feeder losses from the antenna to the receiver are excluded.

The reception sensitivity should be as follows:

- BS, compact BS:
  - 9.6 kbits/s: -123 dBm or less.
  - 4.8 kbits/s: -126 dBm or less.
  - 2.4 kbits/s: -129 dBm or less.
  - 1.2 kbits/s: -132 dBm or less.
  - 0.6 kbits/s: -135 dBm or less.

- WT:
  - 9.6 kbits/s: -120 dBm or less.
  - 4.8 kbits/s: -123 dBm or less.

### 2.2.2. Maximum Input Level

The maximum input level is defined as the maximum input power (dBm) of the radio receiver component that yields a PER of 1.0E-2 when packets with a length of X bits are received (the packet length, X, is TBD).

The maximum input level should be as follows:

- BS: Greater than the reception sensitivity by 55 dB or greater.
- WT: -50 dBm or greater
- Compact BS: Greater than the reception sensitivity by 55 dB or greater.

### 2.2.3. Adjacent Channel Selectivity (WT)

The adjacent channel selectivity is defined as the level ratio of an interfering modulated signal to the desired signal level when the PER of the desired signal is 1.0E-2.

The desired signal and the interfering signal are specified by the following statement: The level of the desired signal is set to +3 dB greater than the level of the specified reception sensitivity.

The interfering signal is mistuned to the ±5.76 kHz band of the frequency 25 kHz distant from the center frequency

The adjacent channel selectivity should be 30 dB or greater.

### 2.2.4. Adjacent Channel/Sub-channel Selectivity (BS, Compact BS)

It is assumed that simple transmission power control is used on WTs for the uplink. Adjacent channel selectivity (9.6 kbits/s) and adjacent sub-channel selectivity (4.8 kbits/s, 2.4 kbits/s, 1.2 kbits/s, and 0.6 kbits/s) are defined as the level ratio of an interfering modulated signal to the desired signal level when the PER of the desired signal is 1.0E-2.

The desired signal and the interfering signal are specified by the following statement:

The level of the desired signal is set to +3 dB greater than the level of the specified reception sensitivity.

The interfering signal is mistuned to the following bands for each rate, respectively.

- 9.6 kbits/s: the ±5.76 kHz band of the frequency 25 kHz distant from the center frequency.
- 4.8 kbits/s: the ±2.88 kHz band of the frequency 12.5 kHz distant from the center frequency.
- 2.4 kbits/s: the ±1.44 kHz band of the frequency 6.25 kHz distant from the center frequency.
- 1.2 kbits/s: the ±0.72 kHz band of the frequency 3.125 kHz distant from the center frequency.
- 0.6 kbits/s: the ±0.36 kHz band of the frequency 1.5625 kHz distant from the center frequency.

The adjacent channel sensitivity and the adjacent sub-channel sensitivity should be 40 dB or greater at any transmission rate.

Measurement conditions are described below.

- Interfering signal is a modulation signal generated at a signal generator.
- Interfering signal pattern: TBD.

### 2.2.5. Spurious Response Rejection Ratio

The spurious response rejection ratio is defined as the ratio of the unmodulated interfering signal level to the desired signal level when the PER of the desired signal is

1.0E-2.

The desired signal and the interfering signal are specified by the following statement:
The desired signal level is set to 3 dB greater than the level of reception sensitivity.

● BS, compact BS

- The spurious response rejection ratio should be 40 dB or greater when the interfering signal is mistuned inside the system band.
- The spurious response rejection ratio should be 60 dB or greater when the interfering signal is mistuned outside the system band.

● WT

- The spurious response rejection ratio should be 30 dB or greater when the interfering signal is mistuned inside the system band.
- The spurious response rejection ratio should be 60 dB or greater when the interfering signal is mistuned outside the system band.

Measurement conditions are described below.

- The interfering signal is a continuous wave (CW) generated at a signal generator.
- The interfering signal is mistuned to a spurious domain specified under Radio Law in Japan. The concrete frequency position of the interfering signal in the measurement is TBD.

## 2.2.6. Intermodulation Characteristics

### 2.2.6.1. Intermodulation characteristics (WT)

The intermodulation characteristic is defined as the level of the interfering signal, specified by the following statement:
The level of the desired signal is set to +3 dB greater than the level of the specified reception sensitivity (see section 2.2.1). The level of each of two interfering signals (related to the desired signal) is the level on yielding a PER of 1.0E-2 on the desired signal. The interfering signals are tuned on the 2nd and 4th adjacent channel.

The modulated interfering signal on the 2nd adjacent channel should be 35 dB or greater.

The modulated interfering signal on the 4th adjacent channel should be 35 dB or greater.

### 2.2.6.2. Intermodulation characteristics (BS, compact BS)

The intermodulation characteristic is defined as the level of the interfering signal, specified by the following statement:

The level of the desired signal is set to +3 dB greater than the level of the specified reception sensitivity (see section 2.2.1). The level of each of two interfering signals (related to the desired signal) is the level on yielding a PER of 1.0E-2 on the desired signal. The interfering signals are tuned on the 2nd and 4th adjacent channel with a transmission rate of 9.6 kbits/s, or on the 2nd and 4th adjacent sub-channel with transmission rates of 4.8 kbits/s, 2.4 kbits/s, 1.2 kbits/s, or 0.6 kbits/s.

Table 2.2-1 Level of modulated interfering signals

| **Transmission rate (kbits/s)** | **2nd adjacent channel or sub-channel** | **4th adjacent channel or sub-channel** |
|---|---|---|
| 9.6 | 45 dB or greater | 45 dB or greater |
| 4.8 | 49 dB or greater | 49 dB or greater |
| 2.4 | 52 dB or greater | 52 dB or greater |
| 1.2 | 55 dB or greater | 55 dB or greater |
| 0.6 | 58 dB or greater | 58 dB or greater |

### 2.2.7. Limit on Secondary Radiated Emission, etc

The limit on secondary emission radiated from the reception equipment should be as follows.

- BS: 4 nW or less.
- WT: 4 nW or less.
- Compact BS: 4 nW or less.

## 3. Supplementary Conditions

### 3.1. Standby Function in WT

Considering that a WT operates for long periods on batteries, it should include provision for operation with intermittent reception.

### 3.2. Transmission Power Control in WT

A WT should provide functionality to control transmission power to reduce its own power consumption, to narrow the required dynamic range to receive signals simultaneously from multiple WTs on a BS and compact BS, and to reduce inter-channel or inter-sub-channel interference on an uplink caused by adjacent channel or sub-channel leakage power. Transmission power control should use open-loop control, based on the received level of the downlink. The control error should be within ±10 dB, excluding the transmission-level differences between the uplink and downlink.

### 3.3. Synchronization Tolerance among BSs

To prevent interference between the uplink and downlink, a BS should be synchronized with the other BSs in terms of frame boundary. The accuracy of synchronization is TBD.

### 3.4. Transmission Frequency Adjustment in WT

To reduce inter-channel or inter-sub-channel interference on the uplink caused by adjacent channel or sub-channel leakage power and to reduce the length of the needed training signal on the uplink for correcting the received signal frequency at the BS, the WT should be equipped with a function that adjusts the uplink signal frequency using the received downlink signal. The precision may have a root mean square error (RSME) of 15 Hz or less with the reception level of -123 dBm at the WT, which is the reception sensitivity at 4.8 kbits/s.

## 4. Coexistence with Other Wireless Systems

The concrete frequency position in this system is not clear, so parameters for coexistence with other wireless systems, such as frequency separation from the other wireless systems and allowable interference level, are unknown. Therefore, in this document, items that need to be examined with regard to coexistence with other wireless systems are described below.

<Items for examination towards coexistence with other wireless systems>

◆ BS, WT, and compact BS

- Filter models.
- Allowable interference time rate.
- Allowable interference level (interference-to-noise (I/N) criteria or carrier-to-interference (C/I) criteria).
- Mobility.
- Propagation model (line-of-sight (LOS) or non-line-of-sight (NLOS)).

◆ BS and compact BS

- Directionality of antenna.
- Number of antennas.
- Aggregation of interferences from multiple BSs in cellular configuration.

◆ WT

- Transmission power control.
- Number of WTs simultaneously transmitting (within one cell, (no. of carriers) x (no. of sub-carriers)).

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