Wide area ubiquitous wireless system for M2M communications

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History of Ubiquitous

In 1984, Dr. Sakamura proposed “Anywhere computer（どこでもコンピュータ）”.

「あらゆるモノの中にコンピュータが入り、それらがネットワークで結ばれる」TRONプロジェクトの根源的な考え方

In 1988, Dr. Mark Weizer proposed “Ubiquitous computing”.

生活や社会の至る所にコンピュータが存在し、コンピュータ同士が自律的に連携して動作することにより、人間の生活を強力にバックアップする情報環境

In 1998, IBM presented the concept of “Pervasive Computing”.

In 1998, the University of California started the “Smart Dust” project.

In 1999, MIT started the “Oxygen” project.

In 2000, HP started the “Cool Town” project.

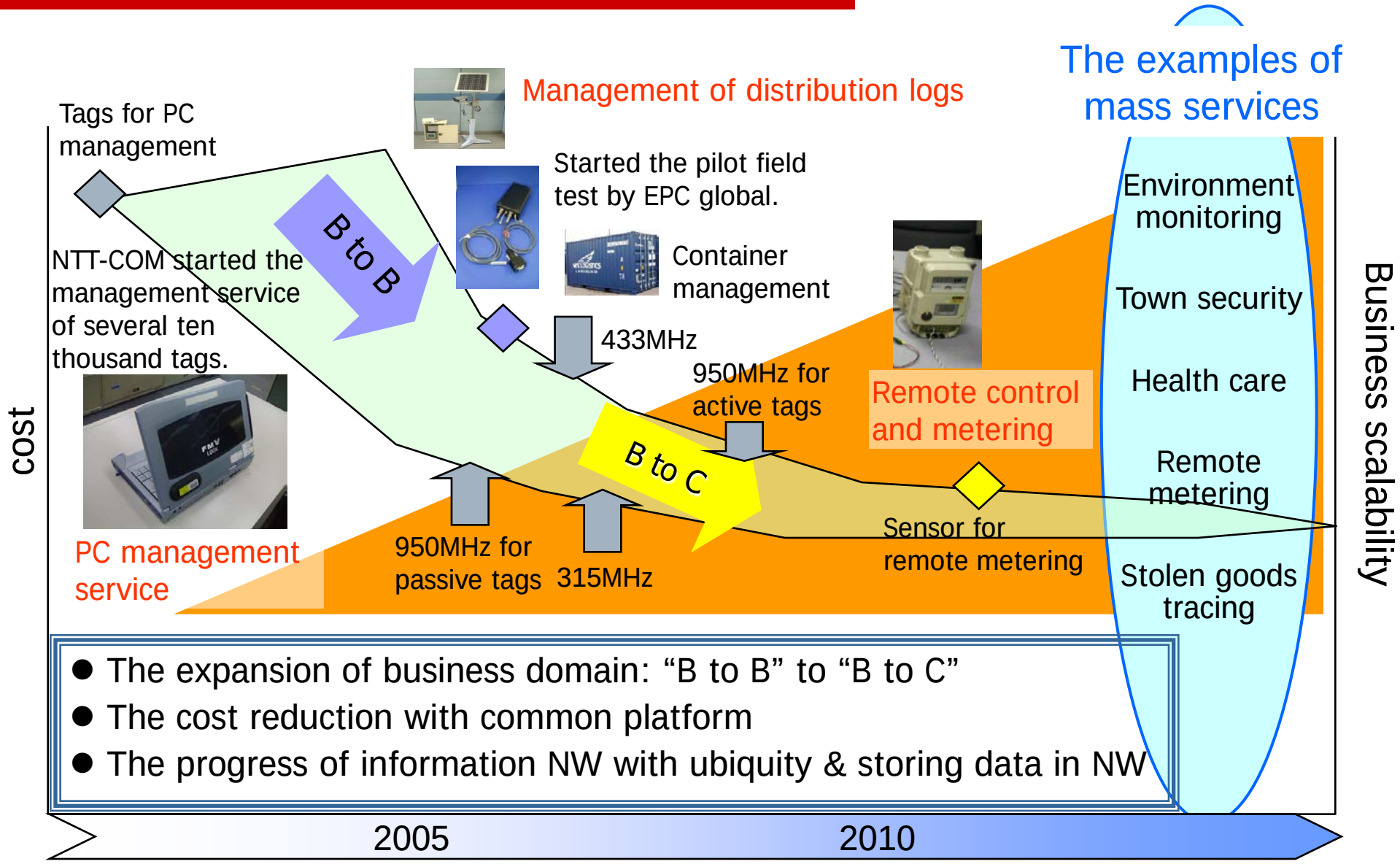
In 2000, NTT presented the concept of “HIKARI vision”.

“光ソフトサービス”＋“ユビキタスサービス”により実現される情報豊かな環境“Informative Ambience”を提唱

Omron presented the plan of “M2M” with NTT docomo and NRI in 2000.

Since then, many research organizations aim at the realization of “Ubiquitous”.

Development of ubiquitous services

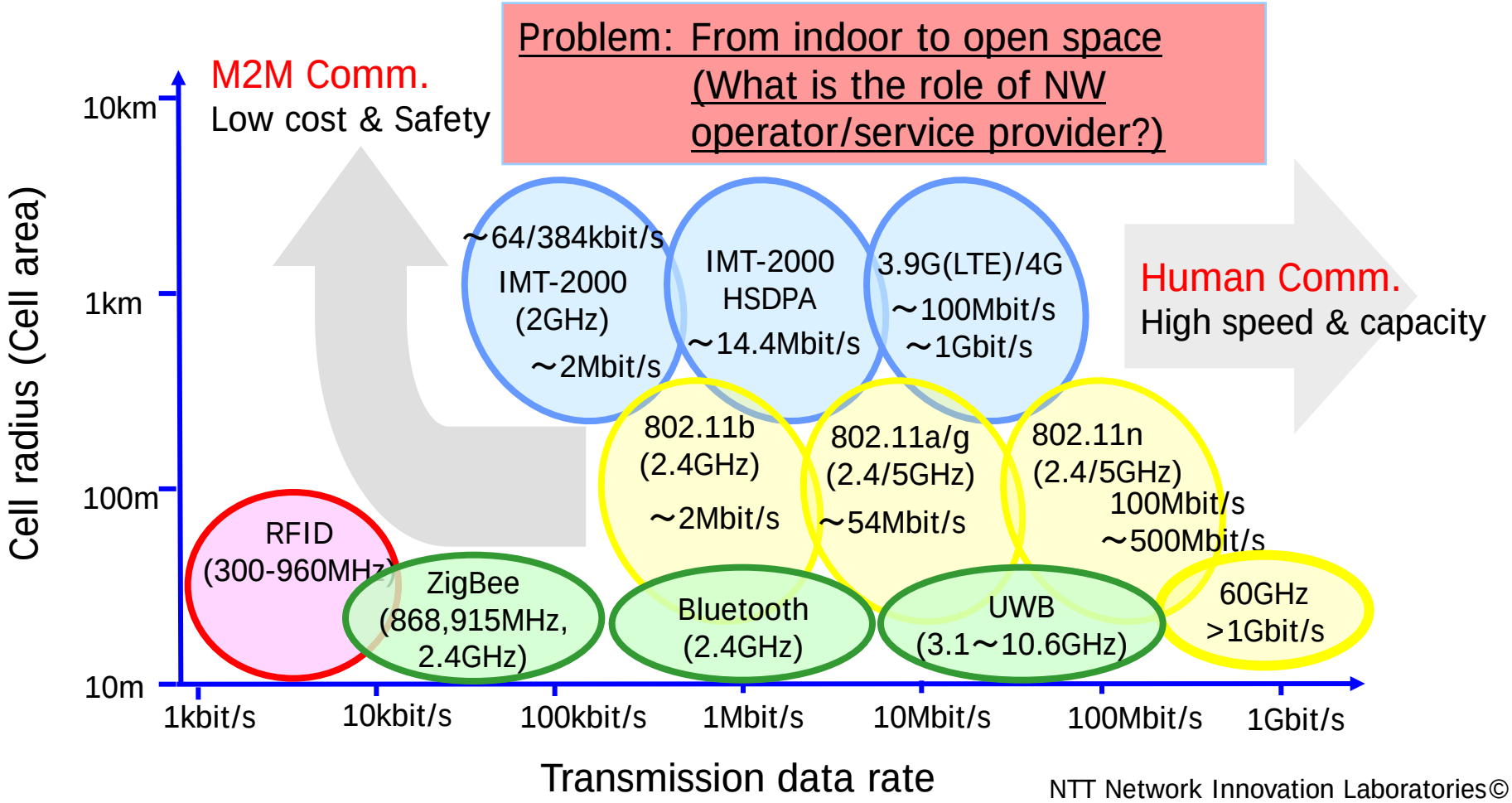


Target of Ubiquitous Network

To provide ICT services expected in ubiquitous society with safety & security and ecology.

Wireless systems for M2M communication

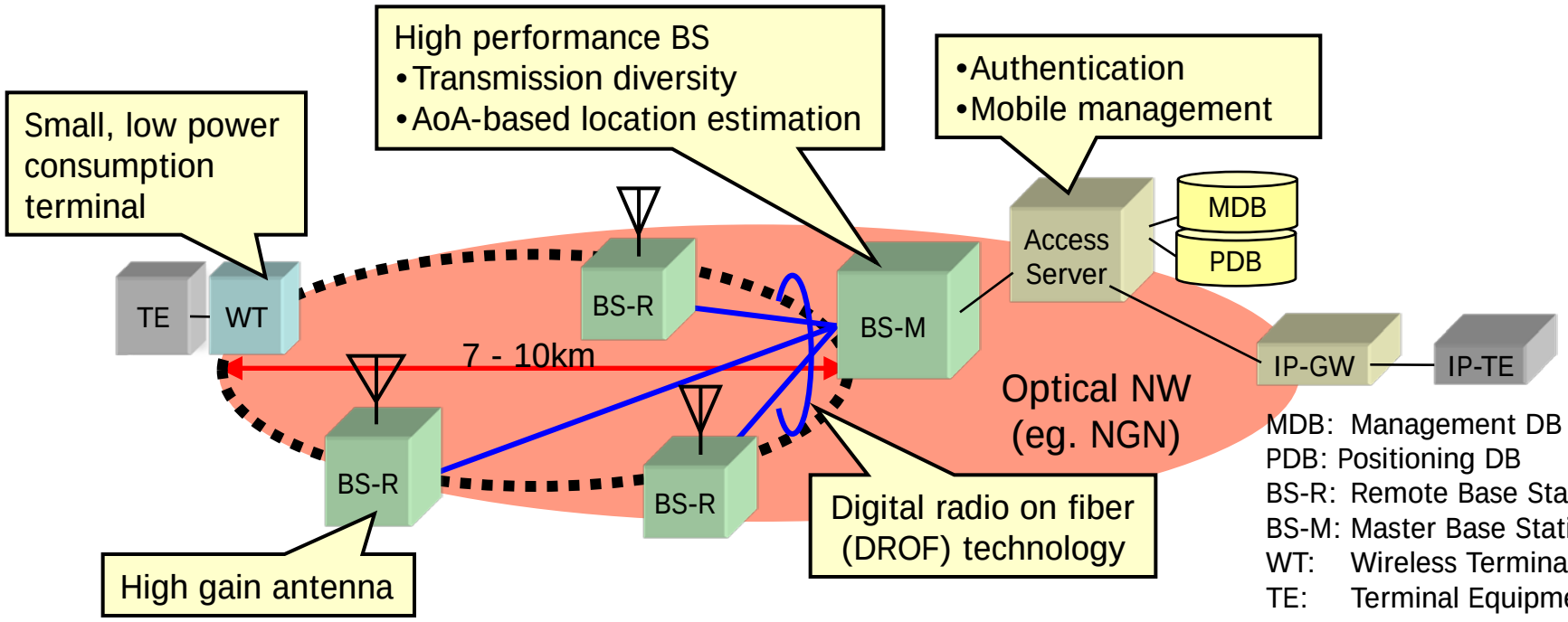
In order to gather information (so-called “life logs”) from so many machines scattered over wide area, it is necessary to integrate into one system.



Wide area ubiquitous network (WAUN)

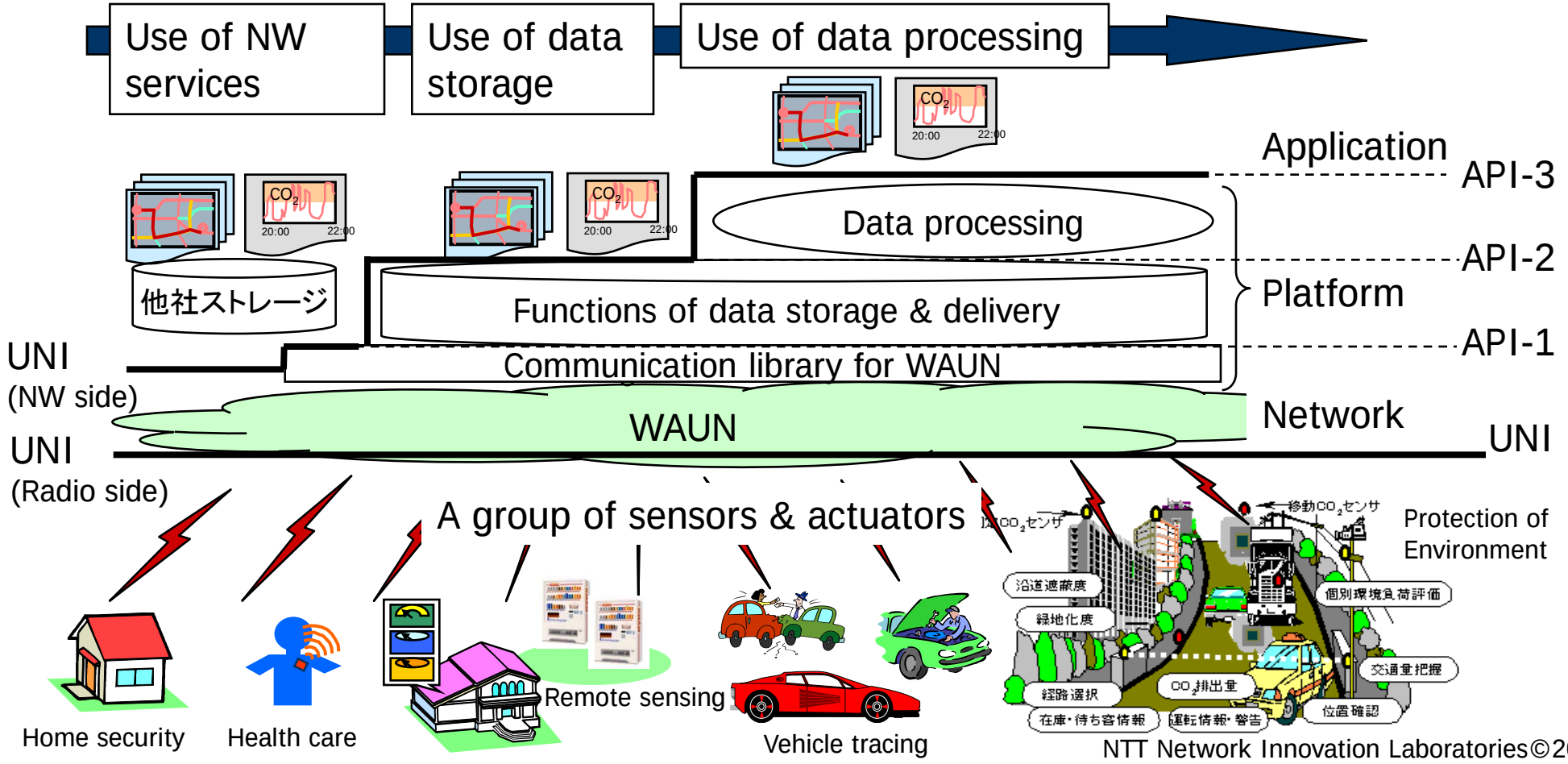
- **A cost effective network infrastructure for pervasively distributed movable wireless terminals (sensors and/or actuators)**
- **Wide-area network with several km radius cell and low capability terminals**

WAUN will be a new type of network to realize service domain that cannot be fully supported by conventional mobile phone network.



Platform for wide area ubiquitous network

In addition to providing conventional network service, WAUN has several functions such that store data in the network and remake them different type of data according to user requests.



Example for Platform Services : Application of “life log”

Environmental sensing for a good and healthy life

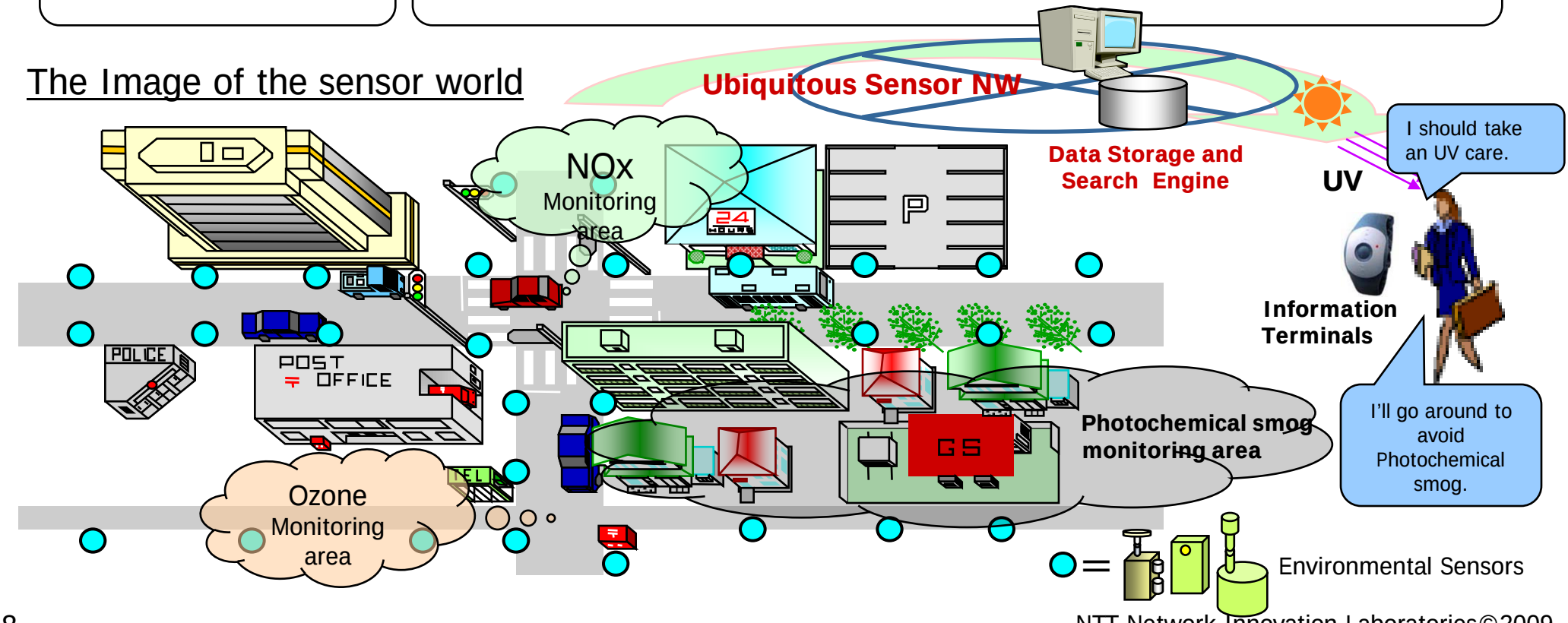
What we do

- Environmental evaluation
- Providing information
- Health advisory
- Applications for disasters

How we do

- Sensing by public sensors (Toxic gas, UV, Pollen, Traffic, Noise, Odor etc.)
- Personal customizations based on measured and predicted data (Caution, Advice)
- Portable information terminals which are enable to exchange information
- Make sensor nodes be like a public post

The Image of the sensor world



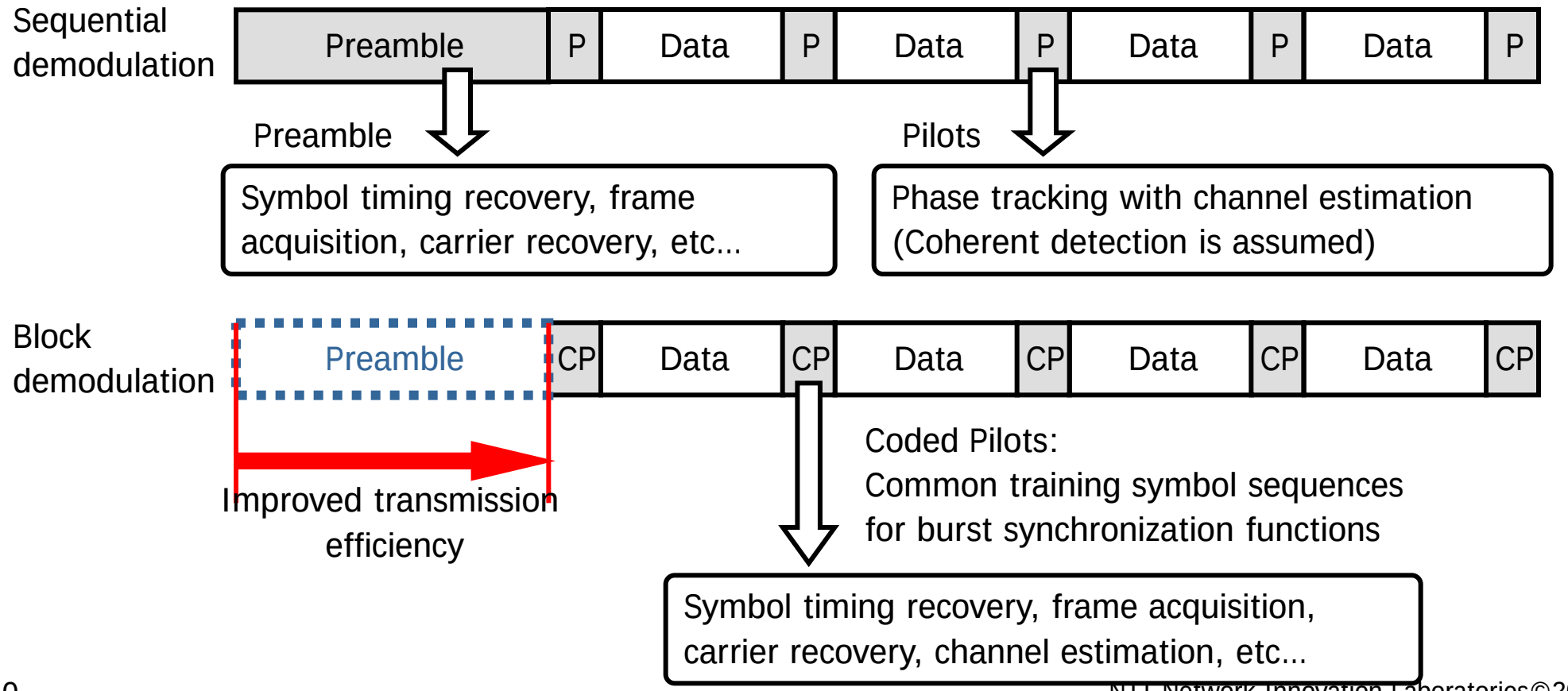
Technologies for wide area ubiquitous wireless system

Technology	Contents
Block demodulation	High receiver sensitivity and frame efficiency for very short packets (Uplink)
Synchronization	Burst synchronization for low power consumption of the WTs (Downlink)
Transmission diversity	Transmission diversity installed on the BS to simplify the WTs (Downlink)
Cell configuration	The BSs are allocated on the edge of a cell to get high diversity gain
AoA-based location estimation	The location estimation method which is enable to apply to narrow band signals (Uplink)
Multiple access control	Combination of random access and demand assign to get higher throughput
QoS control	High capacity and meeting the QoS requirement by controlling access parameters depending on input traffic with QoS classes
Terminal Paging	Low power consumption of wireless terminals without increasing the paging delay
Sleep control	Low power consumption and long battery life of wireless terminals with various delay conditions
Radio resource management	Control huge number of terminals (Millions/ch)
Antenna of the WT	Achieve small and high gain antenna such as a loop dipole antenna using meander lines
DROF (Digital Radio on Fibre)	Realize site diversity reception by using functions such as high-precision time and frequency synchronization
Low power consumption for wireless terminal	Lower maintenance costs by lower power consumption at standby

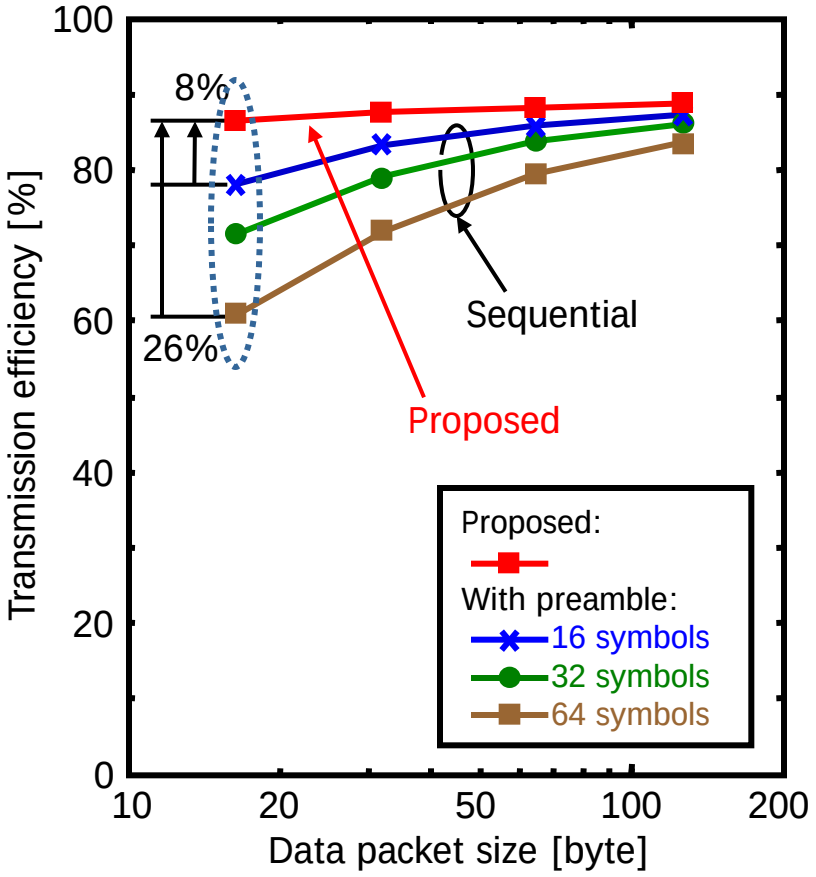
Block demodulation

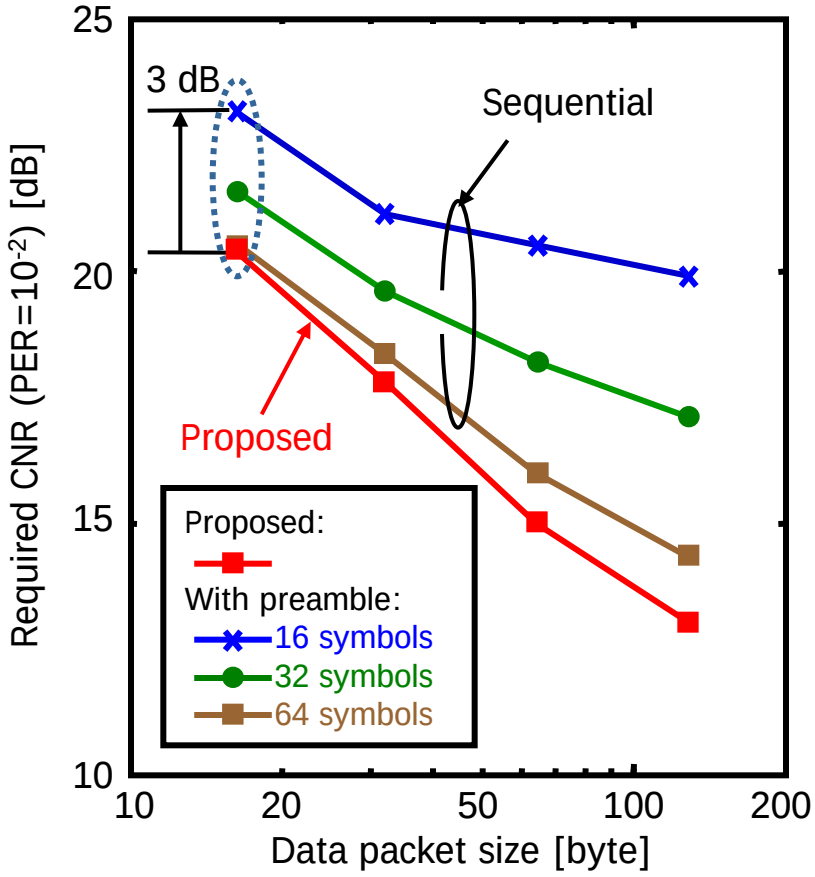
Deterioration of transmission efficiency cannot be ignored, especially when uplink traffic is dominated by short bursts.

Block demodulation technique makes possible preamble-less burst structure that improves transmission efficiency.



Performance evaluation



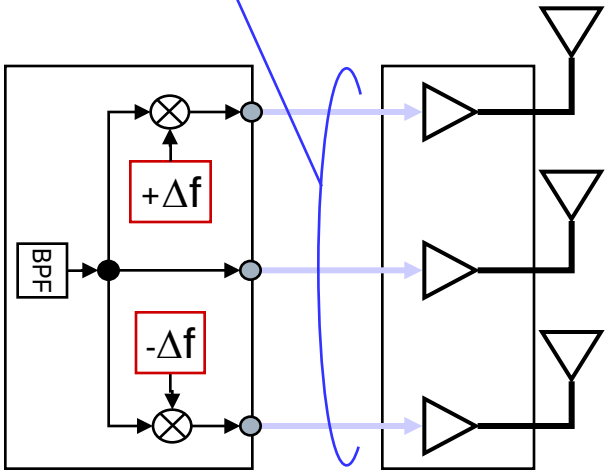


Proposed burst synchronization method achieves superior transmission performance as well as outstanding transmission efficiency, especially under fading environment

Transmitter diversity

different frequency offsets set to each antenna
(amount of frequency offset ; ±Δf)

It is able to simplify the WT.
(no need additional functions such as multiple receivers in order to get diversity gain)



BS

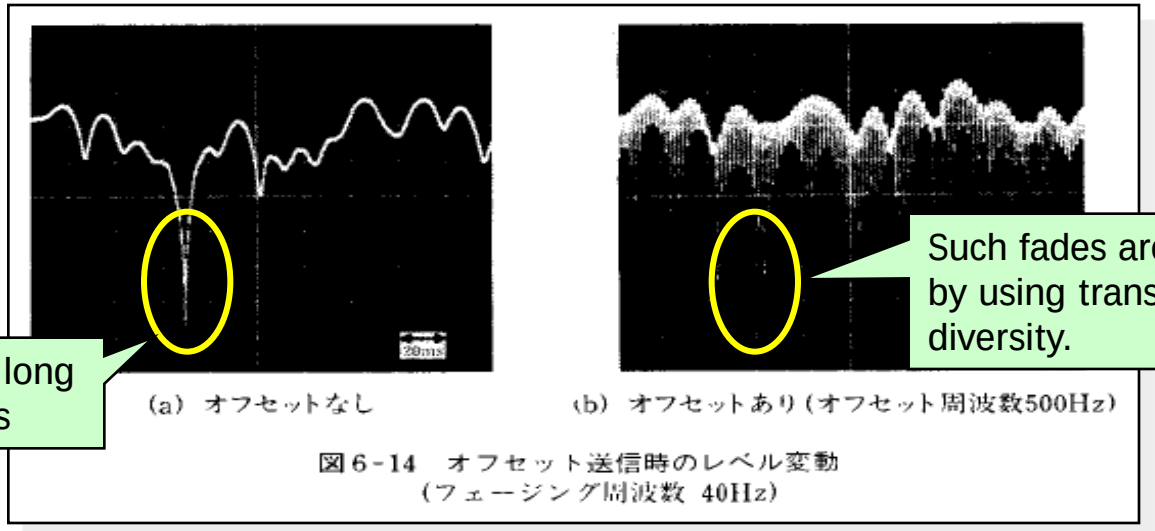
$f_c+\Delta f$

f_c

$f_c-\Delta f$

WT

移動通信（進士昌明編）@丸善より抜粋



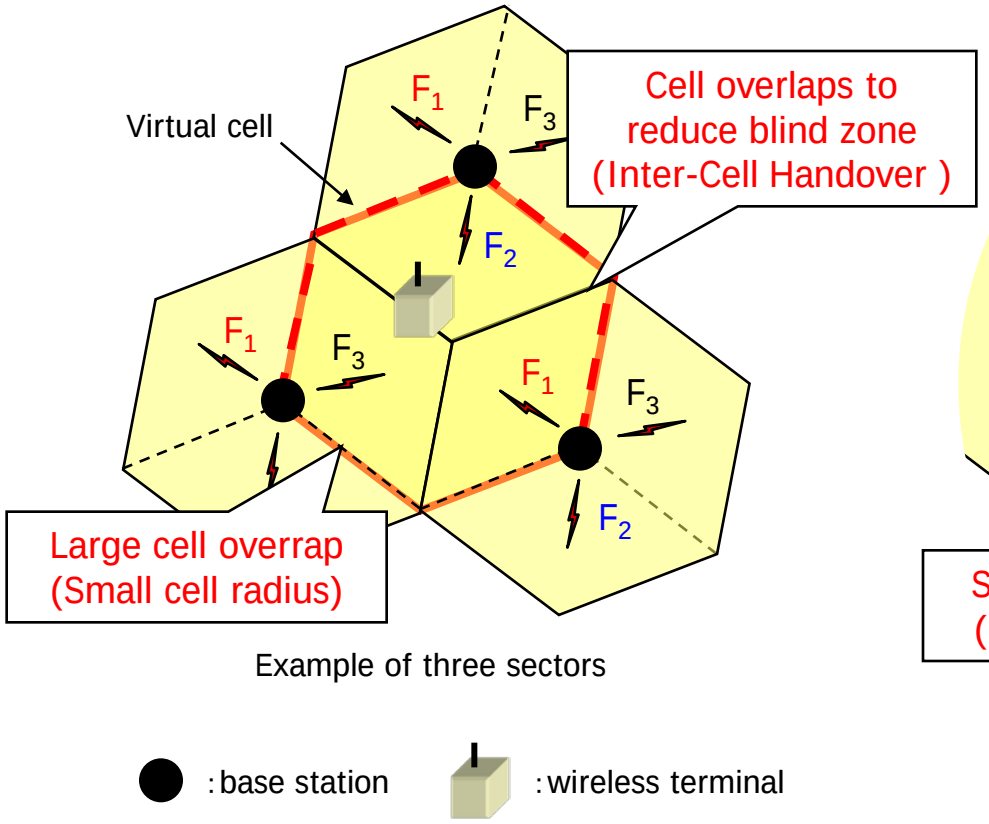
Deep and long term fades

Such fades are improved by using transmission diversity.

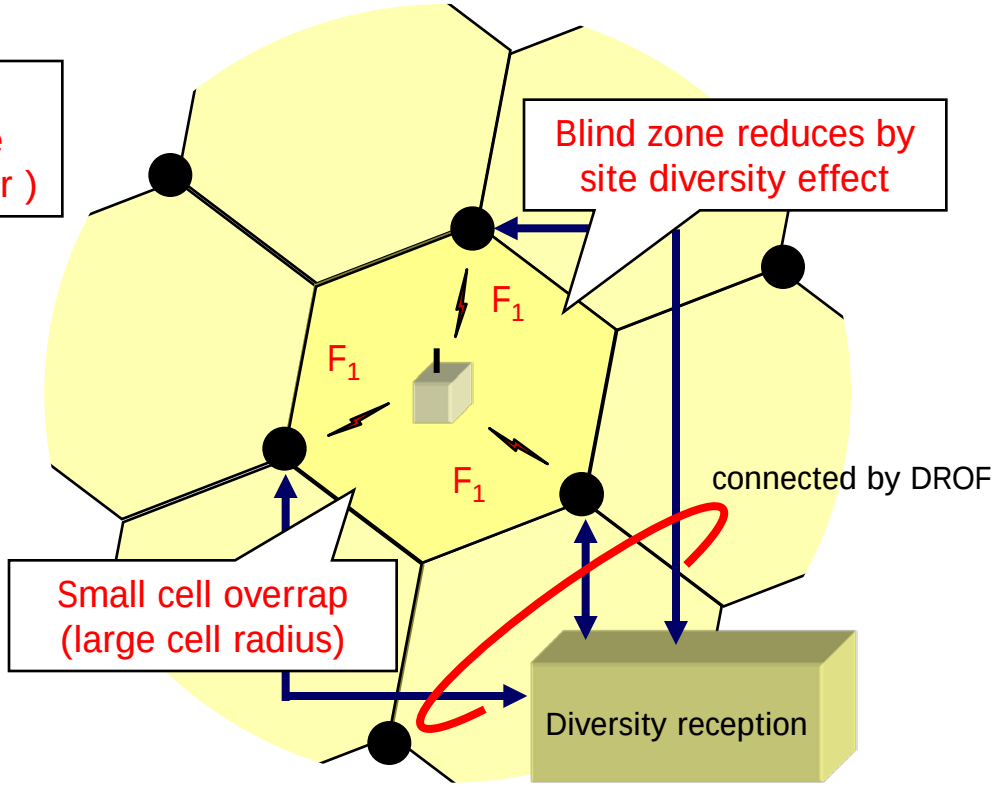
Cell structure

In order to get higher site diversity gain, we introduced new cell structure such that allocated several base stations on the edge of a cell.

Conventional cell structure (e.g. PDC)



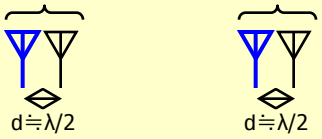
Proposed cell structure



Location Estimation

We introduced the location estimation method which is enable to apply to narrow band signals. By using this method, wireless terminal has no special function such as GPS.

The antenna pair for direction estimation



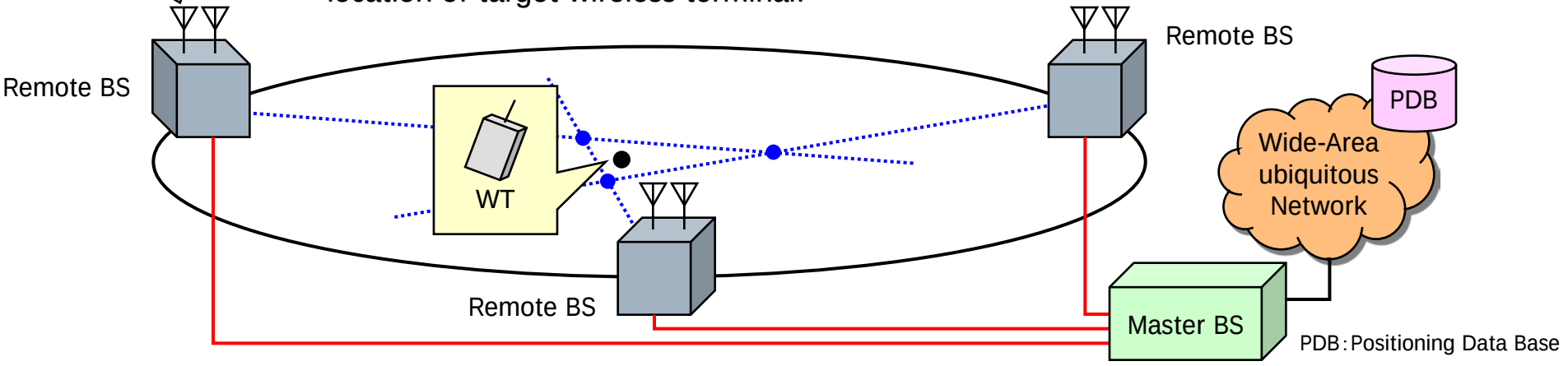
The main antenna pair (L≧10λ)

Component

- Three sites with two pairs of antennas:
  The antenna pair for direction estimation is selected at each site.

The example of protocol for location estimation

- The direction of the arrival is calculated for each BS antenna pair at each site.
- To reduce the influence such as fading, the antenna pair is selected at each site according to received signal power.
- The centroid of the triangle made by each direction of the arrival is estimated as the location of target wireless terminal.



DSA with hybrid access methods

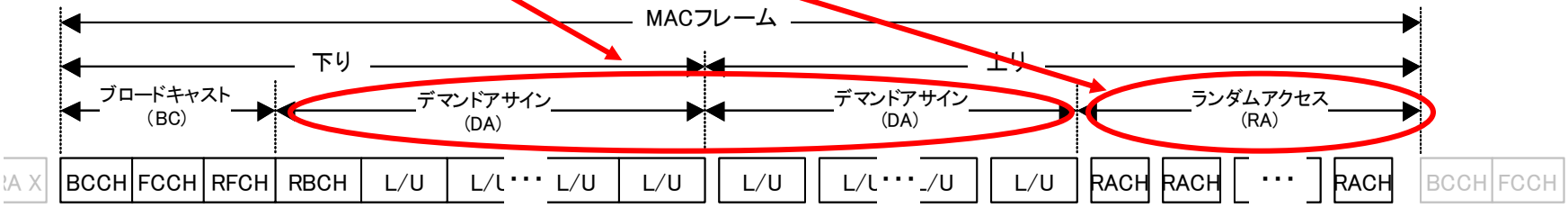
Key points

- Combination of random access and demand assign leads to high throughput performance.
- DSA (Dynamic Slot Assignment) realizes effective radio resource utilization.

MAC frame structre

- TDMA/TDD is employed
- MAC frame is constant length and consists of downlink and uplink periods.
- Downlink-uplink boundary is variable.
- Access method
  - Random access (RA)
  - Demand assign (DA)

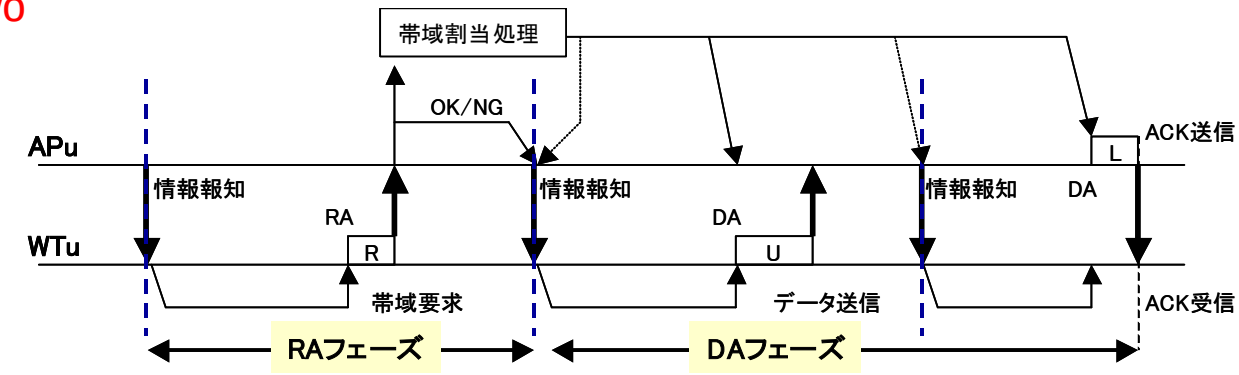
- Logical channels
  - BCCH: Used to report the attributes of AP.
  - FCCH: Indicates the MAC frame structure.
  - RFCH: Used to send information associated with random access.
  - RBCH: Used to a radio link control message.
  - UDCH: Used to transmit user data.
  - LCCH: Used to transmit an ARQ feedback.
  - RACH: Used to send a resource request to AP.



※ L/U LCCH or UDCH

Principle and effectiveness of proposed scheme

- Uplink transmission is achieved by two steps: 1) Resource request (RREQ) transmission in RA, 2) User data transmission in DA.
  ⇒RA slot size reduction
  ⇒RA overhead reduction
  ⇒Suitable for variable data transmission
  ⇒Effective accommodation for by an infrequent traffic by RA use
- All resources are assigned in a request basis. ⇒Prevention of useless assignment



●Both RA (Random access) and DA (Demand assign) are used for an uplink transmission.
●Exponential back-off algorithm is employed to avoid RA collision.

Performance evaluations

- Maximum throughput of our scheme is about 0.34.
- Throughput of our scheme is 20% higher than the best performance of all.
- Our scheme needs the lowest transmission power of all. ⇒Most effective power saving

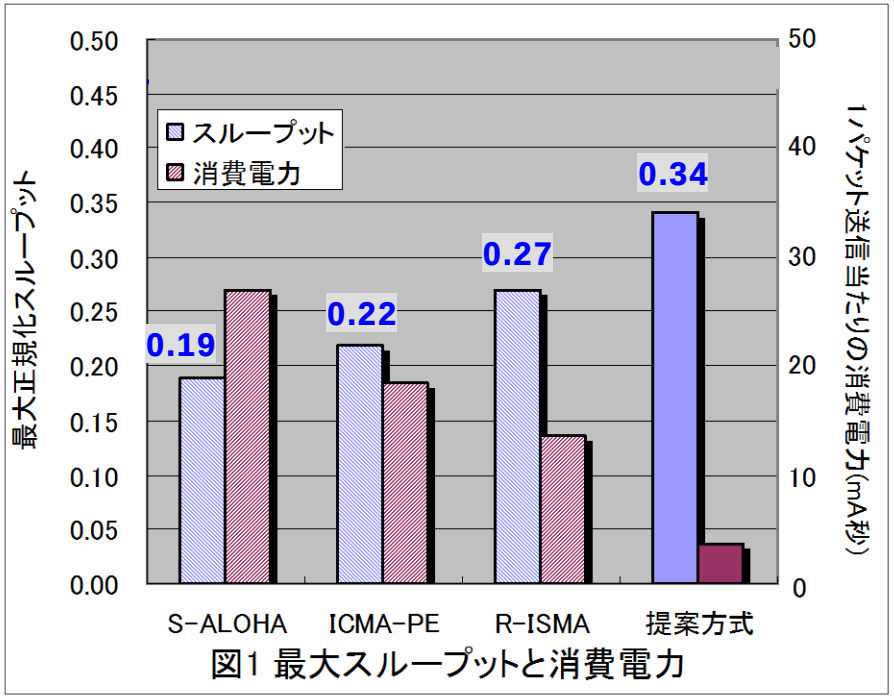
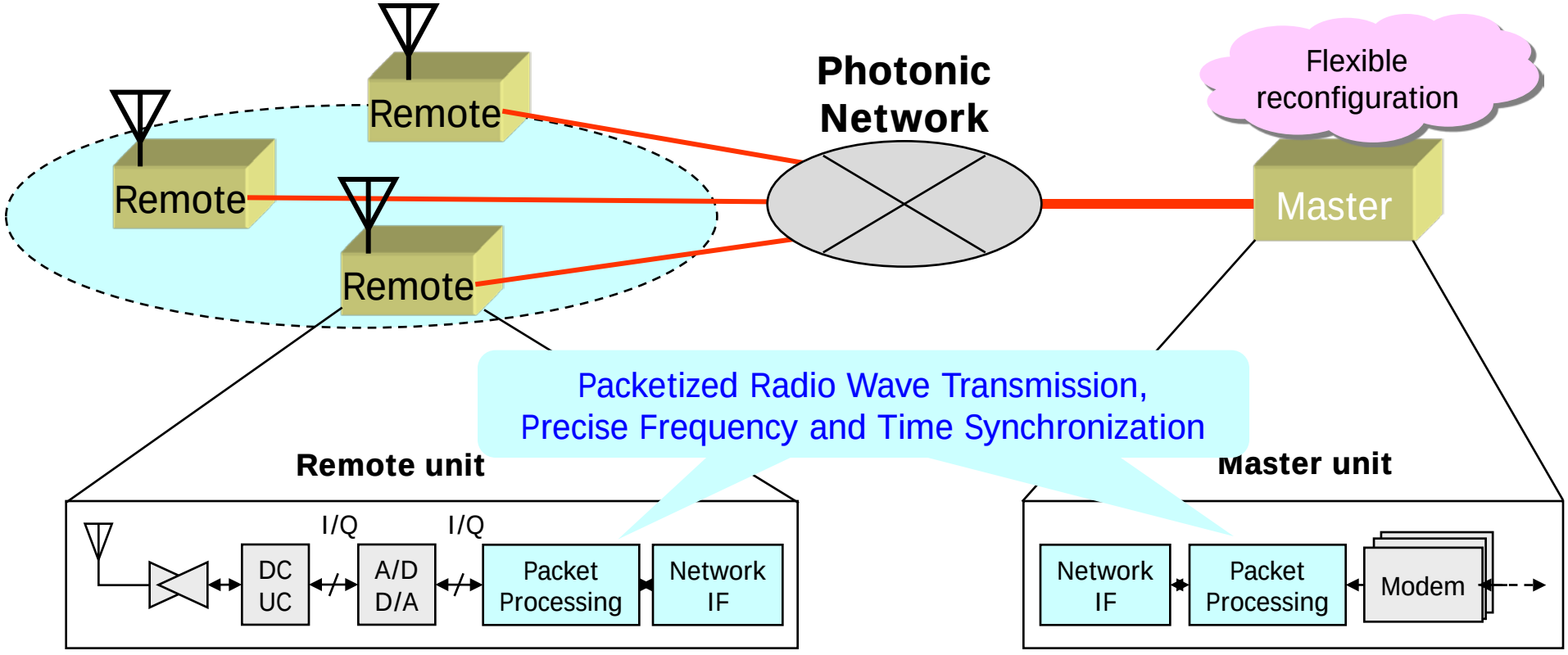


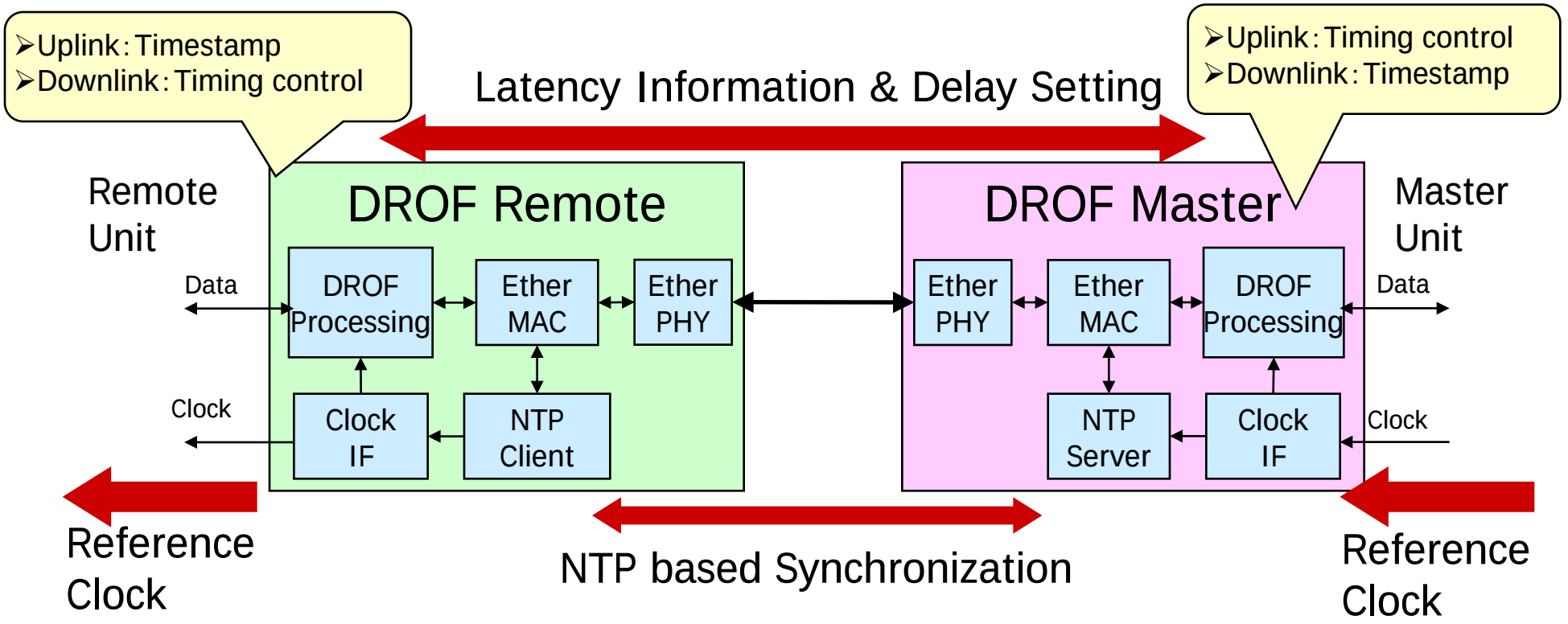
図1 最大スループットと消費電力

Digitized Radio over Fiber (DROF) Technology

To realize “Site Diversity” functionality, the base station is divided into geographically separated units (Master and Remote), and these units are connected by using DROF technology over photonic network.



Precise Synchronization with DROF

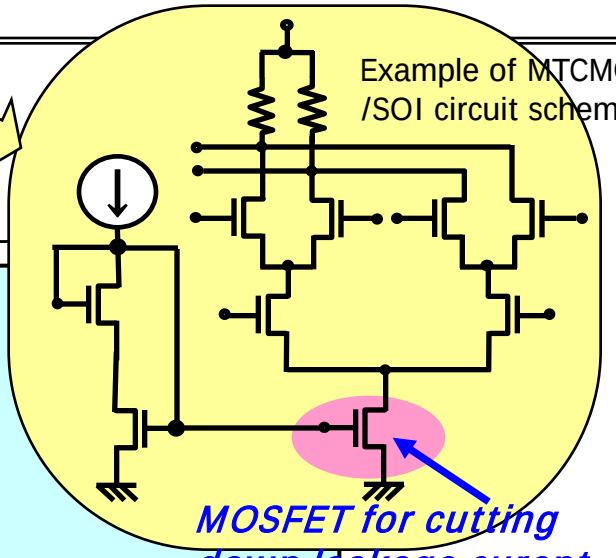


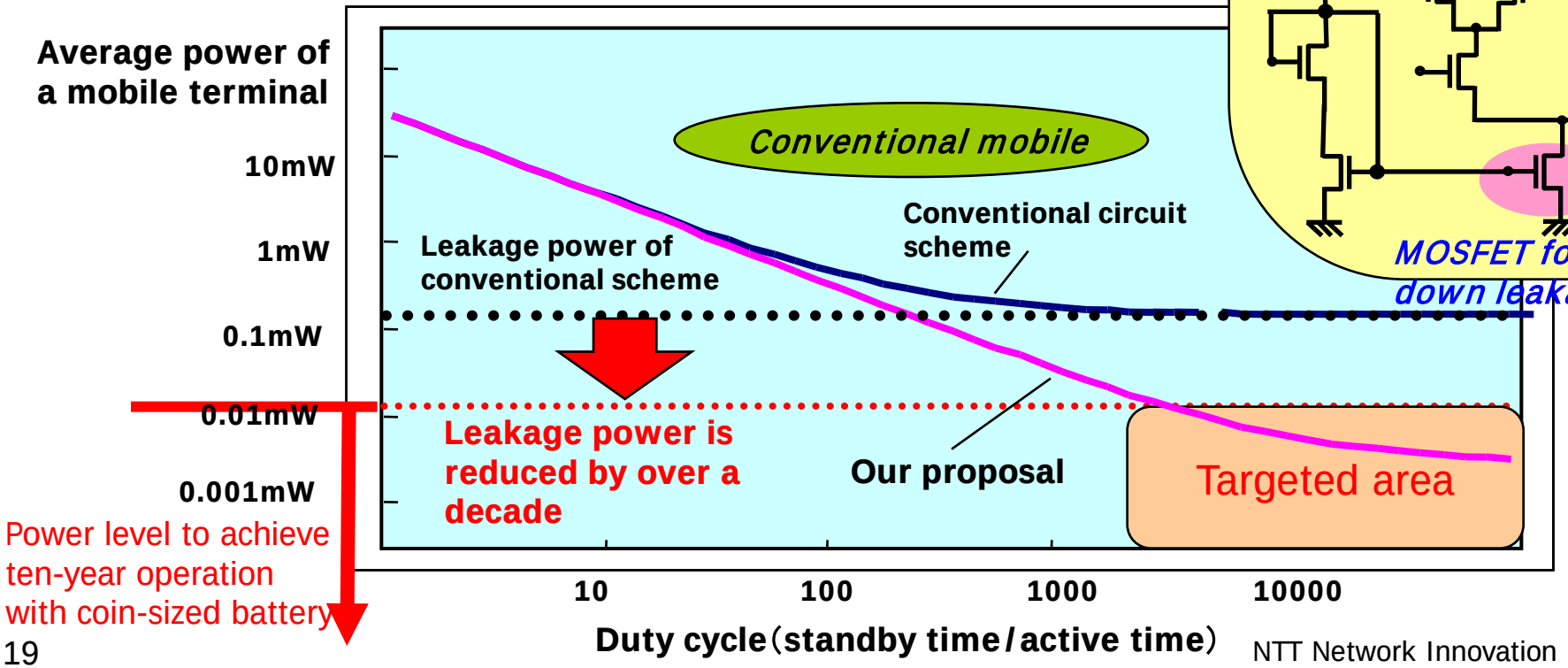
- Hardware implemented Network Time Protocol (NTP) based precise synchronization
  - Frequency Synchronization between Master and Remote Units
- Synchronized Timestamp based Timing Control
  - Fixed Transmission Delay between Master and Remote Units

Low-Power Mobile Technology

MTCMOS/SOI circuit scheme
1) reduces the mobile's power dissipation by over a decade.
2) achieves a battery life of over five years for a low duty-cycle mobile operated with a coin-sized battery

This circuit scheme achieves high-frequency but low standby-current operation by combining two types MOSFETs. One operates at high speed with large leakage current and the other operates at low speed with small leakage current.



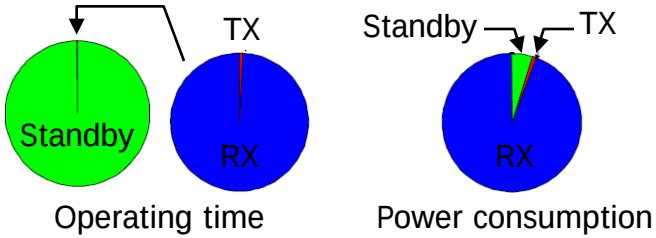


Benefit of low-power mobile technology

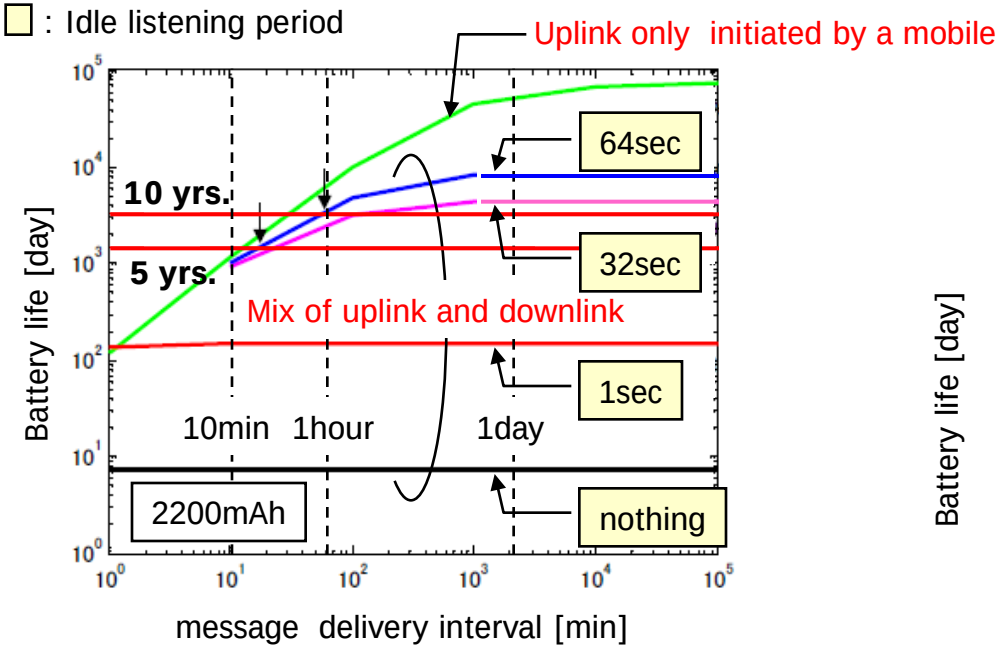
The low-power mobile technology makes it possible to achieve a battery life of ten years (*1) for a wireless terminal that connects with a base station once a two hours.

(*1) Case of a battery capacity of 2200mAh

Condition
Message delivery interval: once a 2hrs.
Idle listening interval: 32sec

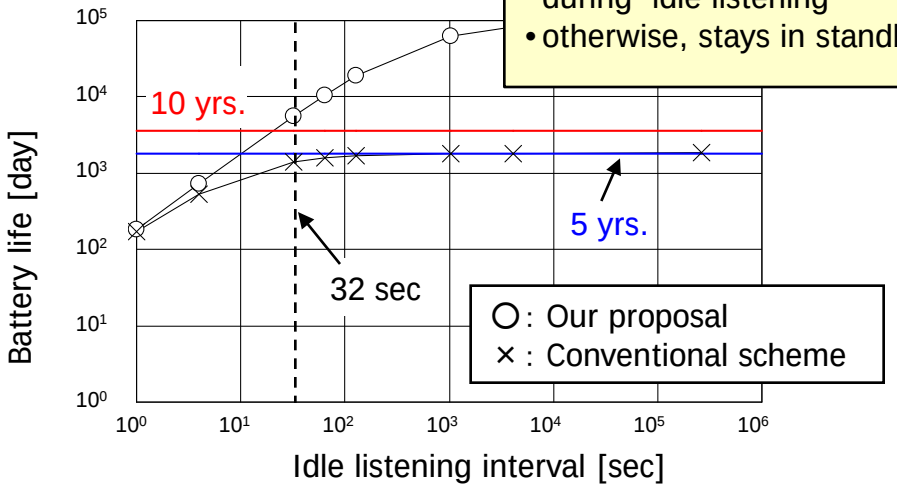


Breakdown of operating time and power



Battery life v.s. message delivery interval

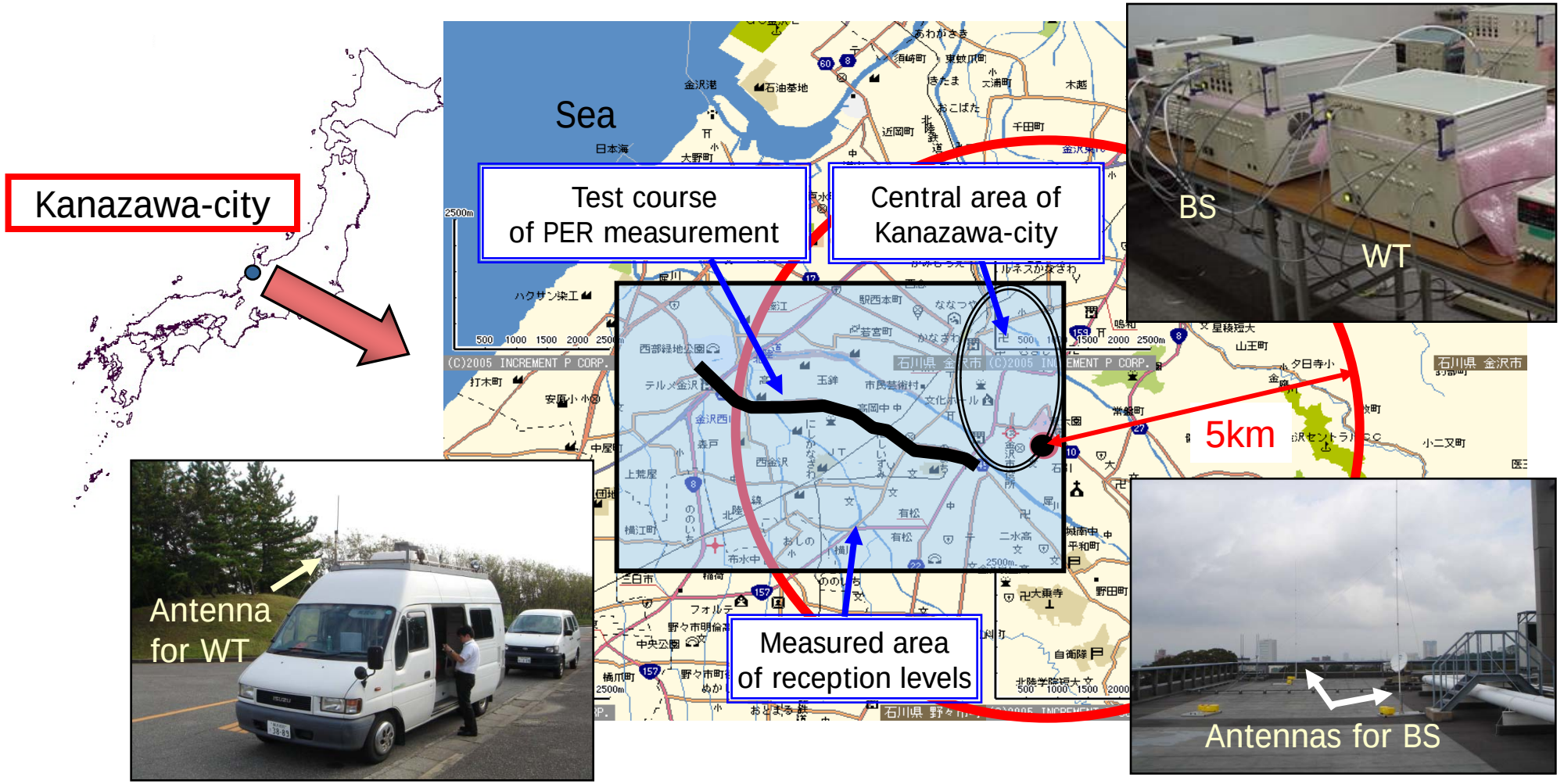
A mobile
- doesn't transmit
- receives only control channels during idle listening
- otherwise, stays in standby



Effect of decrease in leakage current

Field Experiments (2005-2006)

(1) Received level within the measured area.
(2) Packet error rate performance on the sample test course.

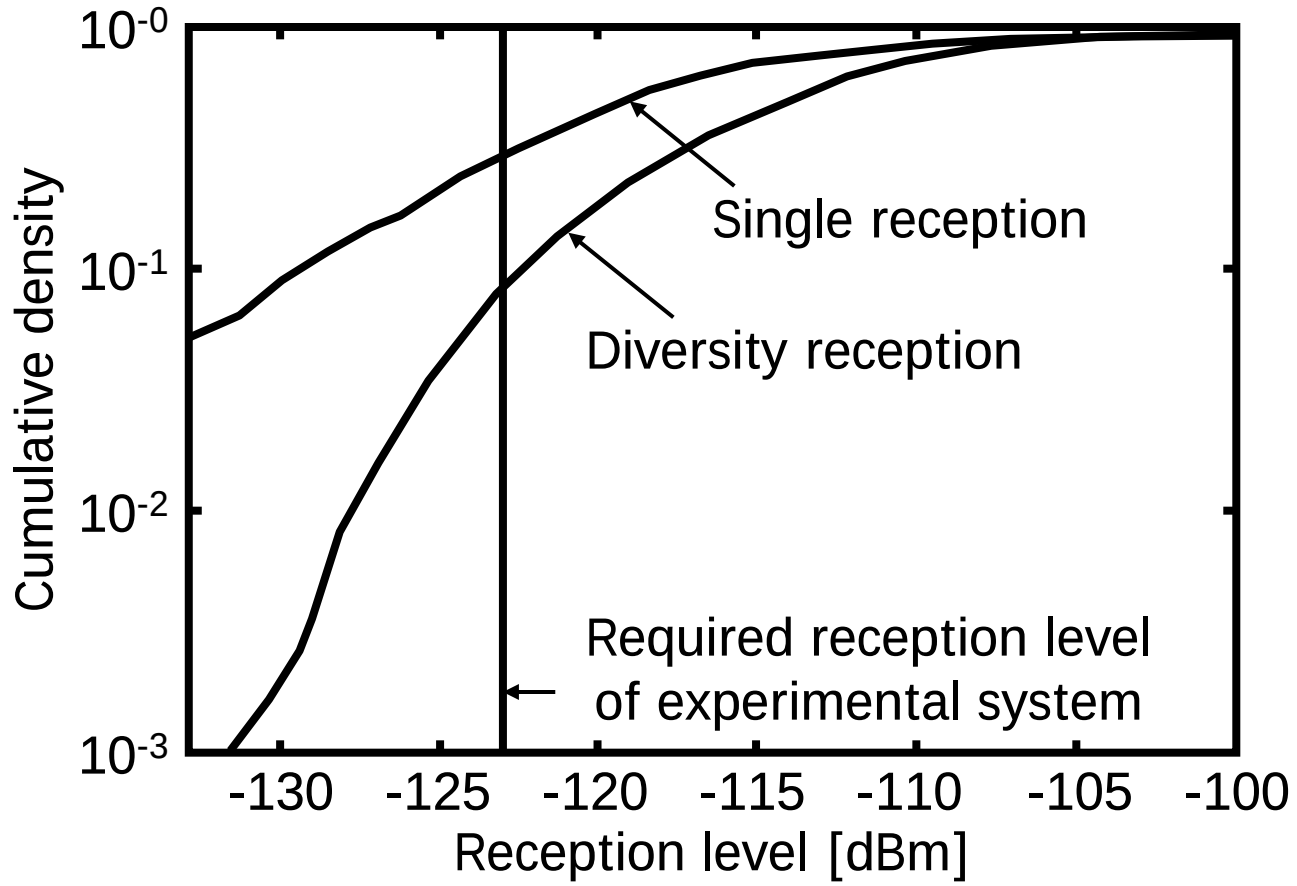


System Parameters for the field experiments

Frequency band	280 MHz
Output power of wireless terminal	10 mW
Modulation / Demodulation methods	QPSK mapping / Coherent detection
Modulation rate	9,600 symbol/s
Transmission rate	9,600 bps
Forward error correction	Convolutional coding / Viterbi decoding (K=7, R=1/2)
Receiver diversity at base station	Maximal ratio combining with 3 branches
Antenna gain	Base station: 10 dBi Wireless terminal: -16 dBi

Results of field experiments (1)

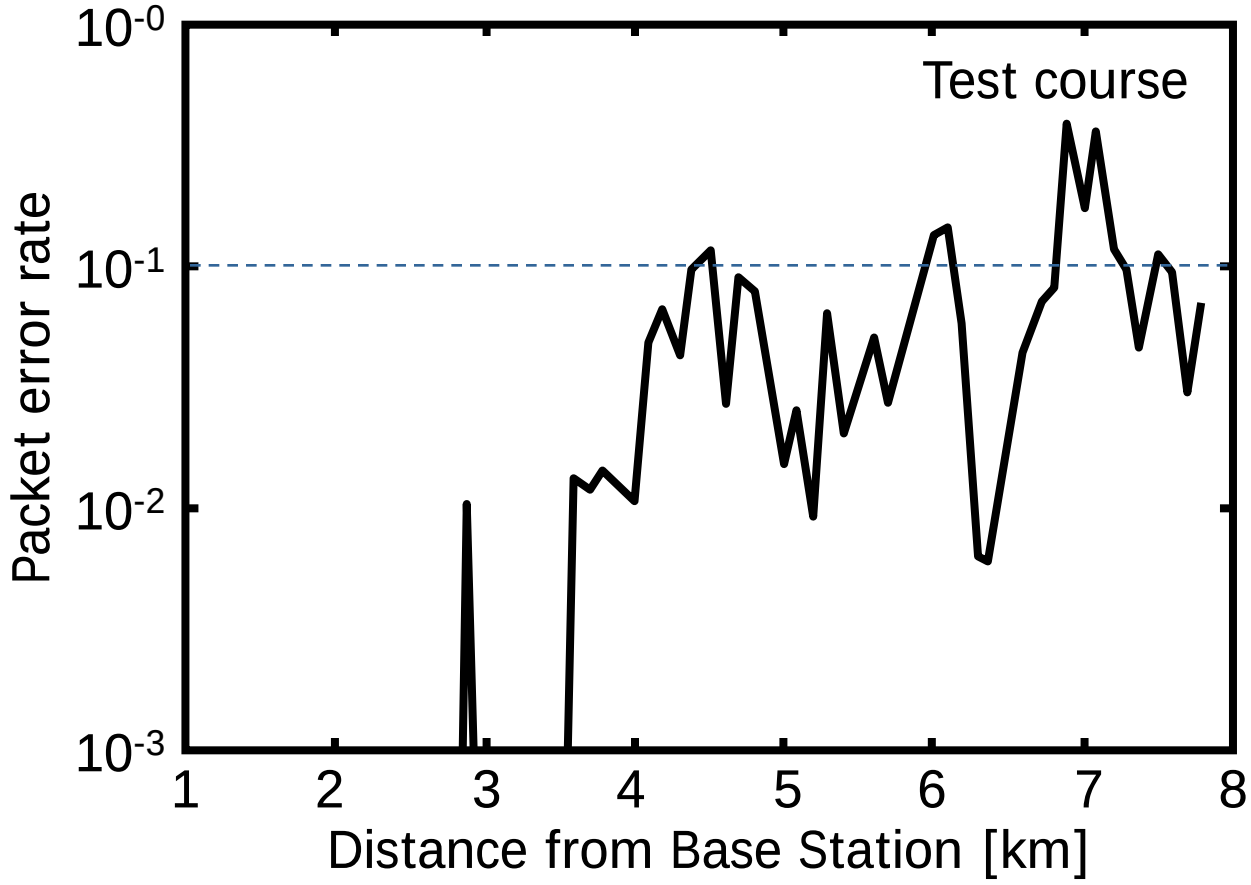
Reception level of -123 dBm is achieved within 92% of the measured area.



Cumulative probability of reception level in measured area.

Results of field experiments (2)

PER was insignificant for transmission distances of up to 3.5 kilometers.



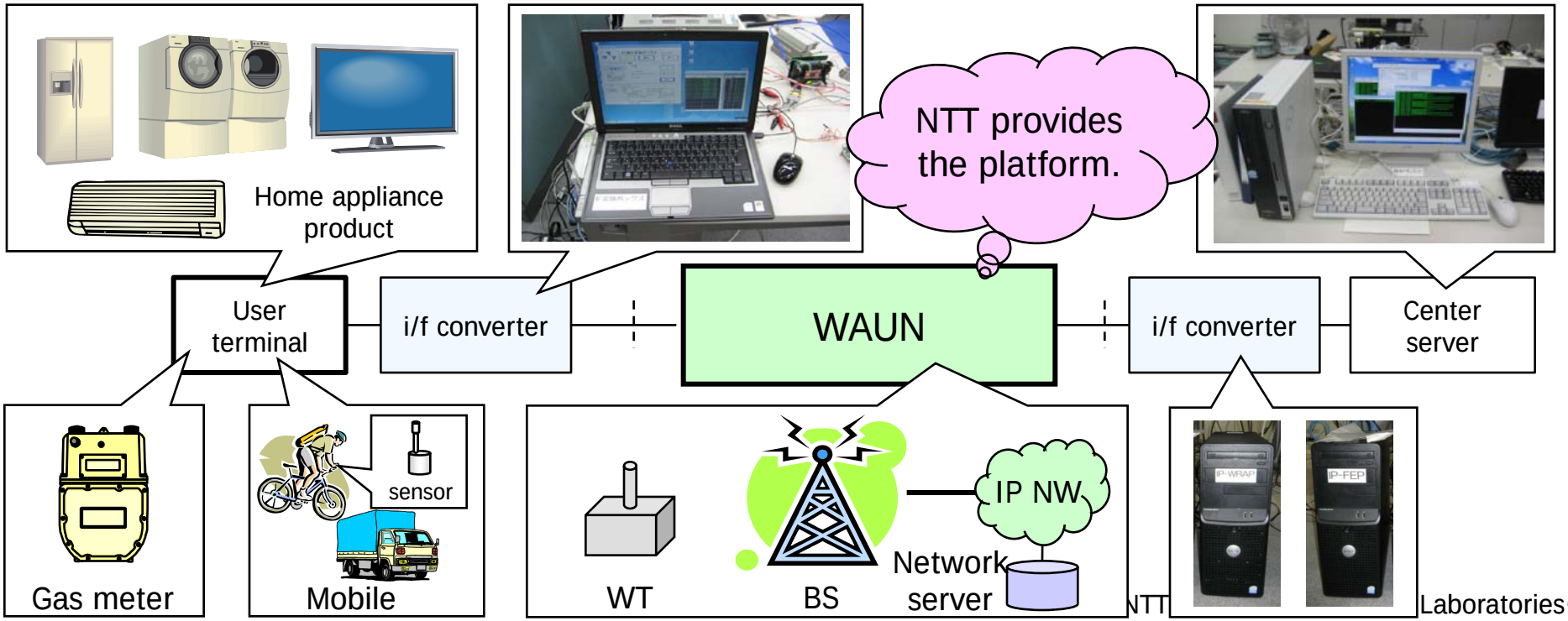
Measured sample of packet error rate on test course.

NTT activities in u-Japan project of MIC

Aims for the field test

- Tele-metering & safety
- Mobility & reachability
- Safety & security
- Prevention of accident

	FY2008	FY2009	FY2010
Gas enterprise	Connectivity to WAUN	Communication sequences at the field test	
Comm. carrier	Terminal mobility	Reachability & location estimation	
HA manufacturer	Connectivity to WAUN	Communication sequences at the field test	



Geographical map for the field test

Wireless terminal

Now

Few months later

Base station(master)

Laboratory at Mukoujima

Base station
(remote)

Thank you for your attention!