Ubiquitous Sensor Network

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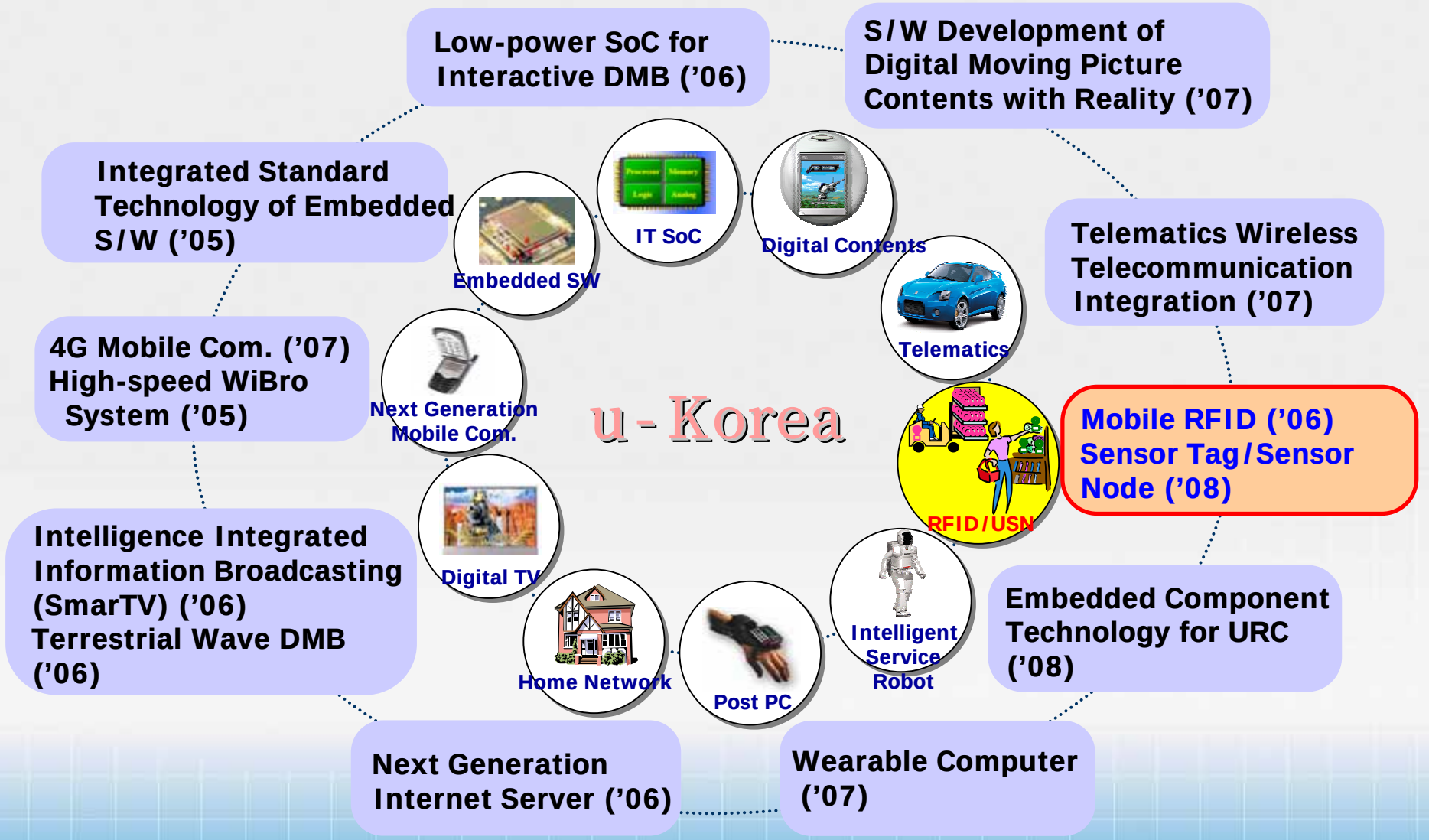
Electronics and Telecommunications Research Institute

Contents

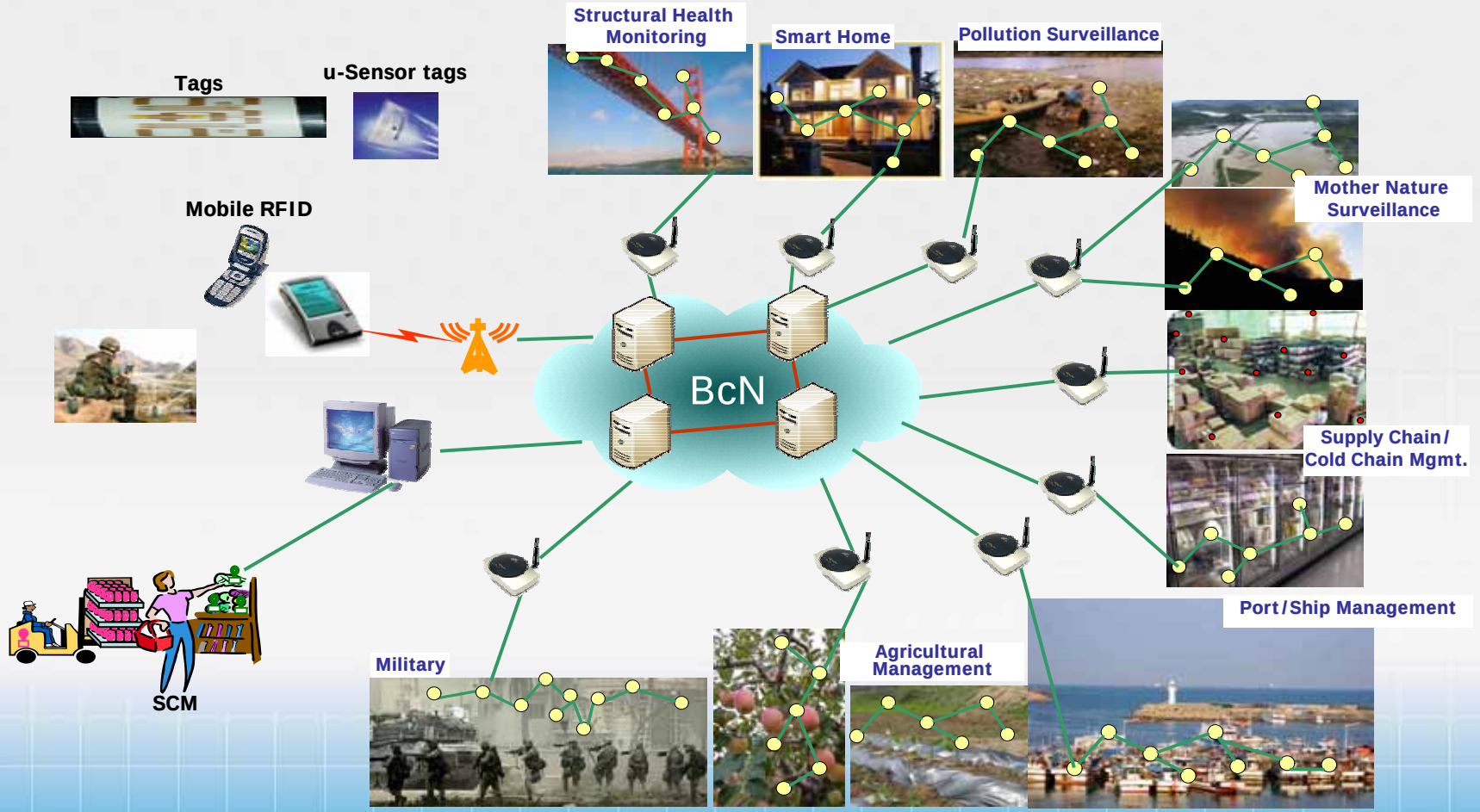
R&D at ETRI towards u-Korea



USN Concept

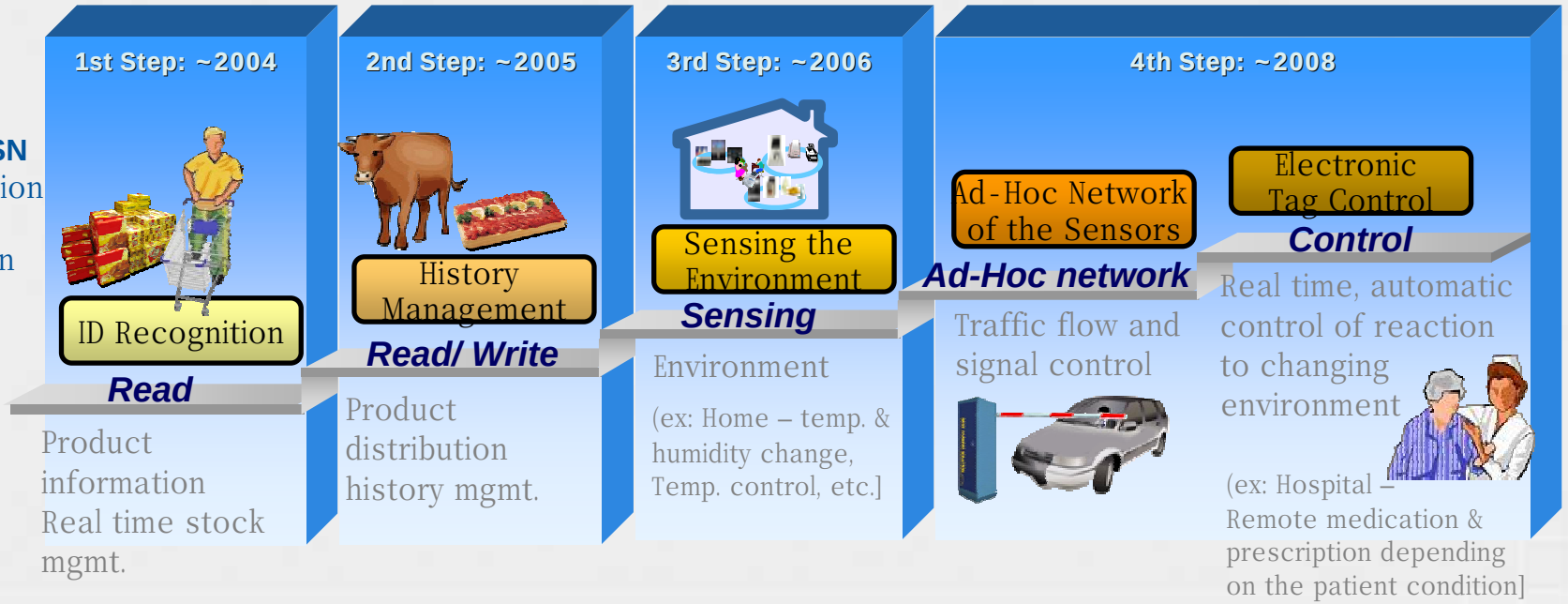
- Everywhere, everything with Tags/Nodes
- Sensing ID and environmental information
- Real-time monitoring & control via network

Ubiquitous
Sensor
Network

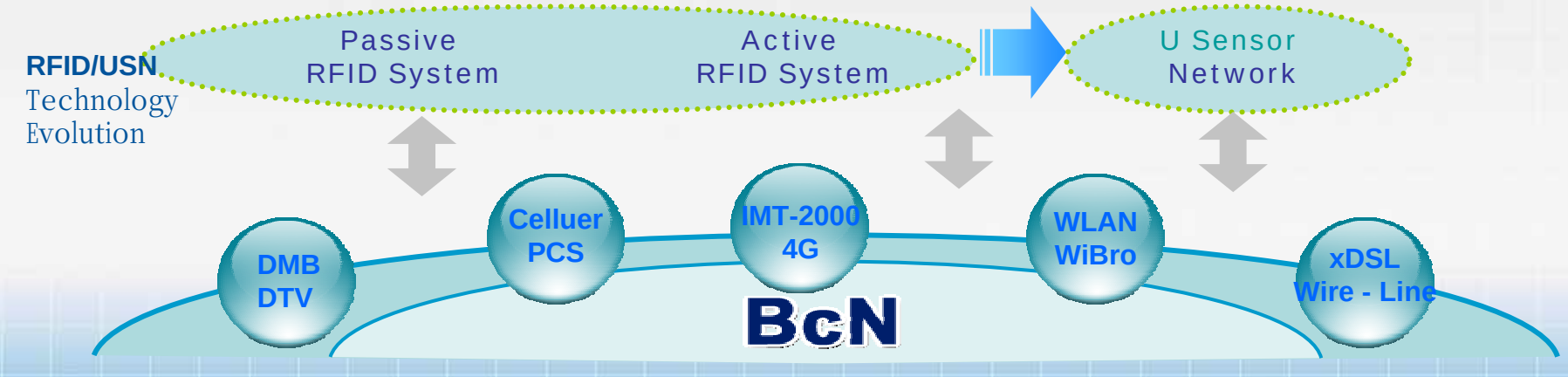


Evolution of RFID/USN

RFID/USN Application Service Evolution



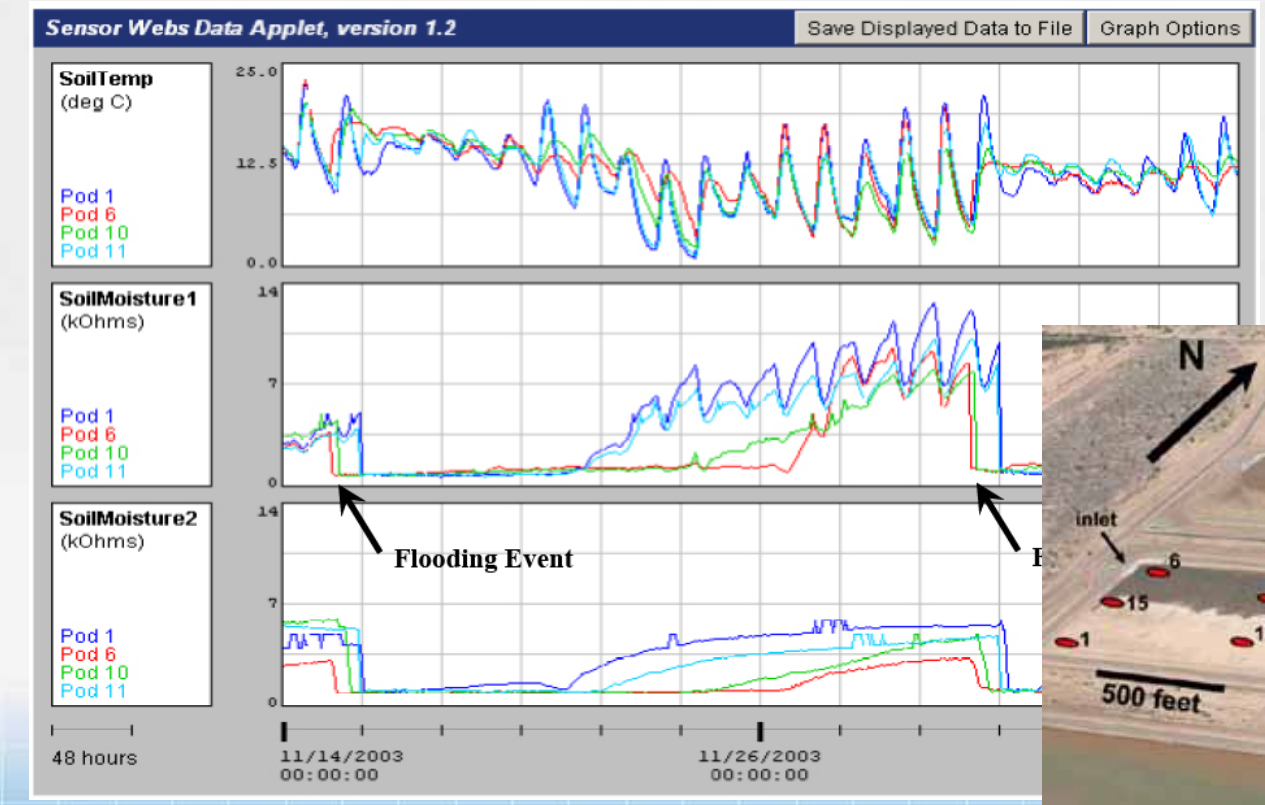
RFID/USN Technology Evolution



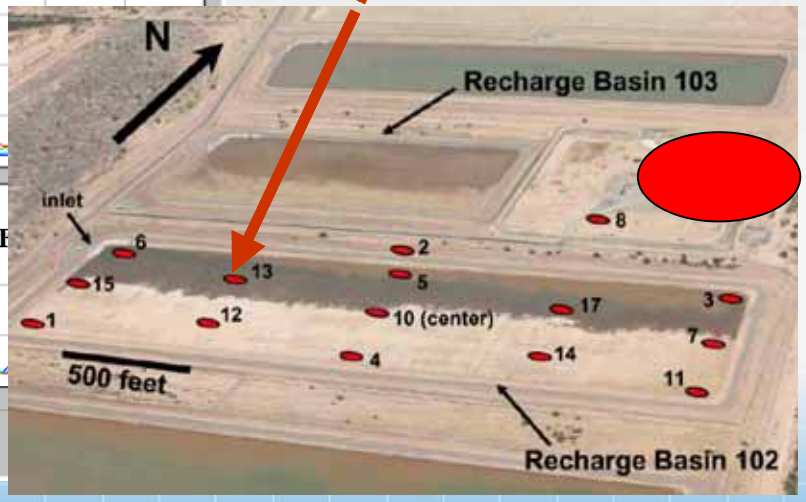
Senser Web for Hydrological Monitoring

Central Avra Valley Storage and Recovery Project (http://datura.unm.edu/webgui/)

- Inundation monitoring of recharge basin 102 (210×720 m²) in Tucson, Arizona
- 16 Sensor Web 3.2 pod (Energy harvesting by solar cells) deployed
- Pod 0 : the Gateway delivers sensed data to the Internet



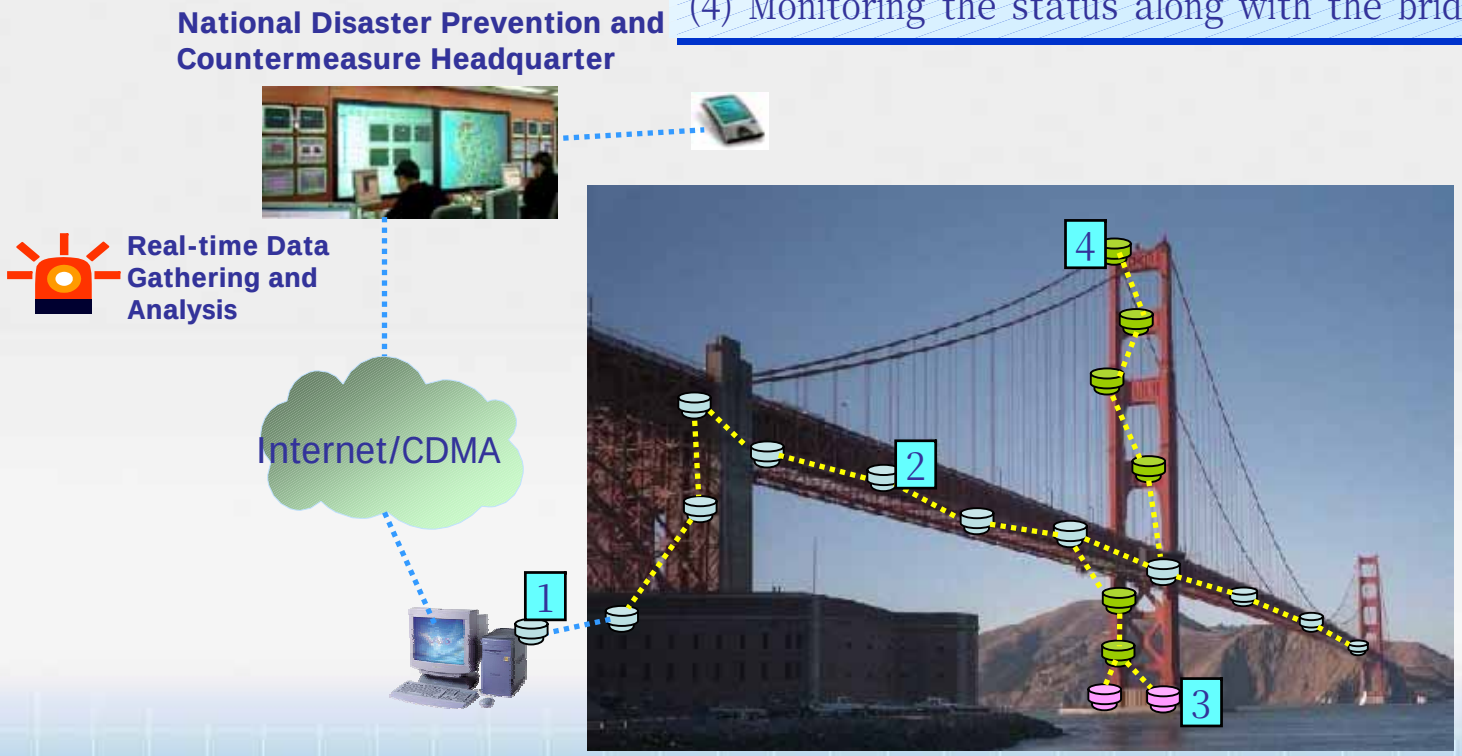
Sensor Web Pod



Structural Health Monitoring

Bridge Health Surveillance

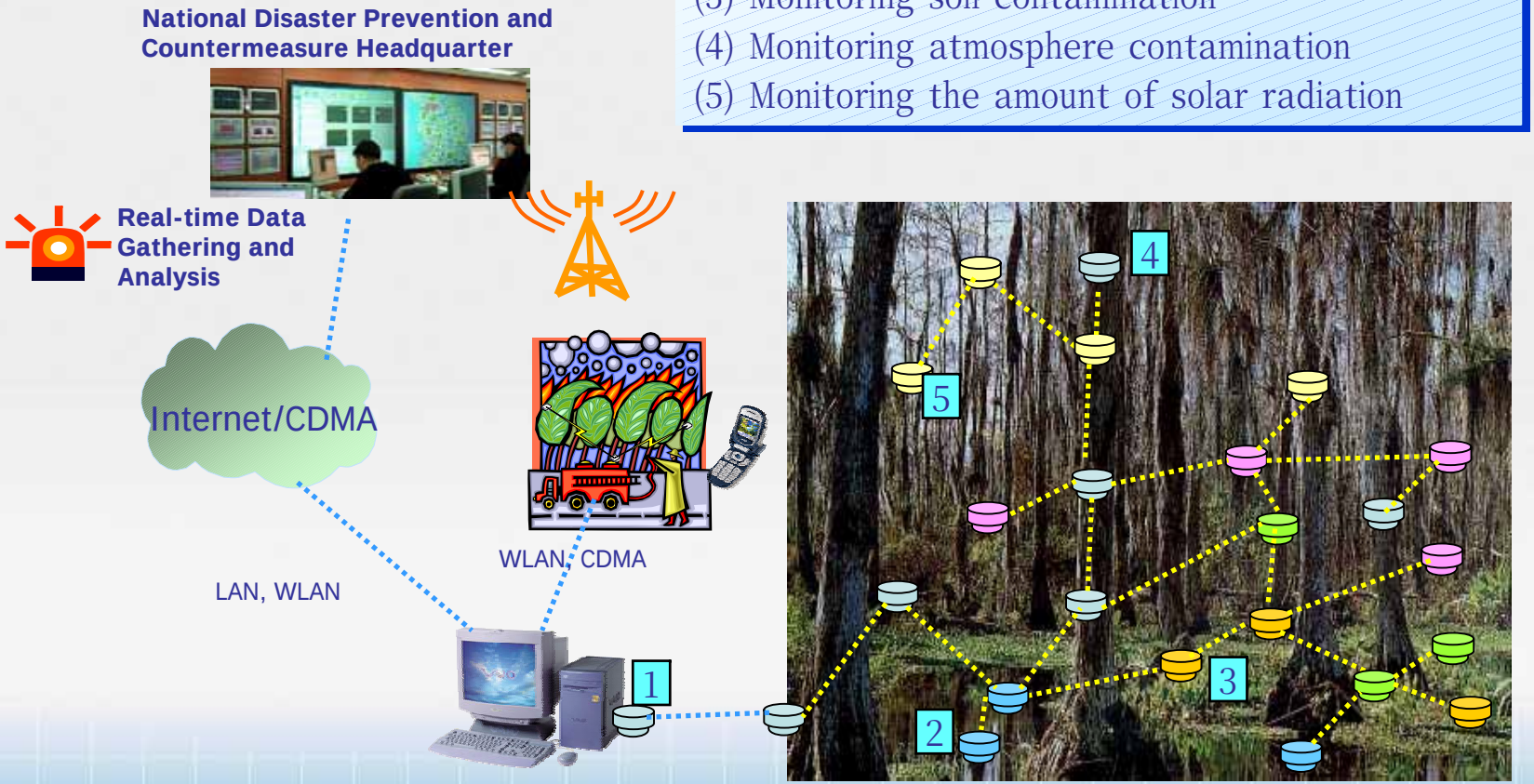
(1) Sink node/ u-Sensor Gateway
(2) Monitoring bridge distortion or crack
(3) Monitoring the ground/water level around the bottom of bridge
(4) Monitoring the status along with the bridge



Environmental and Ecological Surveillances

Environmental Monitoring

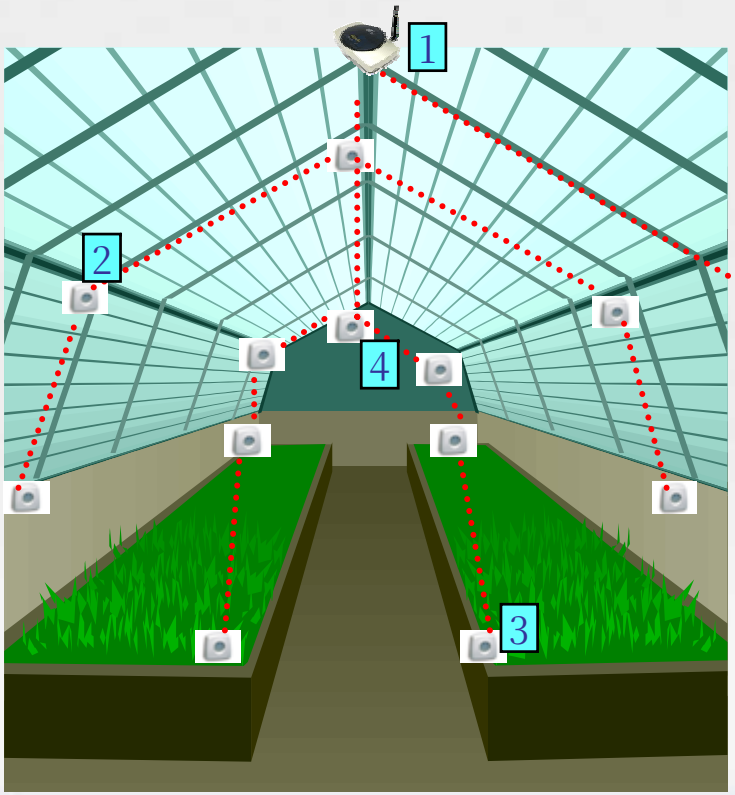
(1) Sink node/ u-Sensor Gateway
(2) Monitoring water quality
(3) Monitoring soil contamination
(4) Monitoring atmosphere contamination
(5) Monitoring the amount of solar radiation

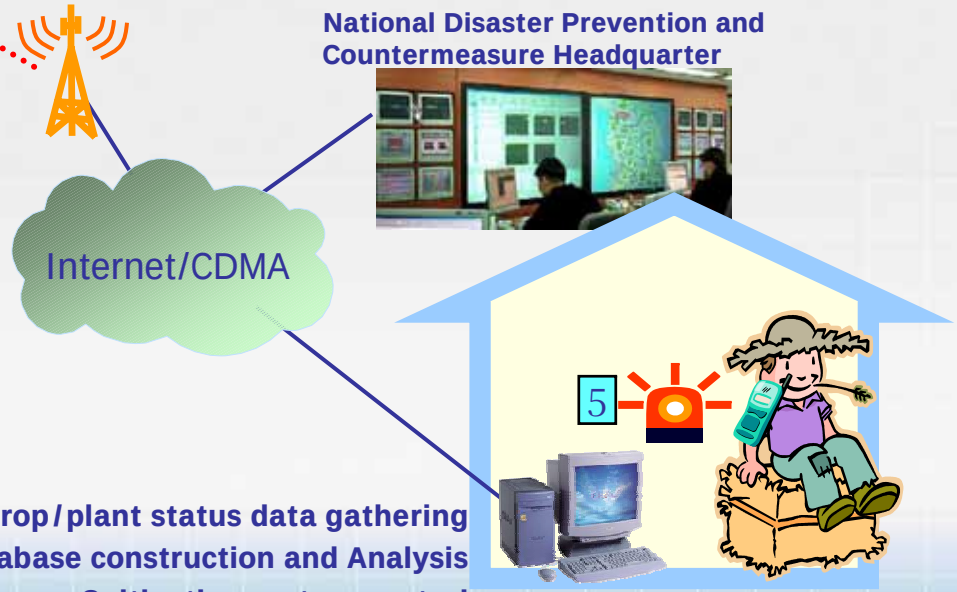


Agricultural Management

Green House Management

(1) Sink node/ u-Sensor Gateway
(2) Monitoring and control of internal temperature/ humidity/ solar radiation and so on
(3) Pest control and monitoring the residual amount of fertilizer in soil
(4) Entrance control and intruder detection
(5) Alerting to flooding, snowstorm, cold snap and etc.





Crop/plant status data gathering
Database construction and Analysis
Cultivating system control

USN Technology Concept

National Disaster Prevention and Countermeasure Headquarter

Services & Applications

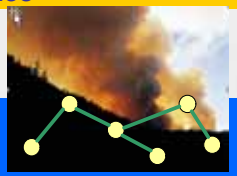
Logistics, SCM

Structural Health Monitoring

Agricultural Surveillance

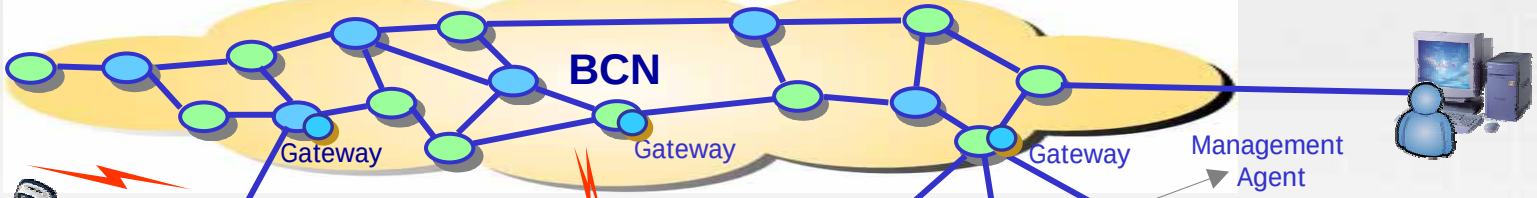
Disaster Surveillance

Military Field



USN Applications

USN Middleware & Service Platform



Infrastructure

Mobile RFID Reader

Sink Node

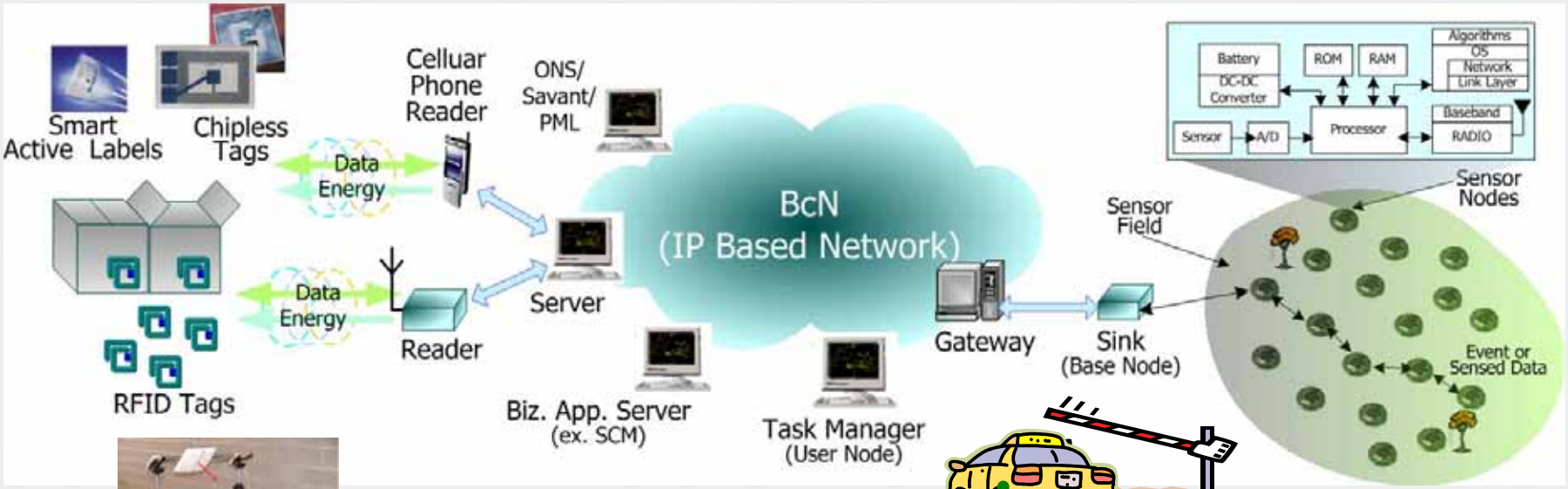
Sink Node

USN-Bridge

Sink Node

RFID & Sensor Network

USN Technology Concept



RFID Applications

Industrial Management

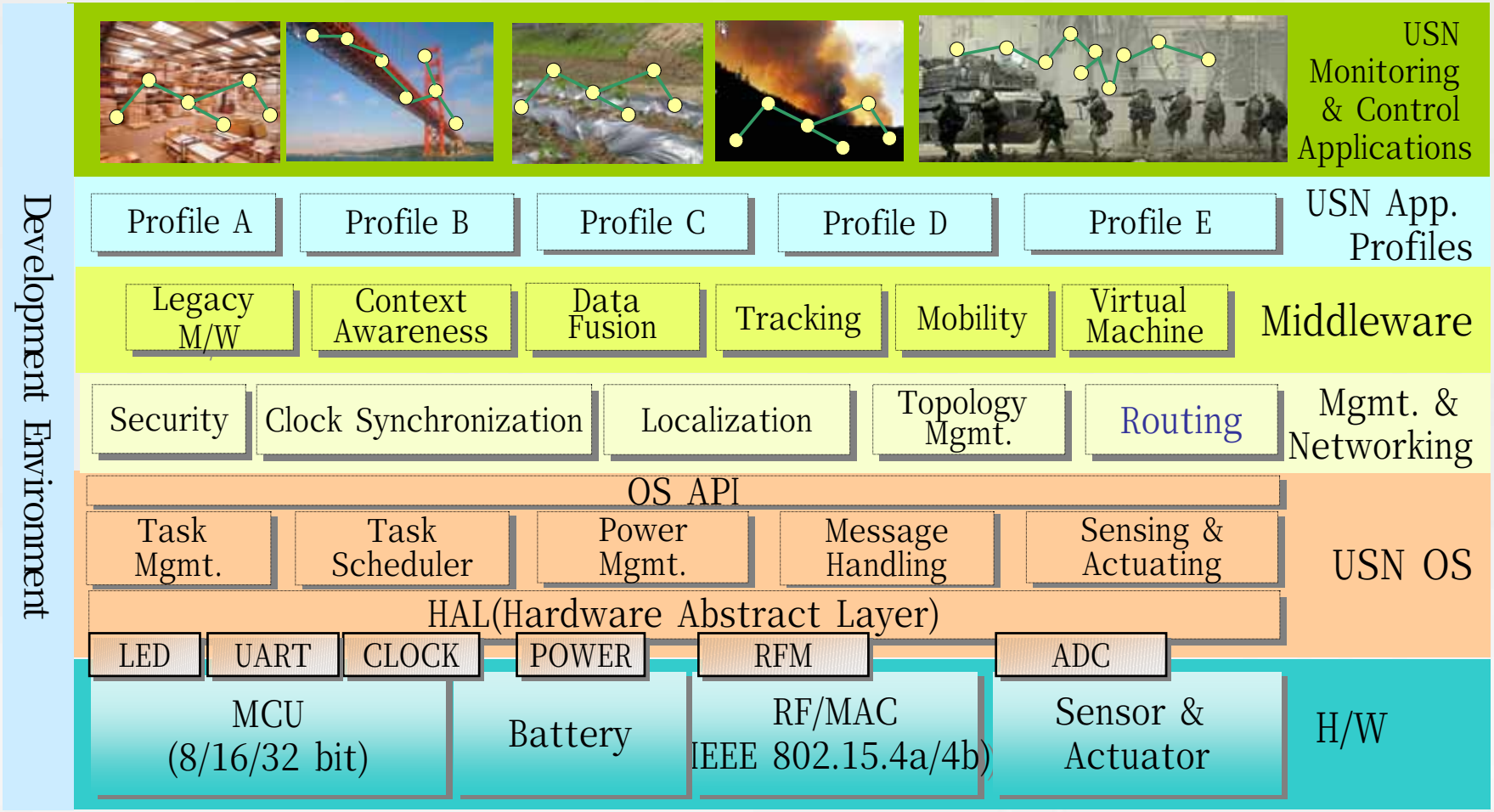
Environmental Monitoring

Automation & Security

Constructive Management

Telematics, ITS

USN System Framework



Considering Scalability, Reconfiguration, and Modularity
Nano-Qplus (ETRI) based Kernel

USN Technology Concept

Key technology innovation

Sensor node

Various sensors | MCU / RF | Antenna
Battery

Wireless sensor

Active Sensor tag

Sensor | MCU / RF | Antenna
Battery

Traditional active RFID
- 433 MHz/ 2.45 GHz
- Separated battery module

Semi-active Sensor tag

1 Extended memory with low power consumption
2 Improving antenna capability

3 Thin flexible battery
4 MEMS sensor technology
5 Cost reduction of package/ assembly

Passive tag

Logic / Memory | Antenna

Class 0-1 tag
- Read only or write once (64~96bit)
- About 4~5m
- Lowest cost

Logic / R/W Memory | Antenna

Class 2 tag
- R/W memory (256 to some MB)
- About 4~5m range

Sensor | Logic / Memory | Antenna
Battery label

Class 3 tag
- Battery assisted label
- Simple sensor function and interface

Print circuit | Antenna

Chip-less RFID
- Printing circuit
- Under 1 cent tag
- Retail to roll assembly

12 Printing technology
- **Polymer technology**
- **Packaging technology**

- **Cover 1 ~ 11 technology innovation**

6 Low cost/power active RF circuit
7 MEMS integration

Sensor | SOC** / RFIC | Antenna
Label battery

Smart active label (Class 3~)
- Longer range (5m→100m+)
- Active transmission (tag speaks first operating)

Various sensors | SOC | Antenna
Label battery

Sensor node (also class 4)
- Communicate each other
- Consists self-sustaining network

8 Ad-hoc networking capability
9 Function integrated device
10 Effective tiny OS development
11 Middle ware technology

2004 | 2005 ~ 06 | 2007 ~ 08 | 2008 ~

Current technology level

Technology for Sensor Tag

Direction of Evolution

Passive RFID Tag

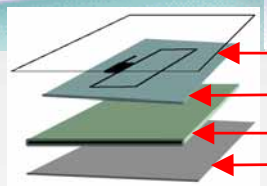
Semi-active Sensor Tag (Semi-SAL)

Fully-active Sensor Tag (SAL) (ex. Peni Tag)

Chipless Sensor Tag

SAL

Smart Active Labels Consortium



- Label surface substrate and overlay protection
- RFID inlet (Antenna, chip, etc)
- Power Source (Thin and flexible battery)
- Backing substrate and adhesive layer

SAL : Thin and Flexible Labels having an IC and power sources

Started from early 2002, now has 17 companies

- Power Paper, Graphic Solutions, KSW microtec, etc
- 4 sub-working groups: Standard, Technology, User, Demonstration

First targeting semi-SAL with temperature tracking

Technology for Sensor Tag

Phase 1 (2005 ~ 2006): Semi-active Sensor Tag with a sensor

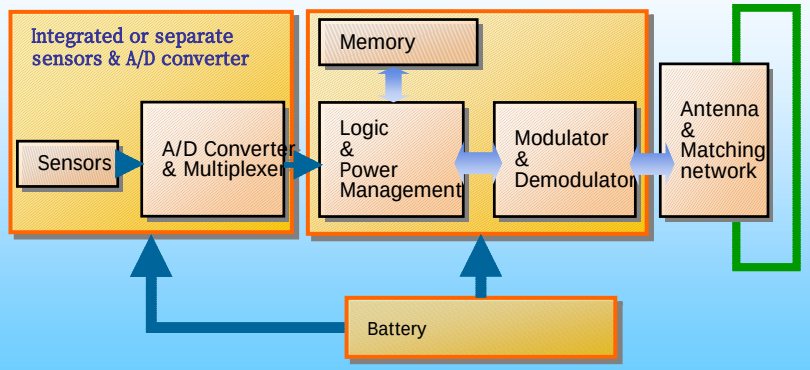
- Battery-assisted passive tags (3 ~ 10m, Battery capacity: 3.0mAh/cm^2)
- Semi-active Sensor Tag with a Sensor

Phase 2 (2007 ~ 2008): Fully-active Sensor Tag with humidity and chemical sensors

- Fully-active Sensor Tag with humidity and chemical sensors (10 ~30m, Battery capacity: 4.0mAh/cm^2)

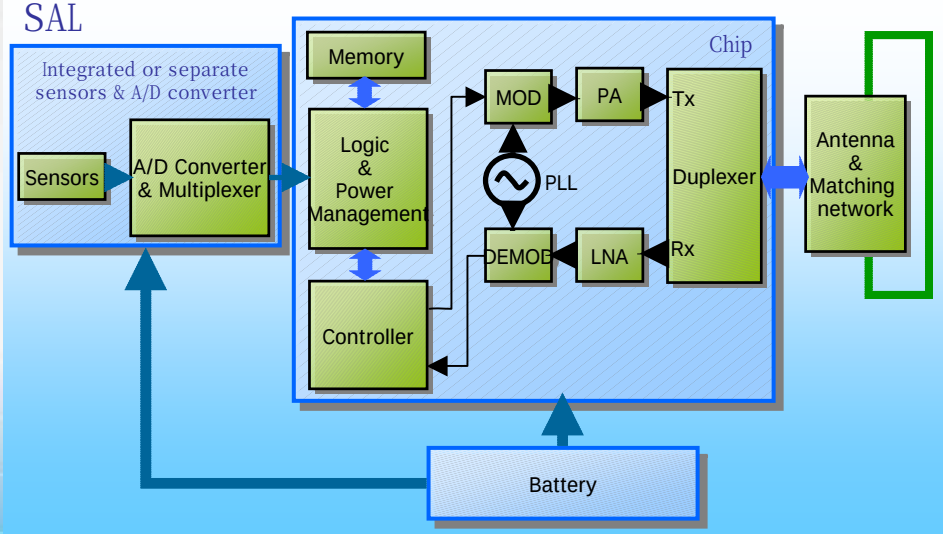
Semi-active Sensor Tag

Semi-SAL



active Sensor Tag

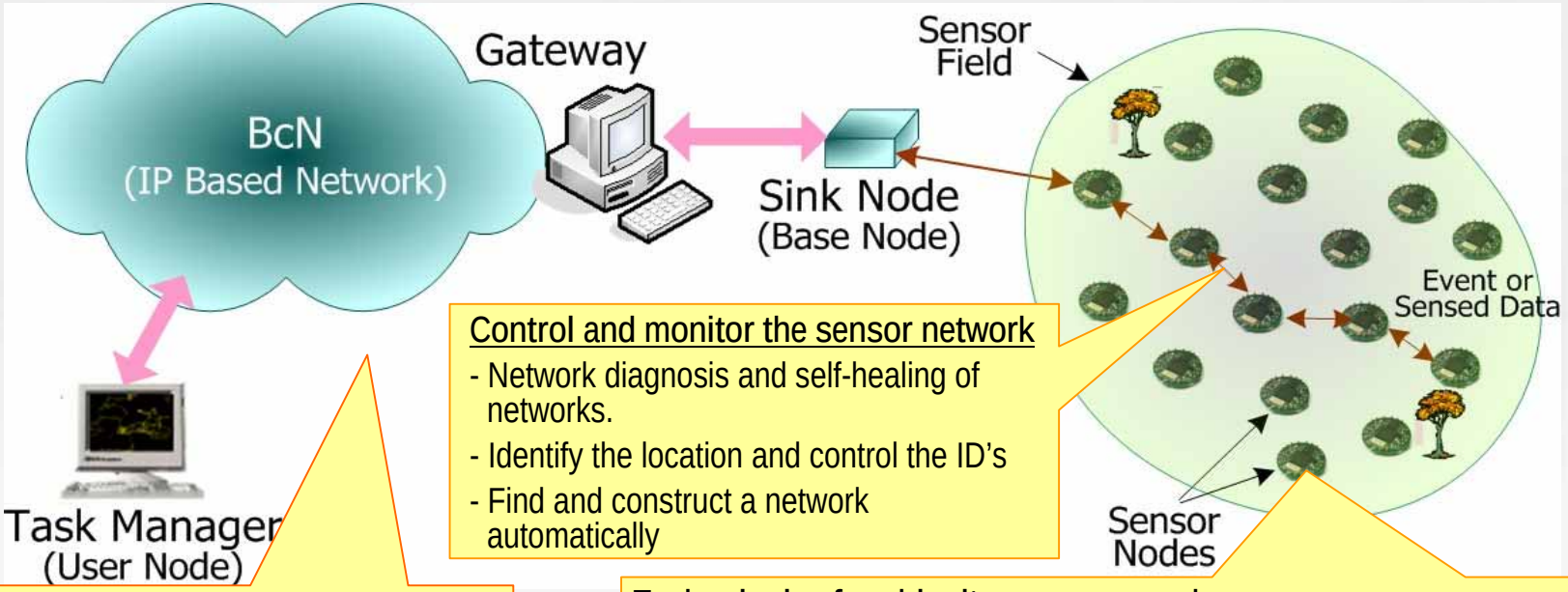
SAL



Technology for Sensor Network

Sensor Network

- **A self-configurable network, in which sensed data or an event is delivered via multiple hops of sensor nodes such that it is utilized to enhance human life**
- **Sensor node: sensing + computation + communication**



Control and monitor the sensor network
- Network diagnosis and self-healing of networks.
- Identify the location and control the ID's
- Find and construct a network automatically

Processing large capacity data in real time
- Control and search sensored data
- Extract meaning of real time information
- Process the sensored information appropriately

Technologies for ubiquitous sensor nodes
- Prevents interference and unnecessary communications
- Self-corrects errors, Synchronizes data
- Implements Micro-electro Mechanical Systems (MEMS)
- Provides power

Technology for Sensor Network

Direction

Small Sensor Nodes

Extra Small Sensor Node

MEMS Type Sensor Node

Standardization

IEEE 1451

- Networking of Sensors
- Sensor/Actuator Microprocessor/ Network Interfaces
- 5 WGs
- IEEE 1451.5: Wireless Interface of ZigBee, Bluetooth, IEEE 802.11

IEEE 802.15

- 802.15.4: (LR-WPAN)
- IEEE 802.15.4a (PHY : UWB)
- IEEE 802.15.4b (Improvement of 15.4)

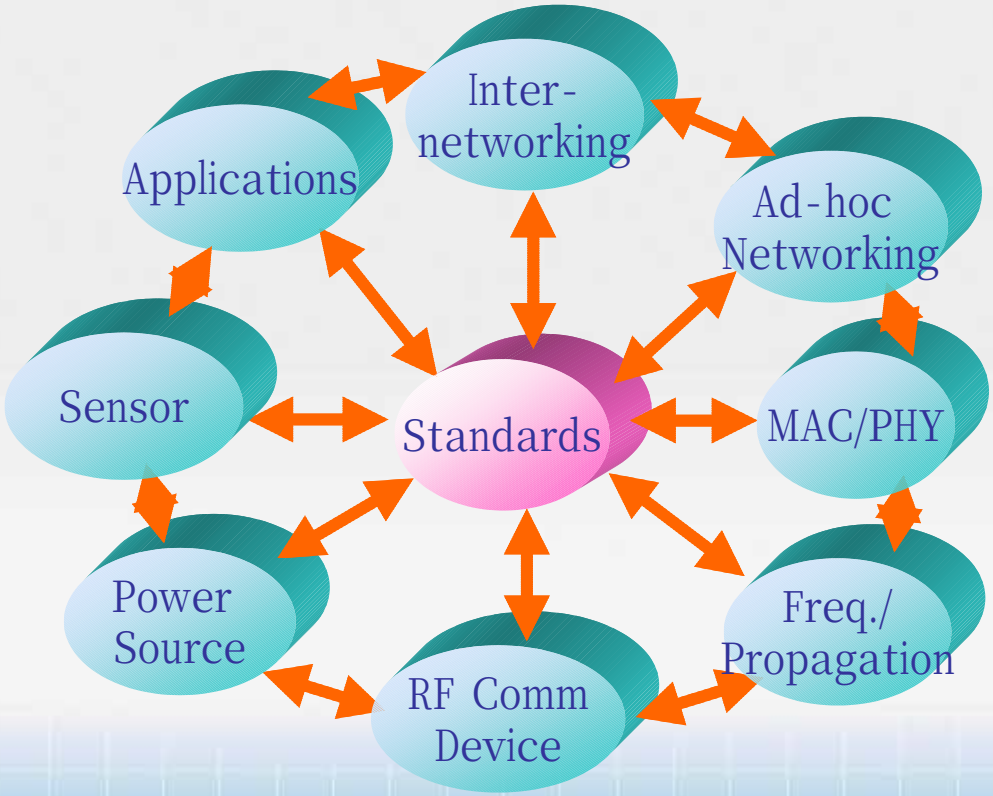
ZigBee

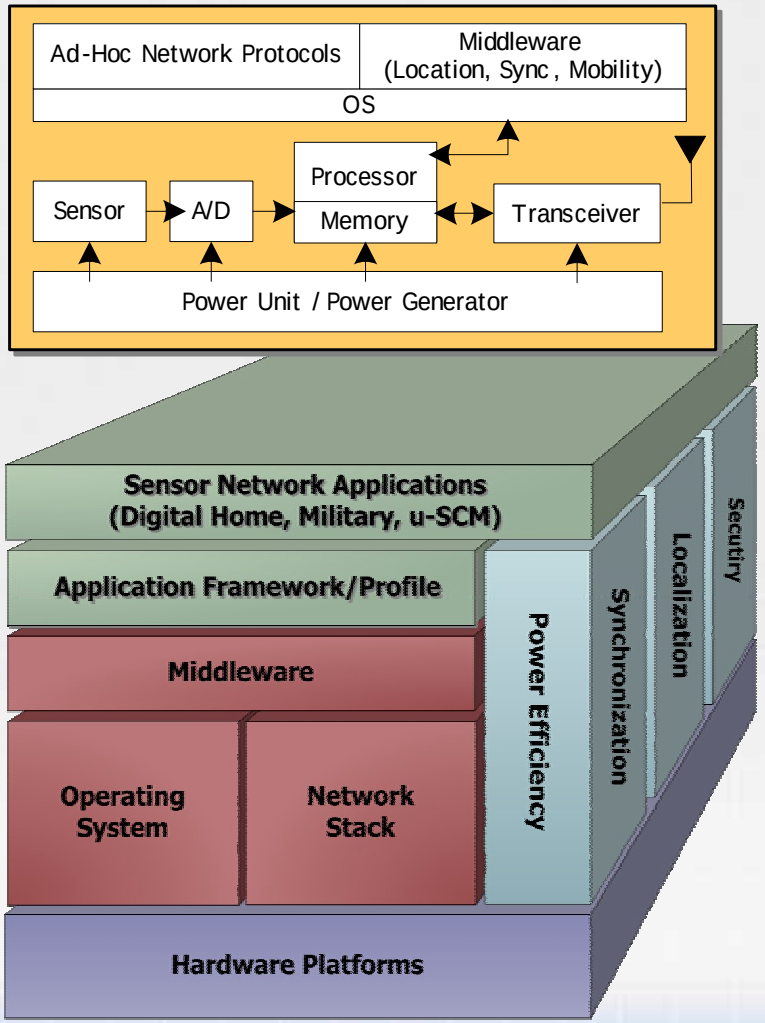
- Application Profiles
- Z-stack & Security
- PHY & MAC of IEEE 802.15.4
- Home Automation
- Building Automation
- Factory Automation

T-engine

- Ken Sakamura TRON project (Founded 2002. 6.)
- Ubiquitous Platform
- Pico, Nano, Micro, Standard (4 types)
- Support of T-Kernel, T-Monitor, Middleware & GNU tools

Technology for Sensor Network





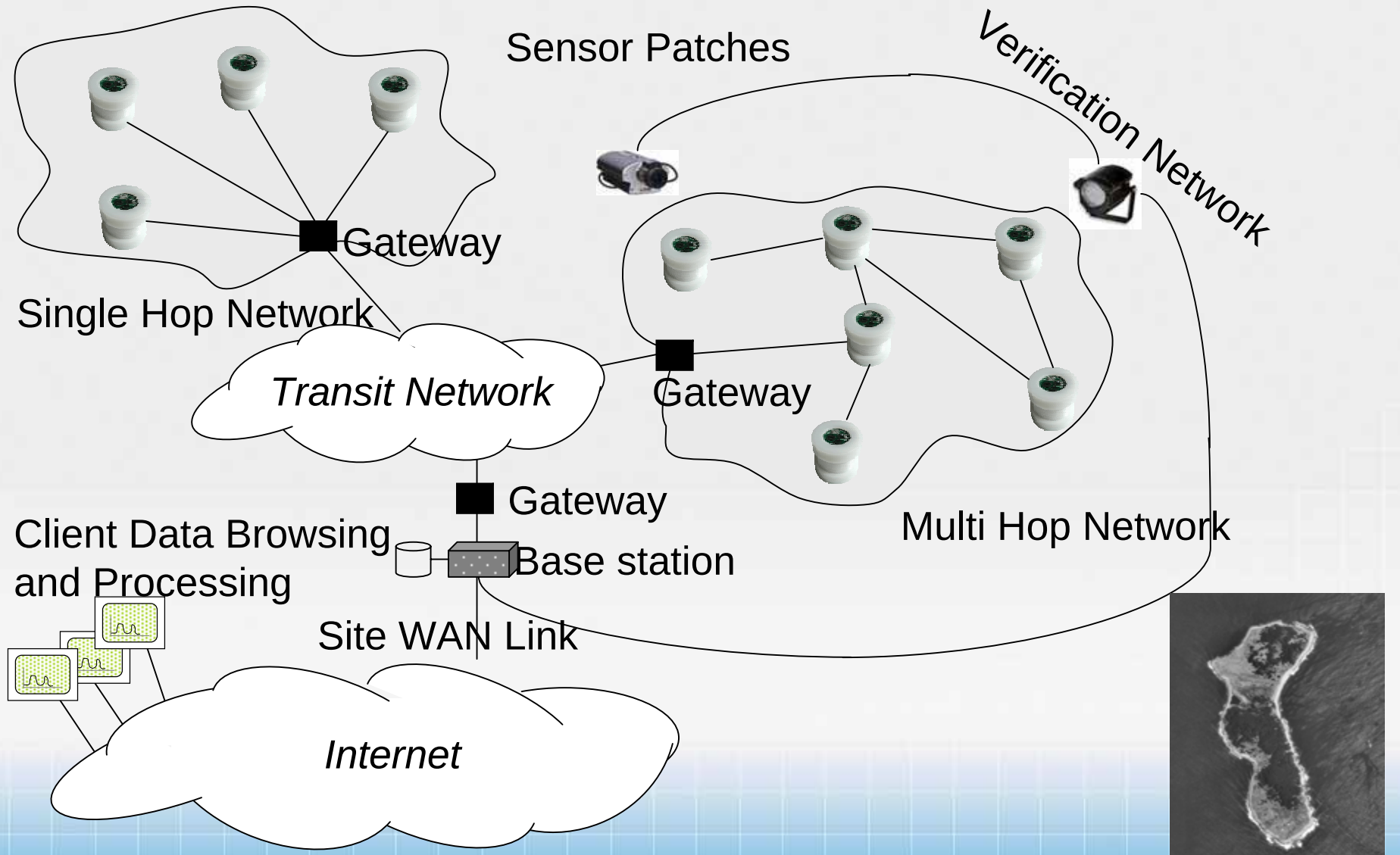
Technology for Sensor Network

Pursuing Open USN Architecture

- to standardize the development platform (interoperability)
- to spread USN technology fast and easily
- to shorten the development period for USN services
- to provide right configuration, considering various USN services' requirements

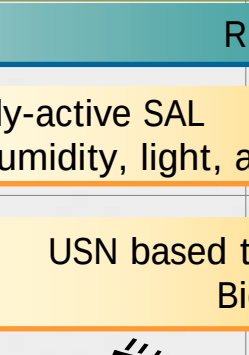
Level	Size	Sensors	Power	CPU	Memory	OS	Displa	Network
Gateway	STB or Home Server	Optional	Power main	32 bit	Flash memory	Embedded Linux	Expen.	Bluetooth Or 802.11 GPS / IEEE802.15. 4/4a/4b
Macro node	PDA	Advanced Sensors (Image)	Battery or power main	32 bit	Flash memory	Embedded Linux (Standard OS)	Inexp.	Bluetooth Or 802.11 Beacon / IEEE802.15. 4/4a/4b
Micro node	Coin	Primitive Sensors	Battery	16 bit or less	Flash memory	Nano Qplus (Micro OS)	No	IEEE802.15. 4/4a/4b
Nano node	Very Small	Primitive Sensors	Battery or Solar cell	8 bit	No	Nano Qplus (Nano OS)	No	IEEE802.15. 4/4a/4b

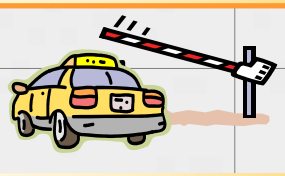
Technology for Sensor Network

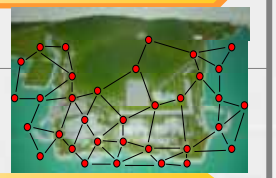


Roadmap for USN Technology R&D

Technology	2005	2006	2007	2008
u-Sensor Tag	900/433 MHz RFID Systems	Semi-active SAL - Temperature sensor	Fully-active SAL - Humidity, light, and chemical sensors	RFID/USN Test-bed
USN Applications	RFID Applications	USN Service Modeling ex. Logistics, Smart Building, Tracking	USN based telematics services Bio-sensing services	
USN Middleware	RFID Middleware	Location based context-aware middleware S/W	Intelligent context-aware middleware S/W	
USN Networking and Configuration	Low power communication Low power routing, Ad-hoc Networking nano/micro/macro-sensor nodes u-Sensor Gateway		High-powered sensor nodes BcN Networking USN Service Modeli	







SoC node (MCU+MAC+RF)
Big Coin size
1,000+ node networking

Tiny nodes
Small Coin size
10,000+ node networking

USN R&D Activities at ETRI

R&D Target for USN Technology

Network Architecture
- Tiered network configuration including homogeneous network

IEEE 802.15.4a/4b Compliant PHY and other protocols
- Sensor Node Soc, Routing and Security

OS and Management functions
- Energy-optimized kernel considering modularity and network scalability
- Localization
- Synchronization
- Mobility-awareness

Middleware
- Application specific context-awareness handling
- Sensor data fusion and processing
- Sensor database management

Applications
- Smart Office/Building & Diagnosis
- Asset Tracking
- Structural Health Monitoring
- Environmental Surveillance
- Millitary

R&D Focus for the 1st Phase

USN Processor
- Low power microcontroller solution based on EISC* core for USN
- Basic architecture to constitute 8- to 32-bit sensor nodes (8/16/32 bit)

USN SoC and Sensor nodes
- 32 bit MCU + MAC + RF transceiver
- Hierarchical Node Structure

Rechargeable battery and solar cells

Smart Office/Building & Diagnosis

*EISC: Extendible Instruction Set Computing
cf) CISC, RISC

R&D Target

USN R&D Activities at ETRI

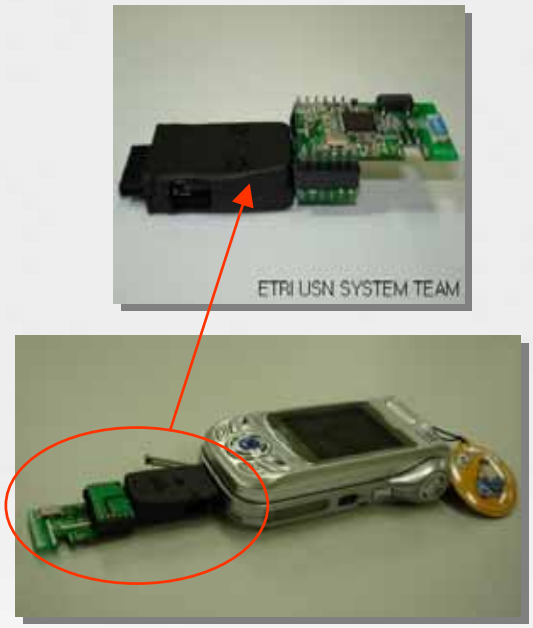
Classes of Main Modules

Main Modules

Node	Figure	Size (cm)	Specification	Usage
PSN (Portable Sensor Node)		2.1 x 5.8	- 8MHz 8-bit MCU - 2.4 GHz RF Communication - IEEE 802.15.4 Compliant (& ZigBee) - Nano Qplus based Kernel	Linking Mobile Device to Sensor Network (Interface module with Cellular phone)
SN-1		5.2 x 3.6	- 8MHz 8-bit MCU - 2.4 GHz RF Communication - IEEE 802.15.4 Compliant (& ZigBee) - General interface with sensor module	Sensed signal processing from sensors and communication
SN-2		3.3 x 2.4	- 8MHz 8-bit MCU - 2.4 GHz RF Communication - IEEE 802.15.4 Compliant (& ZigBee) - General interface with sensor module	Control data processing and communication with other nodes

USN R&D Activities at ETRI

Wireless Monitoring and Control Modules



Cellular Phone + PSN

Sensor Modules

- Temperature, light, current, and gas sensors
- InfraRed and pressure sensors
- Ultra-sonic sound sensors

Controller Module

- AC/DC Relay Switch

USN Sensor & Actuator Nodes

Features of 32bit USN EISC Microcontroller

Built in 32bit CPU	Special Features
• Maximum 30Mhz CPU Operation • Simple EISC Core SE3208 • 8 x 32 General Purpose Registers • Up to 30MIPS Throughput at 30MHz • 32bit X 32bit 1 cycle Multiplier	• Power-on Reset and Programmable Brown-Out Detector • 7 Sleep Modes - ¼ System clock mode, ½ System clock mode, - Idle, Power Save, Standby, Power Down • Global Pull-up Disable • Digital and Analog Regulators • JTAG and Boundary Scan Test Support
Program and Data Memories	**Peripheral Interfaces**
• 128KBytes of In-System Reprogrammable Internal Flash - Endurance : 10,000 Write/Erase Cycles - SPI Interface for In-System Programming • 16KBytes Internal SRAM • 4KBytes Internal EEPROM - Endurance : 100,000 Write/Erase Cycles • Up to 2MBytes External Static Memory Space	• 31 Ch. Priority Interrupt Controllers • 8 External Interrupts • 4 Channel Timers • Watch Dog Timer • Real Time Clock • SPI with 64Bytes FIFO • TWI
Operation Voltage	**Package**
• 3.3 V(+/- 10%)	• 100 Pin LQFP

USN Processor

Smart Office / Building

Description

- Enhancing energy efficiency for office and building maintenance
- Advancing working conditions at office/ building by utilizing the context awareness of USN based office/ building

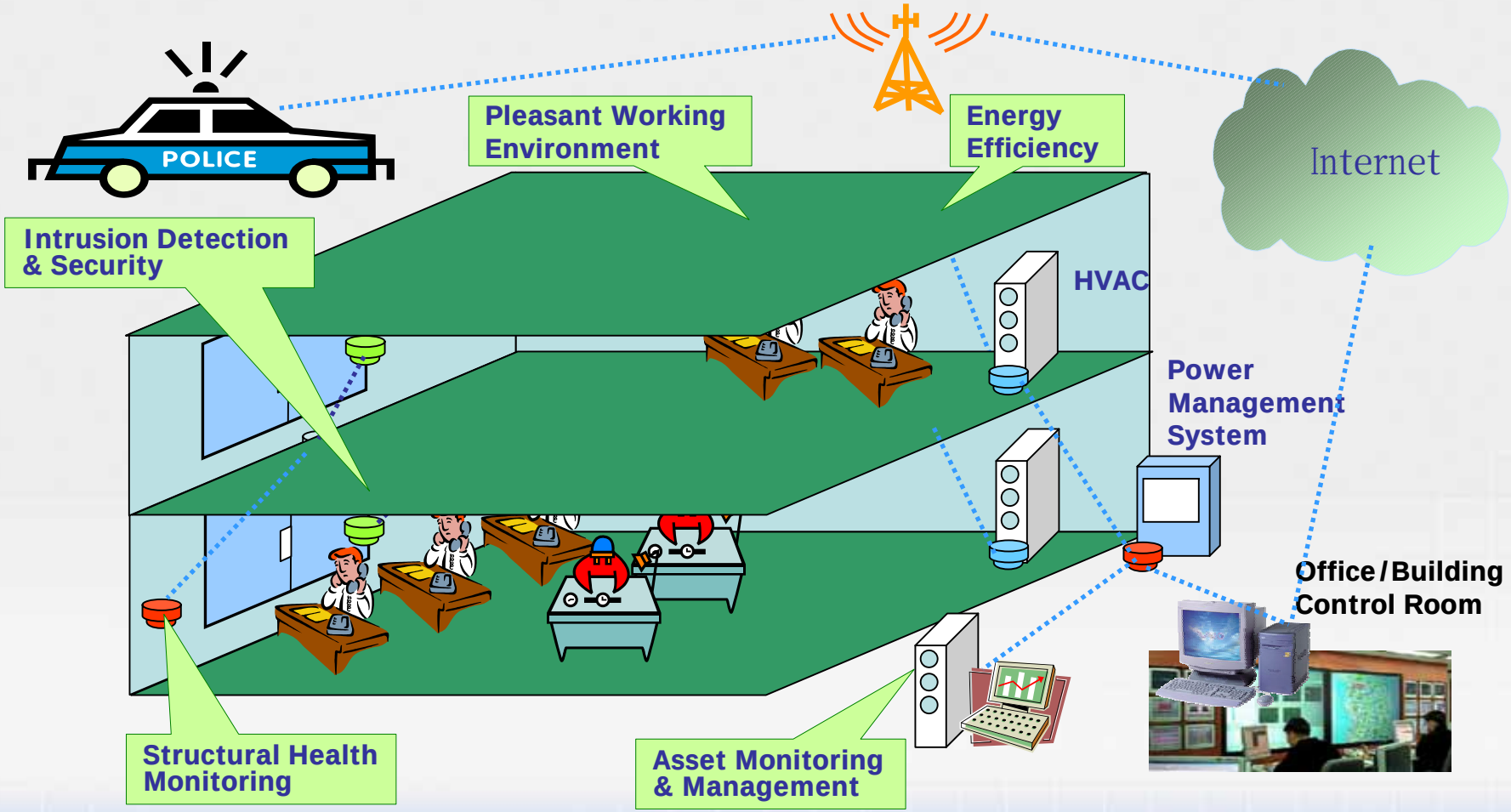
System Architecture

- **Sensor Network Components**: Sensor (Actuator) node, Sink node
  - ※ **Sensing**: Temperature, Humidity, Luminance, Pressure, Magnetic, and so on
  - ※ **Controlling**: HVAC (Heat, Ventilation, Air conditioning), Lighting, Locking and so on
- **u-Sensor Gateway**: Gateway that connects sensor network to BCN
- **Server**: Sensor data, event, and network management, service control

Benefits

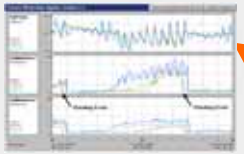
- Wiring cost down ($40/ft to $2000/ft) (by the Source of Frost & Sullivan market forecast for wireless sensors)
- Decrease system commissioning time due to the **reduction of installation risk and issues, minimization of wiring errors**
- Reduction of installation cost
- Large-scale and in place monitoring that was impossible previously

Smart Office / Building



USN Service

Configuration of Smart Office / Building Service



Temp, Moisture, Brightness etc.

BcN

Another Visitor Mr.Kim has come.

NoSeong

#309 Conference : No

#303 Visitor : Yes

#304

JongOh

SeHan

JiEun

Visitor Mr.Park has come.

Visitor Kim
Service Terminal

The boss has a visitor. Please wait at Conference room #309.

Visitor Park
Service Terminal

JiEun is at her desk. Please go to the Office #304.

Smart Diagnosis

Description

- Prevention or minimization of damage due to the faults occurred at facilities in industrial fields by monitoring error conditions at low cost
- Reduce the cost demanded on laborious diagnosis procedures and network installation due to the advantages of wireless sensor network

System Architecture

- **Sensor Network Components**: Sensor (Actuator) node, Sink node
  - ※ **Sensing**: Sensors suitable to the specific diagnosis such as acoustic, temperature, current, UHF frequency, and so on
  - ※ **Controlling**: Appropriate controllers to solve the detected errors
- **u-Sensor Gateway** : Gateway that connects sensor network to BCN
- **Server**: Sensor data and event handling, network management, and service control

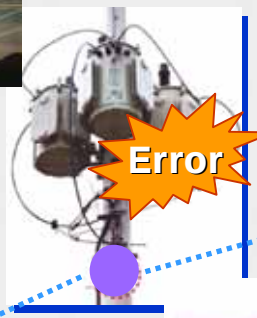
Benefits

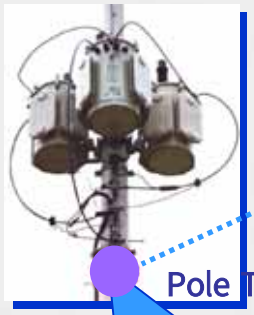
- Predict the failures for critical assets
- Monitor energy efficiency

USN Service

Smart Diagnosis

Pole Transformer Diagnosis



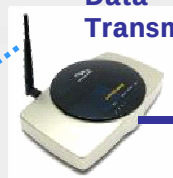


IEEE 802.15.4

Pole Transformer

Monitoring and Diagnosis Vehicle Dispatch

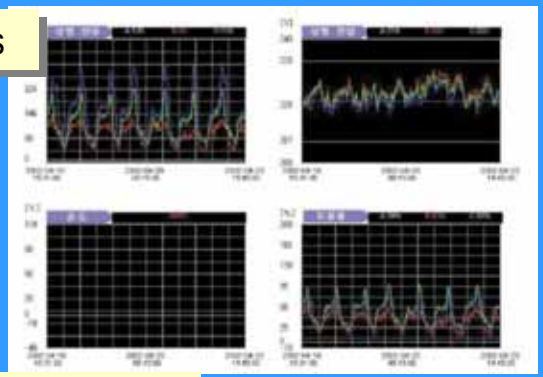
Data Transmission



u-Sensor G/W

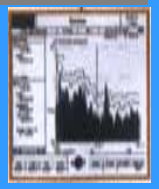
Real-time Data Gathering and Analysis

Analysis



Report Formatting

Temperature Measuring



Partial Discharge Monitoring

Sensing Data Analysis

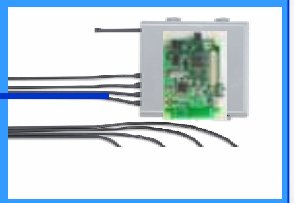
Event Analysis

Acoustic Emission Sensor (Partial Discharge)

Temp. Sensor

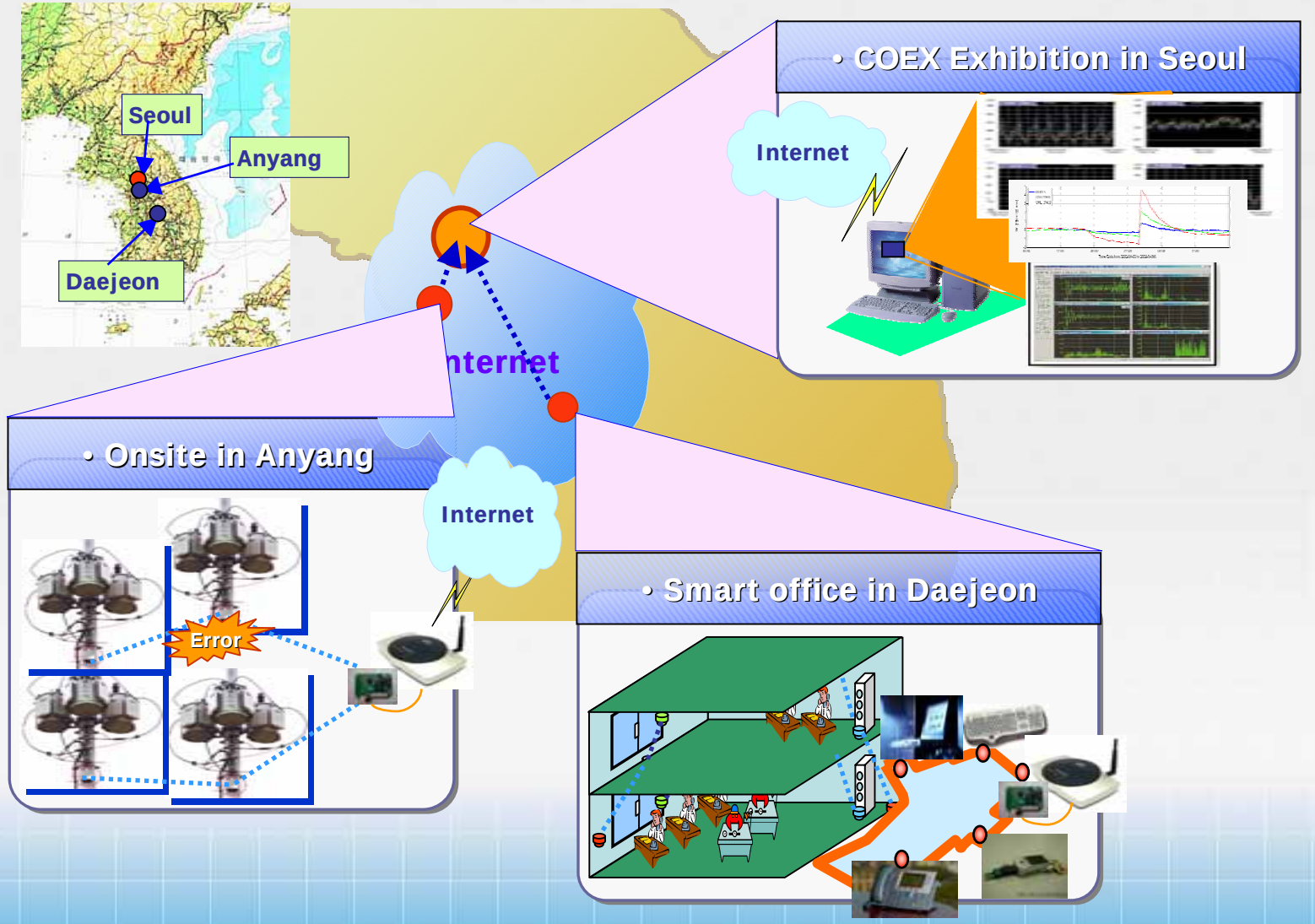
Current Sensor (Leakage Current)

Sensor Node



Wireless Monitoring via Internet

Wireless Monitoring & Control via Internet



Conclusion

Issues for USN's proliferation

- Noise and spectrum availability
- Calibration of sensors
- Scalability
- Stable & efficient deployment and testing
- Network Longevity: Self-powering
  - Power source technology including energy harvest
- Modularity
  - Fit-to-many applications
- Reliability including packaging
- Security
- Interoperability
- Standardization

Currently, ETRI is developing core technology for USN, which can be well adapted to various applications

- USN Processor and SoC technology
- Smart office/building and smart diagnosis services

ETRI is building up an efficient scheme so as to expand it to the scenarios of

- Telematics
  (Prevention of traffic accident)
- Asset monitoring
- Structural health monitoring
- Environmental monitoring
- Contamination source tracking
- meteorological observation
- Ecological monitoring and so on

Thank you !!