Approaches on USN & RFID technical means testing

Workshop
IMPLEMENTATION EXPERIENCE OF NETWORK PERFORMANCE PARAMETERS CONTROL SYST EMS AND GRANTING REQUIRED LEVEL OF SERVICES QUALITY ON THE OPERATOR NETWORK S. SENSOR NETWORKS – AS OPTIMIZATION TOOL FOR VEHICULAR TRAFFIC FLOW

Moscow

27-29 April 2011

Content

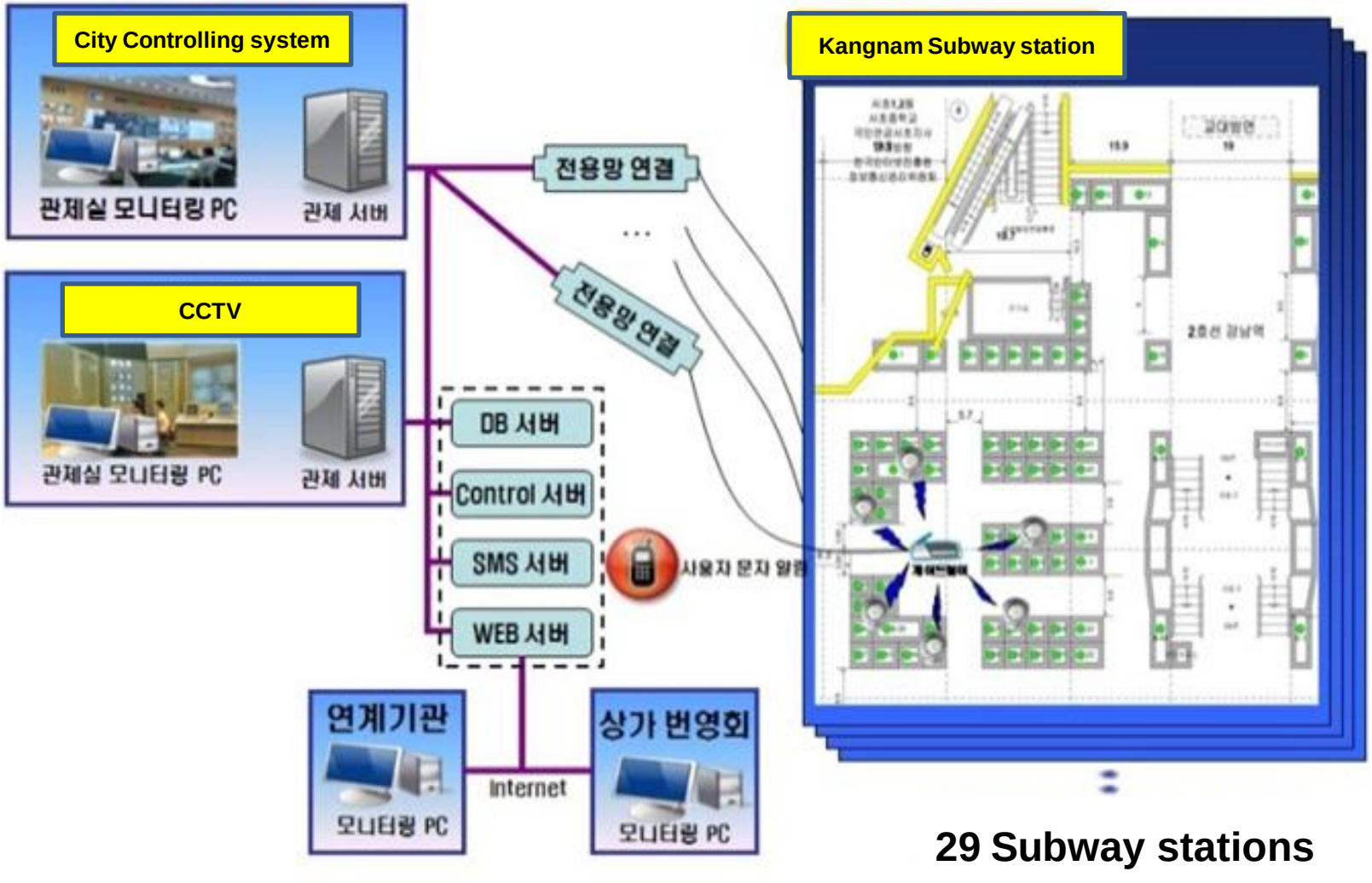
I. Experiments for test specification

II. USN performance test in NIPA

III. USN Testbed

IV. Demo

What if there is no Testing



29 Subway stations

Problems

- High Density of sensor nodes in small place
  - Overhead for communication
- Network Performance & Stability
  - After network become unstable, they cannot recover by themselves (Need to know maximum throughput)
- Interference with each other and other network
- Low Power

Development of USN Test Specification

- **Why Performance Test is important for USN?**
  - **There are huge number of non-standard technologies**
  - **There is no way to certify or verify these USN technologies with Conformance Test**
  - **Only Performance Test could be the answer to verify the quality of performance**
- **Performance Test ….**
  - **increase market growth through verification of products**
  - **Increase level of R&D technology through performance analysis**

Development of USN Test Specification

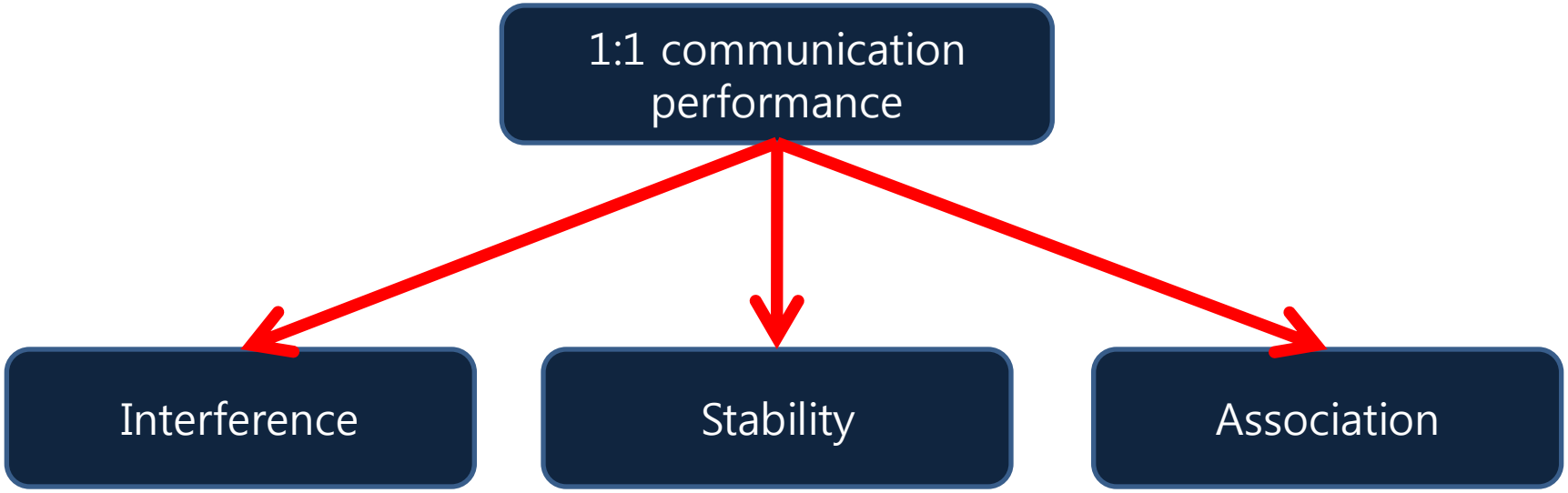
- Key Point
  - Performance Test is not easy to normalize due to their properties
  - But Performance Test has to be normalized for repeatability and reproducibility
- What we have to do…
  - Target 1 : Application layer functional test
  - Target 2 : Network layer performance test
  - Target 3 : Peripheral function performance test

Experiment for Test Specification

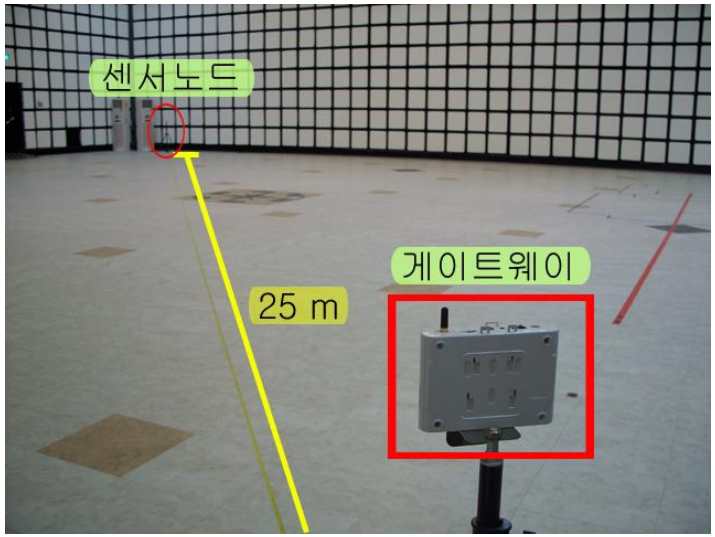
Find out possible problems and its solution for USN

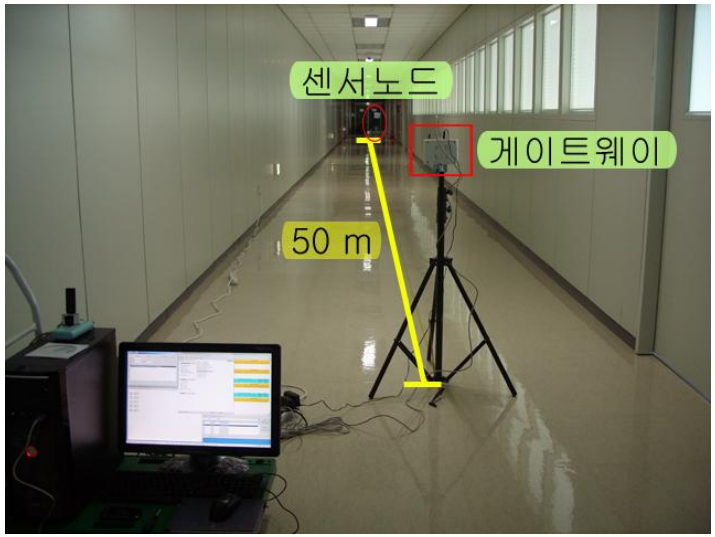
- Develop Test Specification
- Provides Guideline for Development and Field Installation

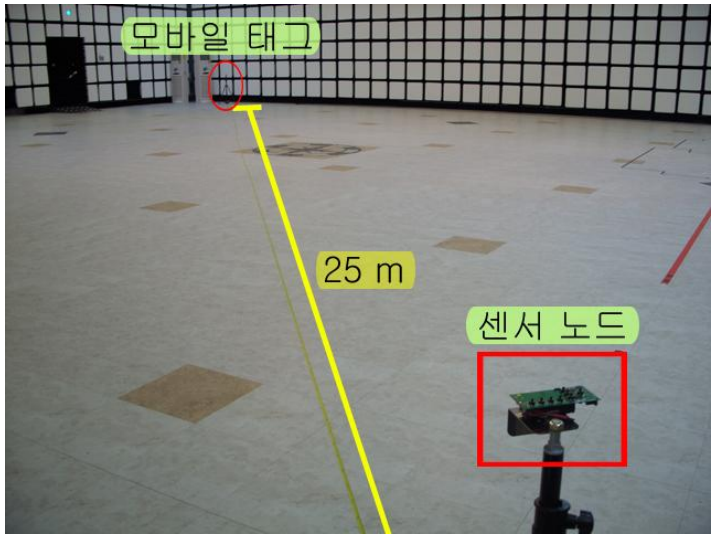
Methodology for Experiment

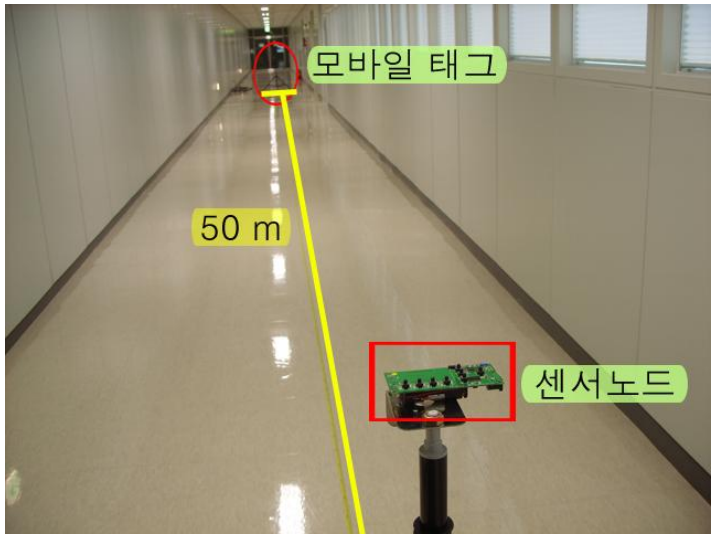


1:1 communication performance

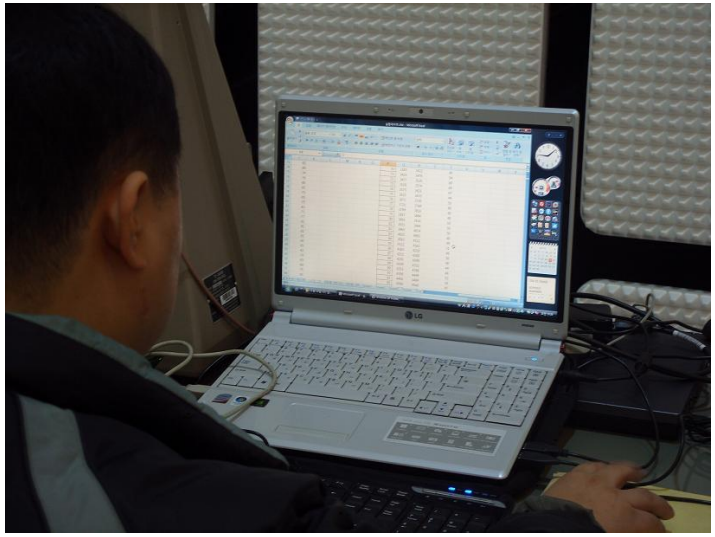


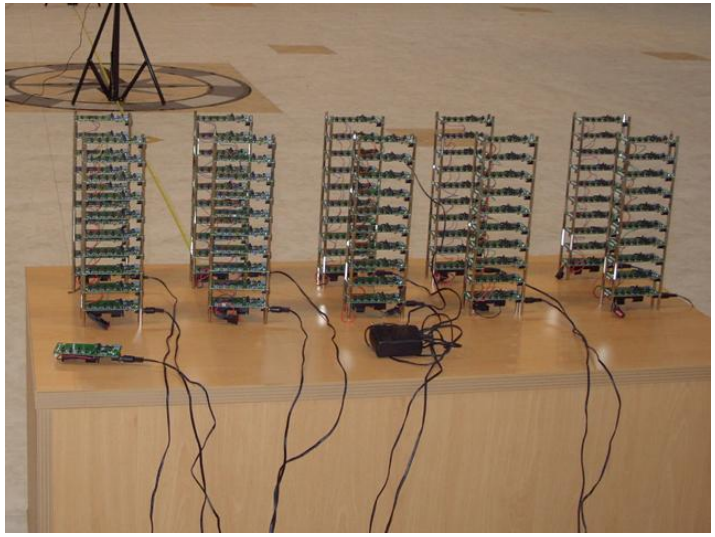




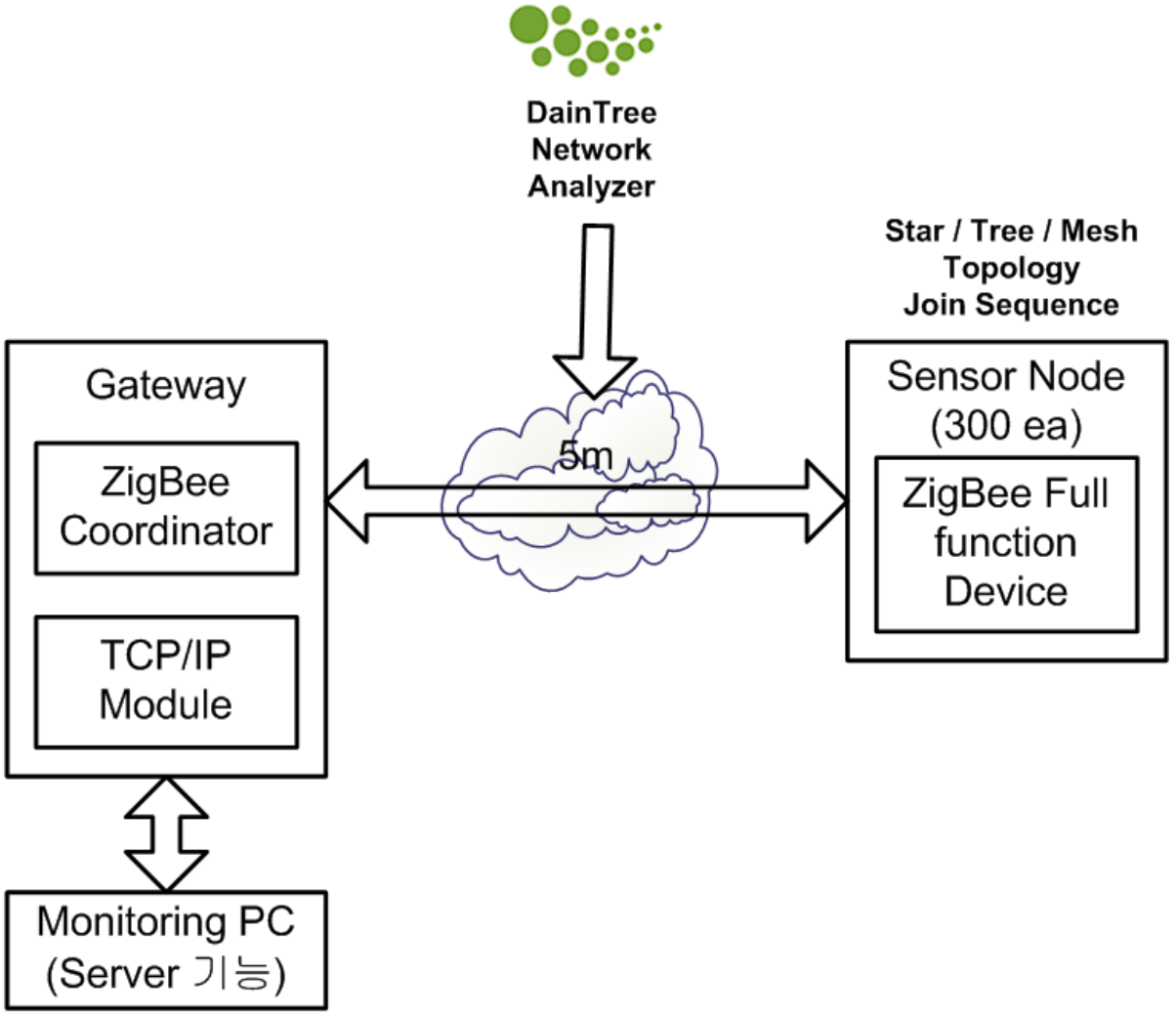


Stability test with 300 sensor nodes

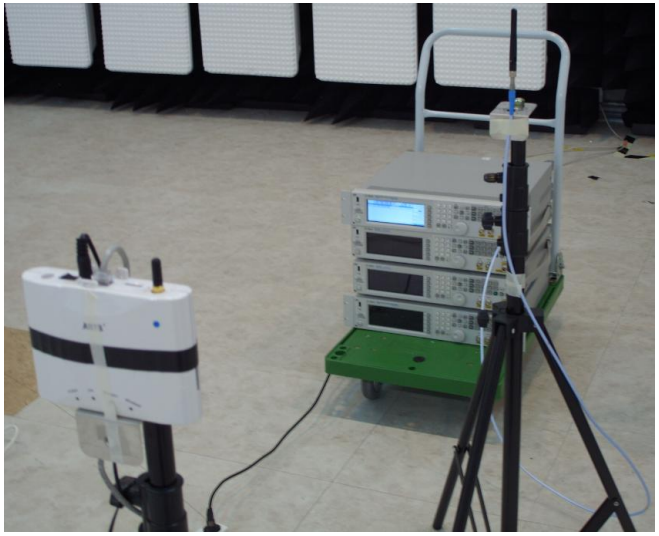


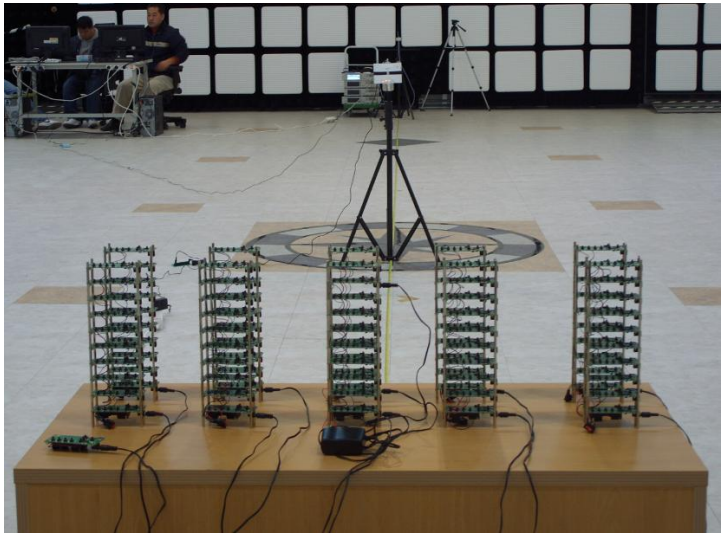


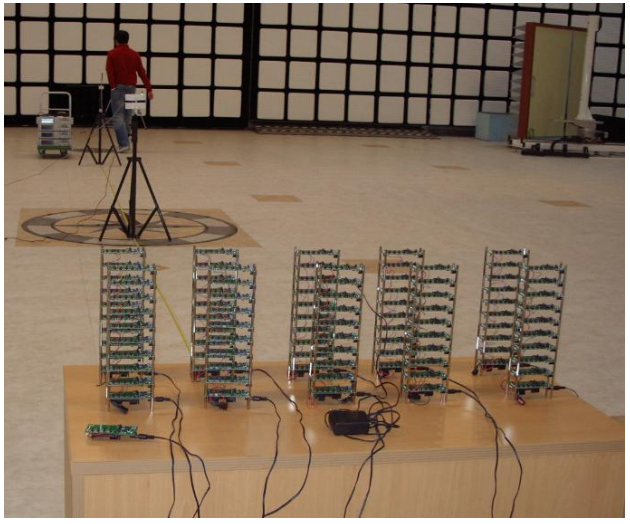
Association Test



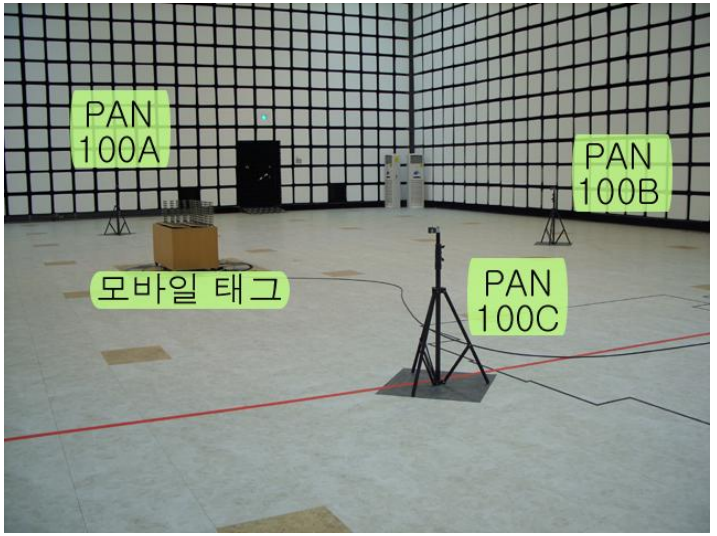
Interference test

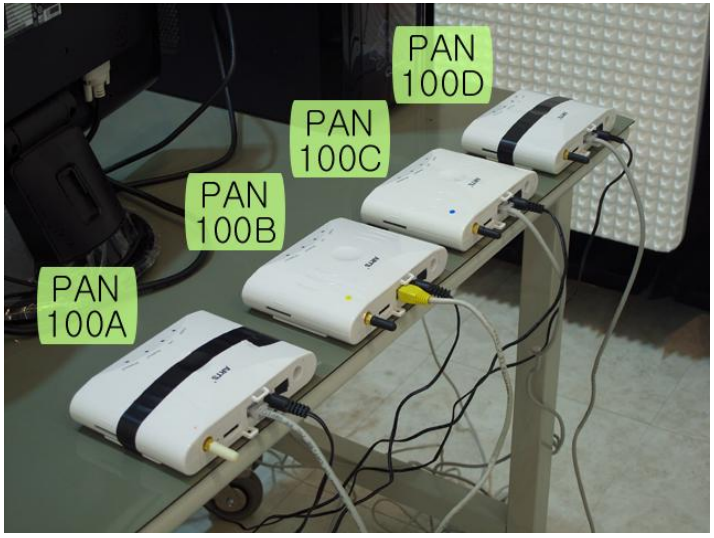






Performance in multi-PAN



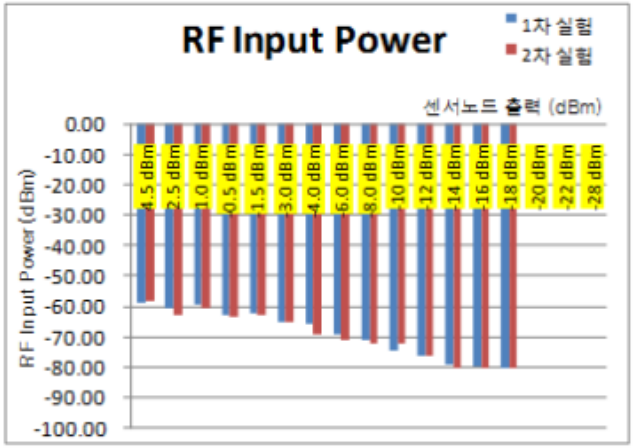


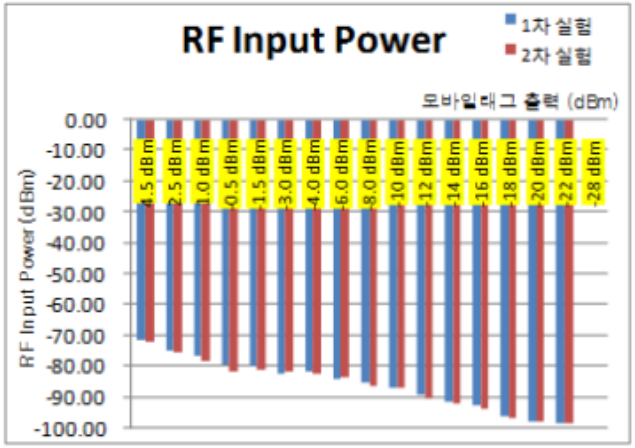
Mobility Test

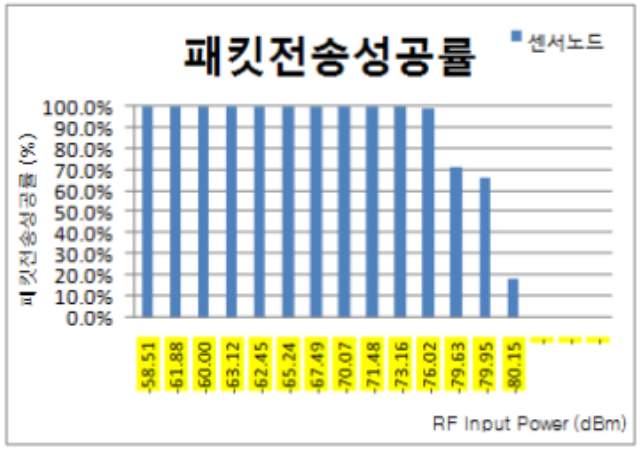
1:1 test result(in anechoic chamber)

X : changing Tx power step by step

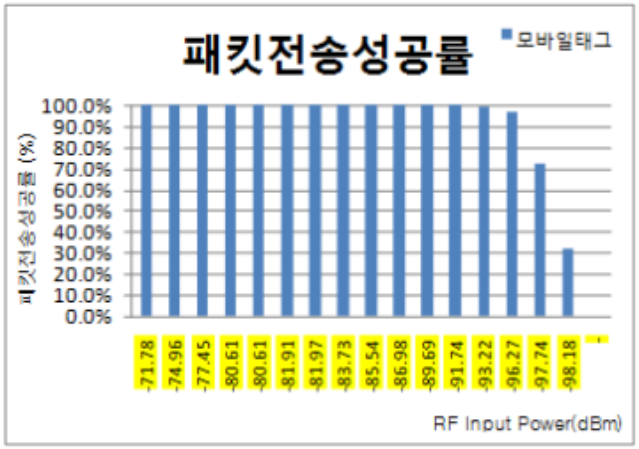
Y : RF input power







CC2420 based Sensor Node

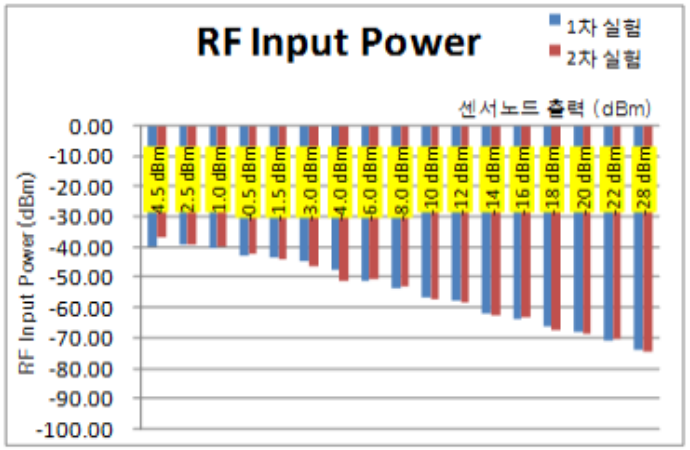


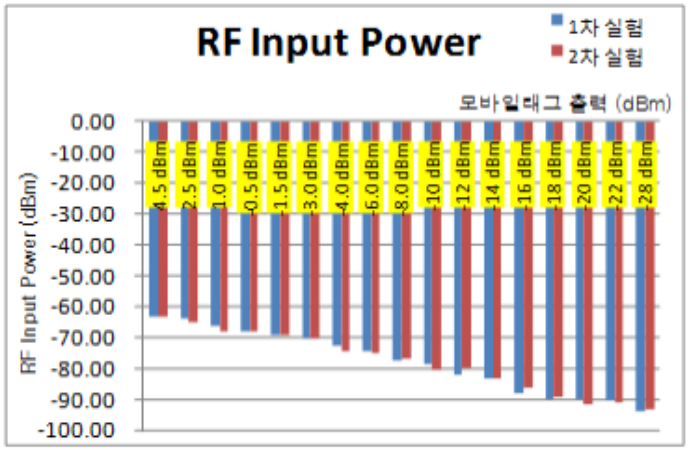
CC2431 based Sensor Node

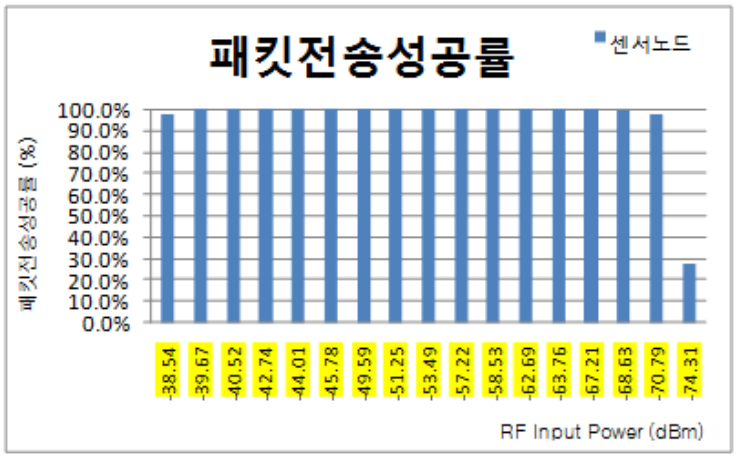
1:1 test result(in building)

X : changing Tx power step by step

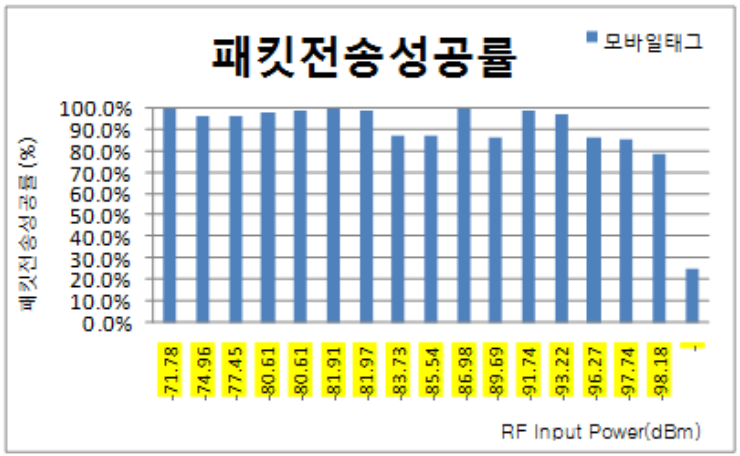
Y : RF input power







CC2420 based Sensor Node

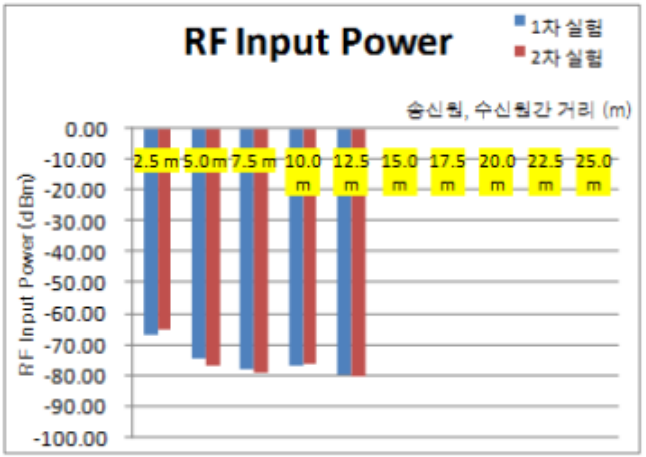


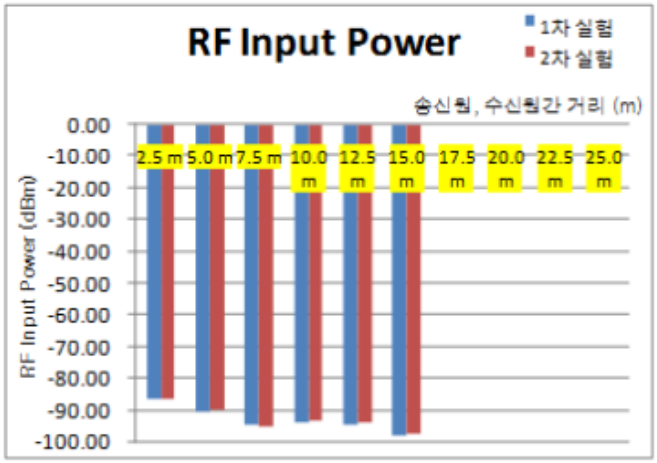
CC2431 based Sensor Node

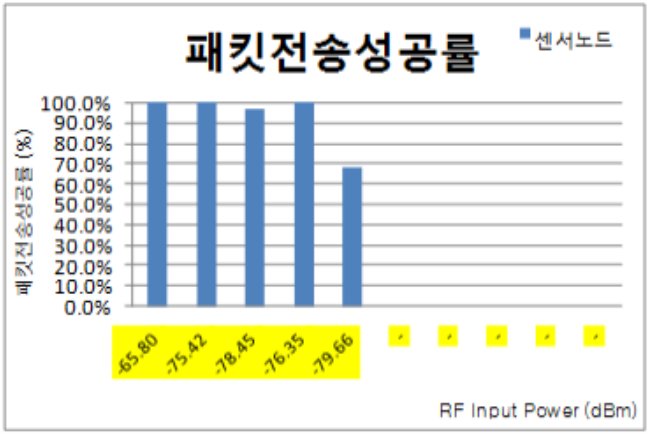
1:1 Test Result(reading range)

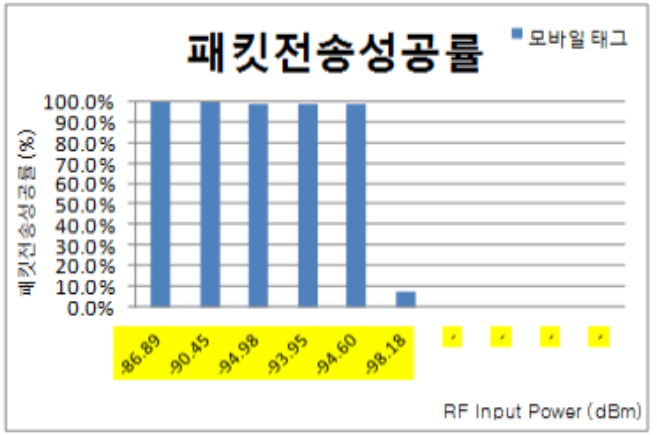
X : changing distances

Y : RF input power





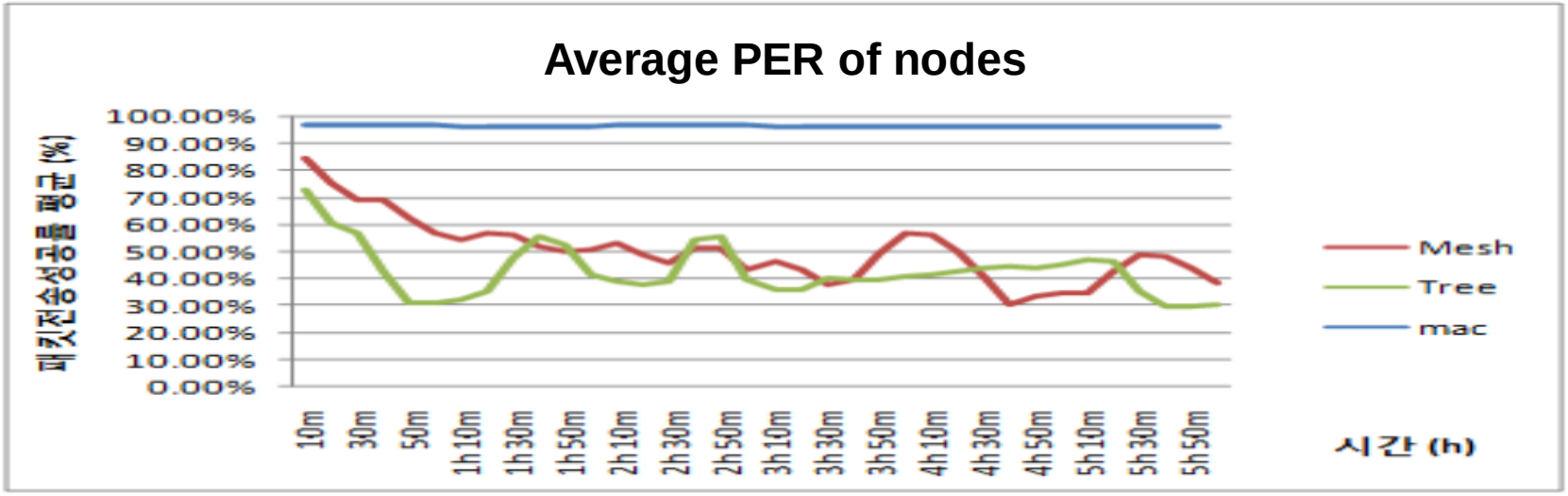


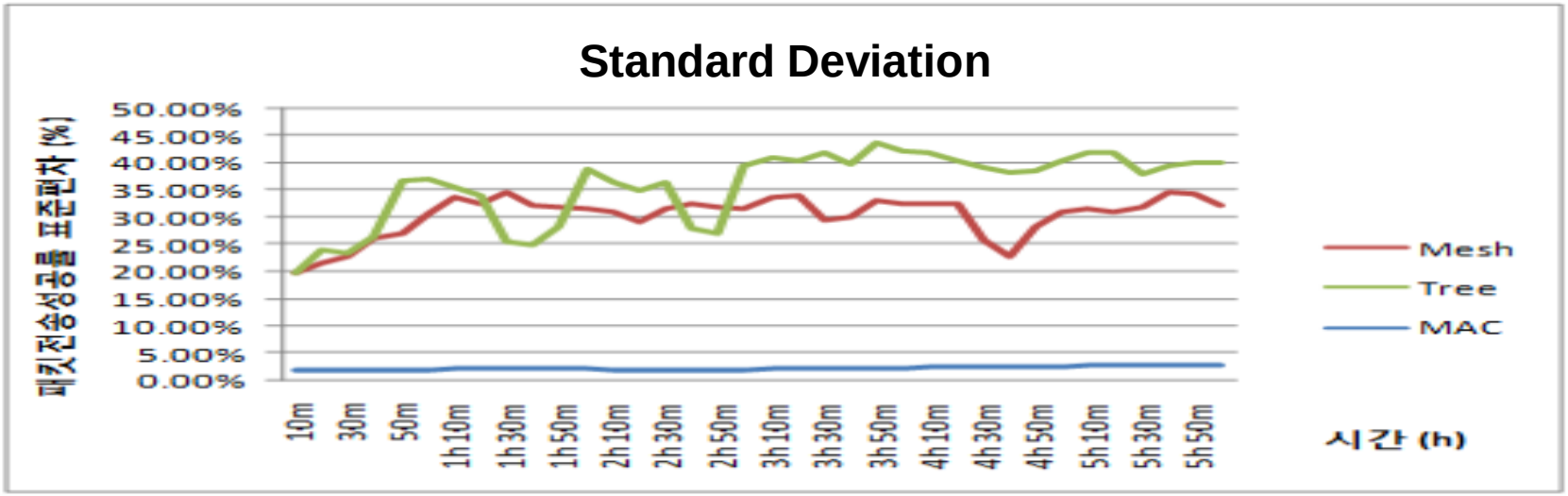


CC2420 based Sensor Node

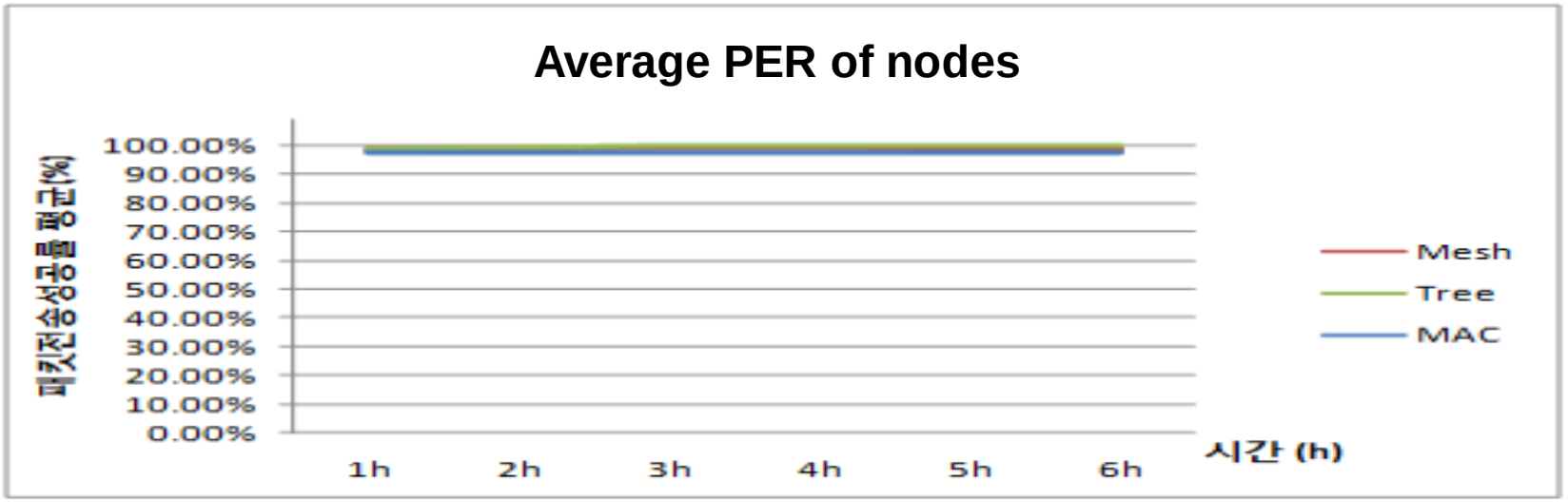
CC2431 based Sensor Node

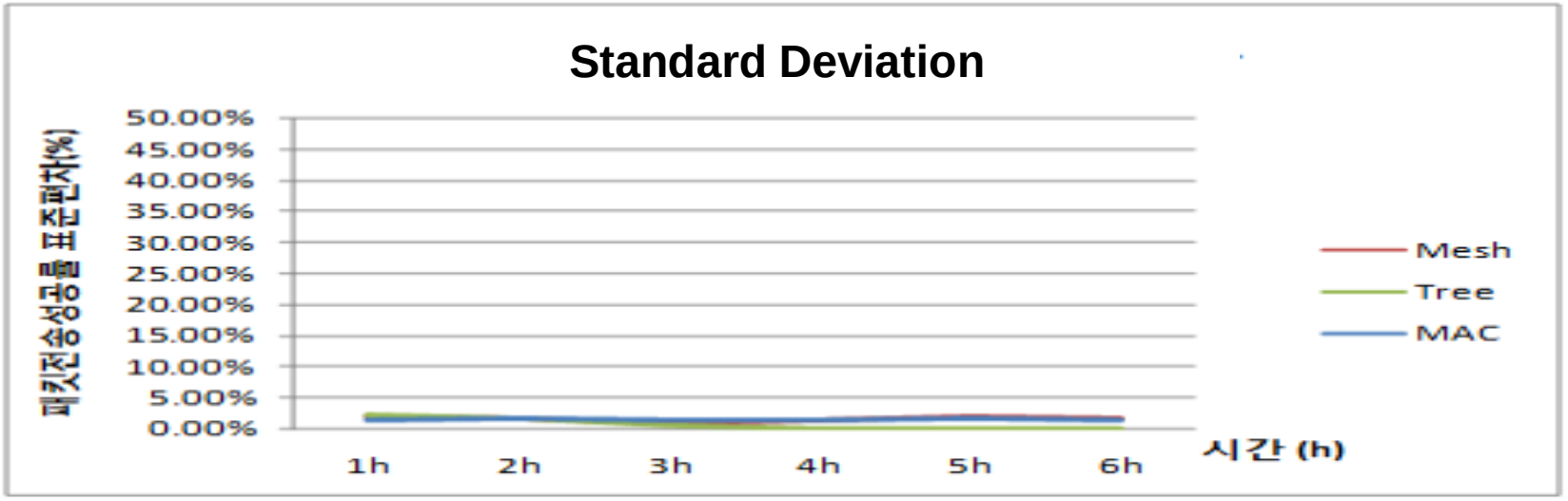
Stability test result(300 nodes)



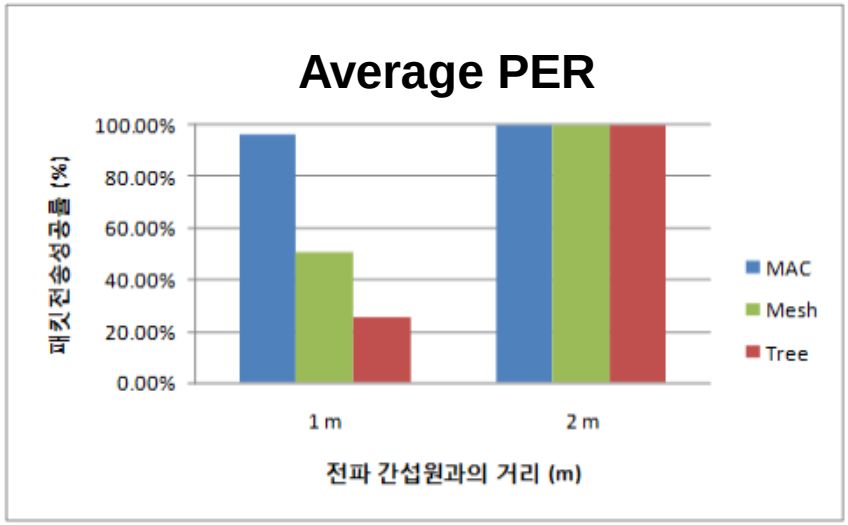


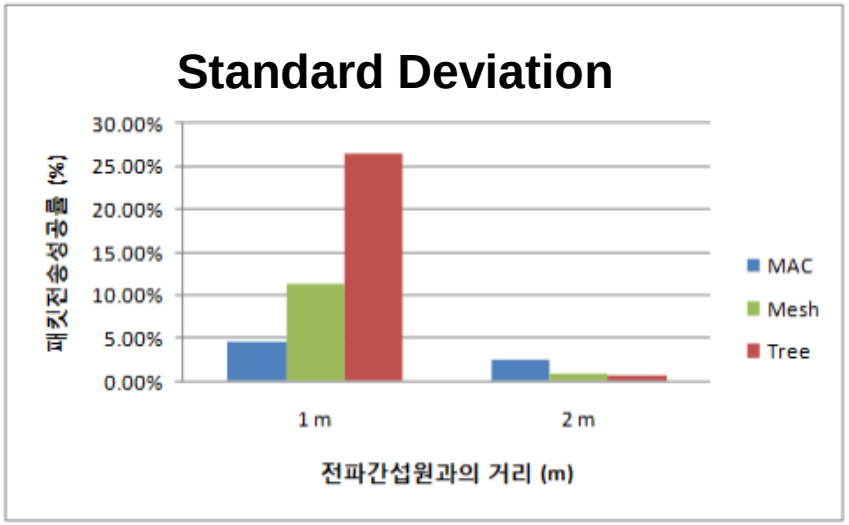
Stability test result(100 nodes)

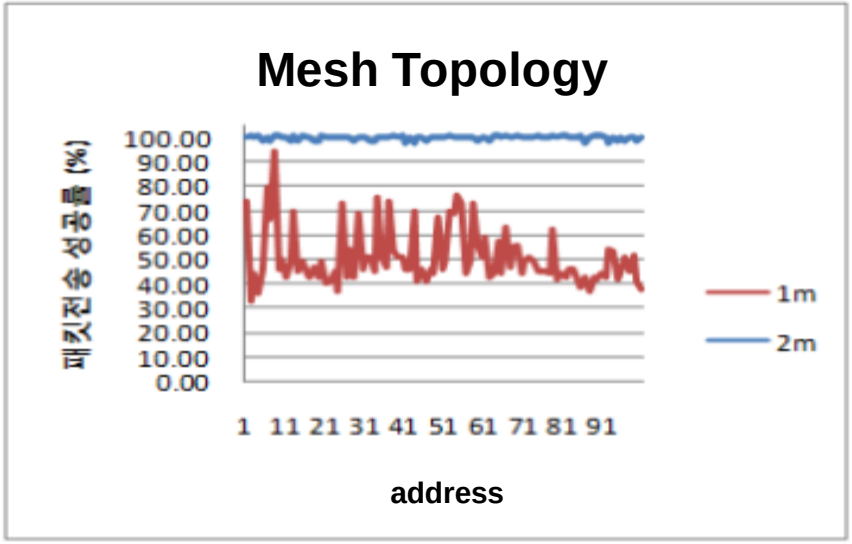


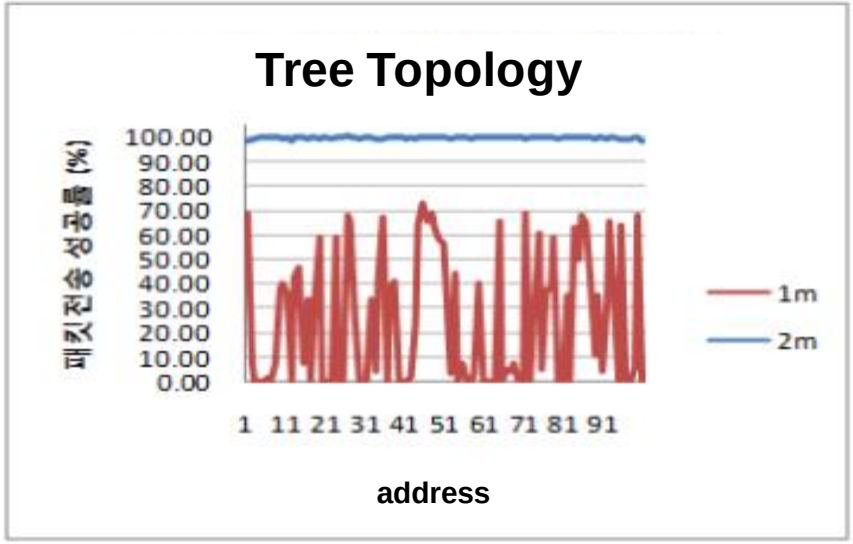


Interference test result

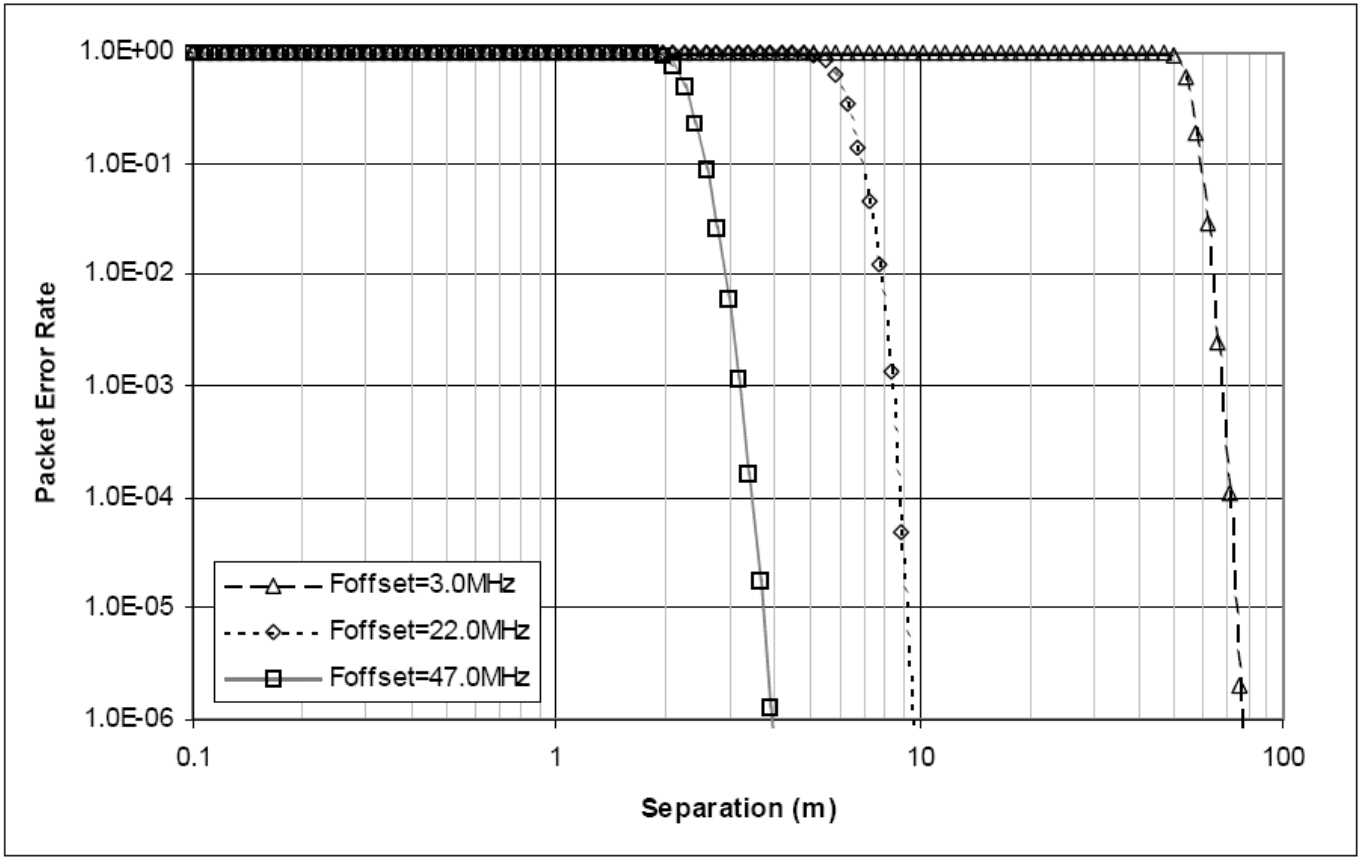




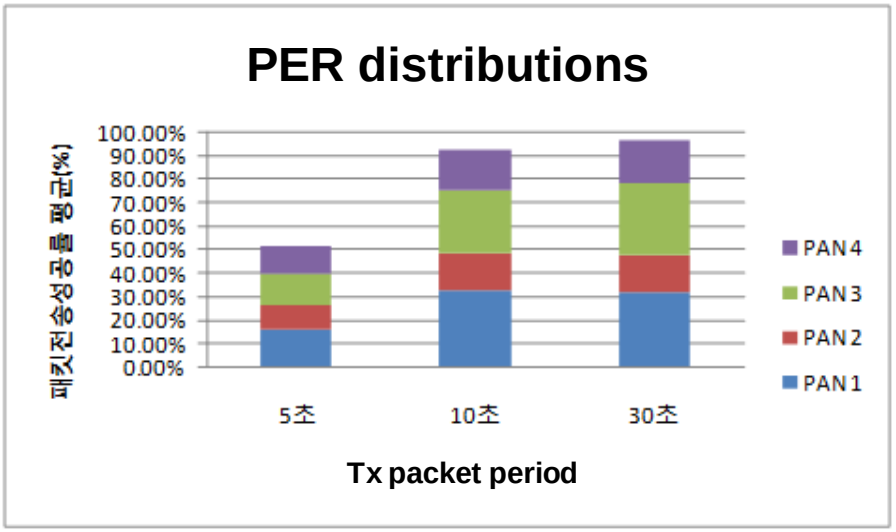


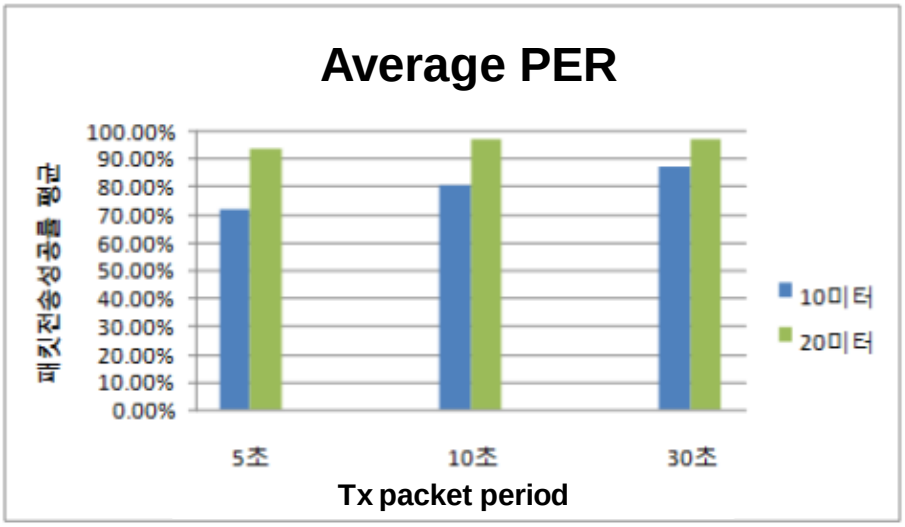


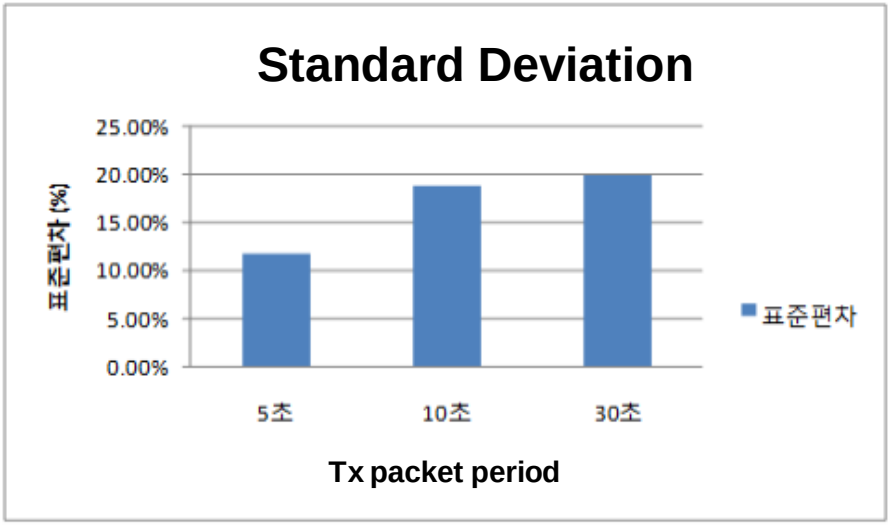
Interference test result



Multi-PAN test result

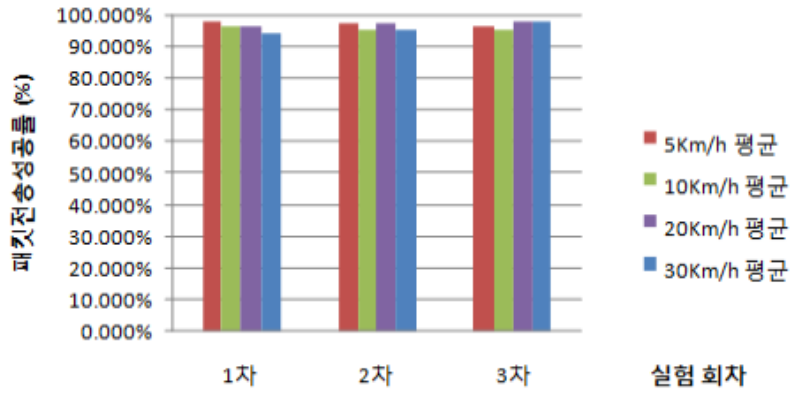




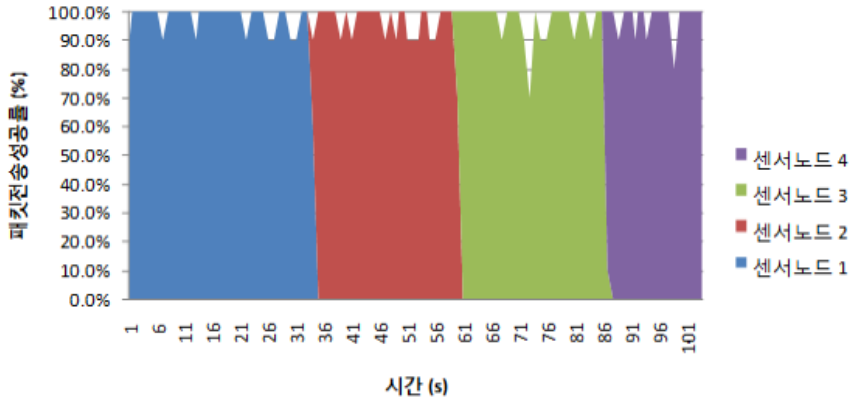


Mobility test result

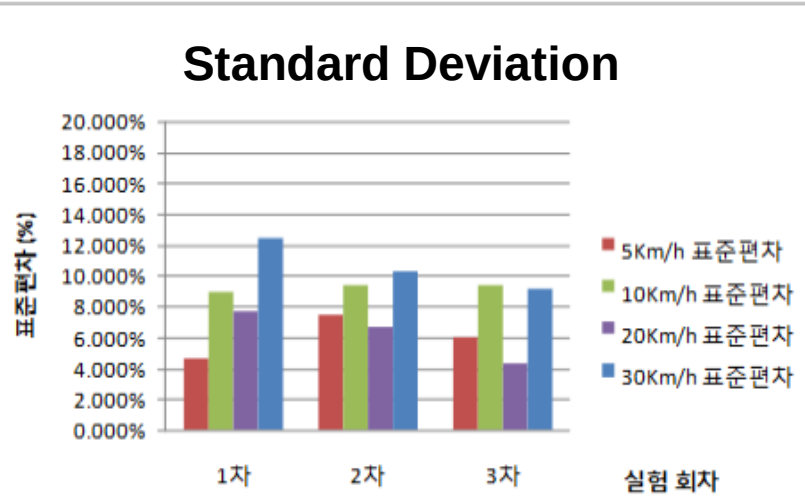
Average PER



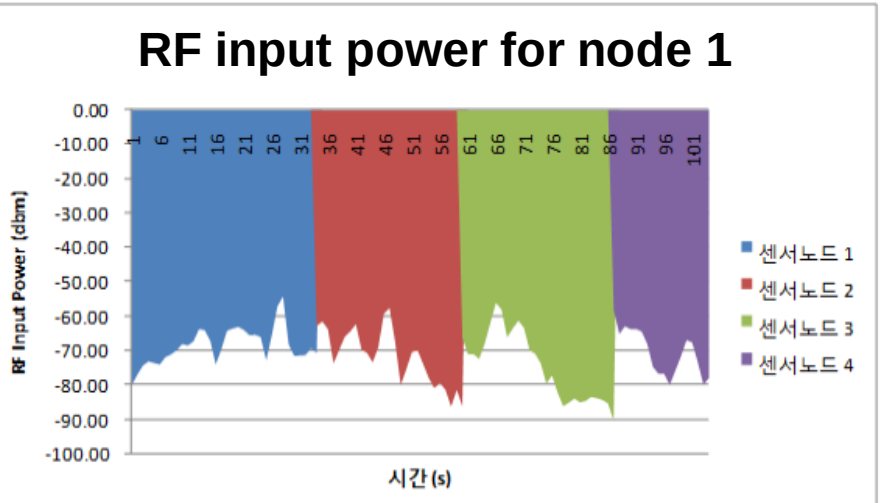
PER for node 1



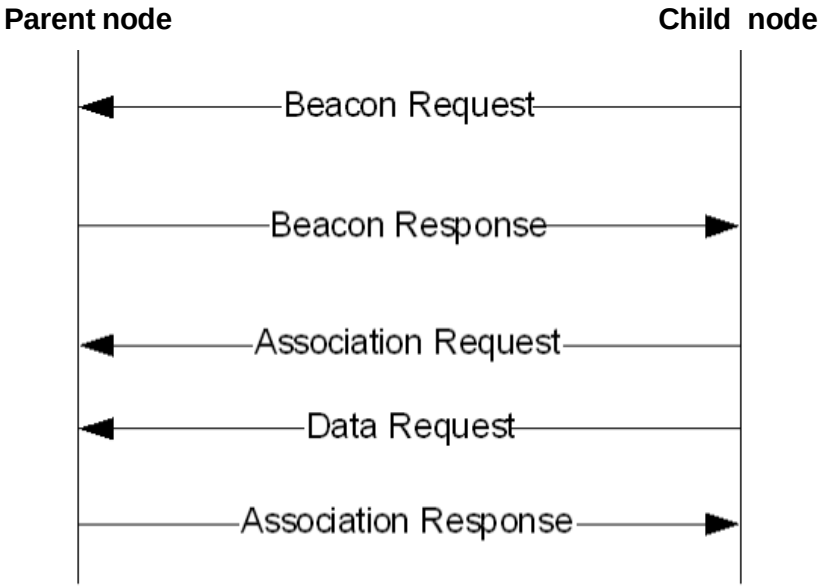
Standard Deviation



RF input power for node 1



Join Sequence problem in ZigBee Protocol



Content

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III. USN Testbed

IV. Demo

Development of USN Test Specification

Goal

A needs for performance verification at each application model is increasing

Development of test list for each application model

Increasing a demand of USN system

Example

Development of Real Environment Test for each Application

Example

ISO 24730, IEEE 802.15.4a, Wi-Fi (RTLS protocols)

- Location Accuracy Test
- Response Time Test

Process

Test List → **Class System** → **Test Standard**

Developing the Real Environment Test List for application test for each application

Classifying the performance for each Test List

Marking suitable class level on each USN application

Development of USN Test Specification

Section	Test Lists	remark
Low Power	Amount of Average Consumed Current	mA
Range of RF	Readable Range of RF	m or dB
Packet Error Rate	Average PER for WSN network	%
	PER for each Sensor Node	%
Packet Delay	Packet Round Trip Delay(delay time/hop count)	ms/hop
Routing	Max Multi-hop Count	hop
	Loop back Recovery Time	s
	Delay Time of Joining Network	s
	Delay Time of Rebuilding Routing Path	s
Retransmission	Max Rate of Retransmission for WSN network	%
Throughput	Data Throughput(QoS)	kbps

Development of USN Test Specification

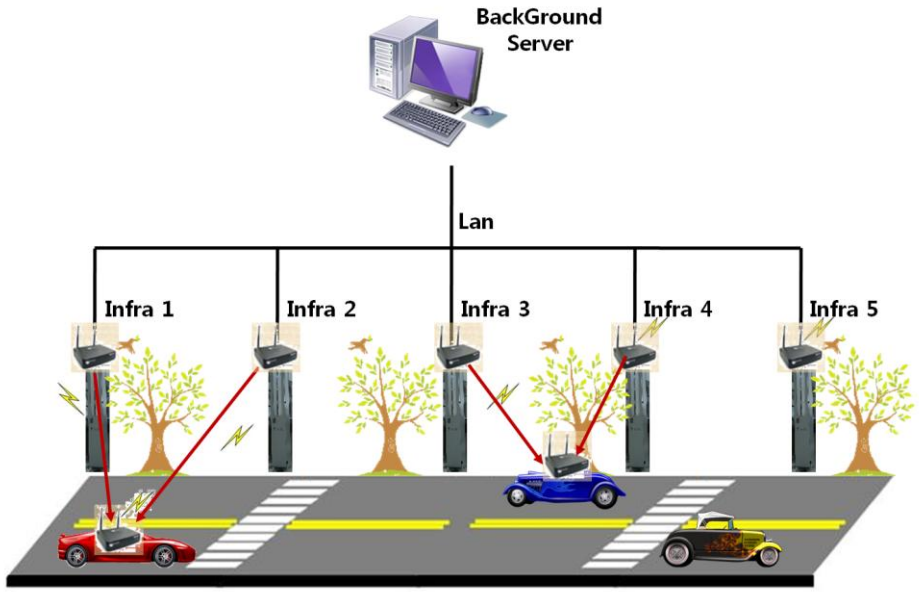
Test List	Level 1	Level 2	Level 3	Level 4	Level 5
Average Current	0.289mA (12 months)	0.385mA (9 months)	0.578mA (6 months)	1.157mA (3 months)	3.478mA (1 months)
Range of RF	100m	80m	60m	40m	20m
PER for Network	90%	85%	80%	75%	70%
PER for each node	99%	95%	90%	85%	80%
Packet Round Trip Delay	1ms/hop	5ms/hop	10ms/hop	20ms/hop	30ms/hop
Max Multihop Count	40hop	30hop	20hop	10hop	3hop
Loop back Recovery Time	1s	10s	20s	30s	40s
Delay Time for Joining Network	1s	5s	20s	60s	600s
Delay Time for Rebuilding Routing Path	1s	5s	20s	60s	600s
Rate of Retransmission	10%	15%	20%	25%	30%
Data Throughput(QoS)	200kbps	150kbps	100kbps	50kbps	1kbps

Development of USN Test Specification

Application Model	Average Current	Range of RF	PER for Network	Data Throughput	Requirement
RTLS	Level 5	Level 2	Level 2	Level 1	
Environment Monitoring	Level 1	Level 1	Level 5	Level 5	
Management of Streetlight	Level 5	Level 3	Level 2	Level 5	

USN Performance Test : proximity RTLS

- **Target**
  - **RTLS based on proximity Algorithm**
- **System Overview**
  - **Location of infra nodes are mapped by user**
  - **Location of target means the location of most closest infra node from target**
  - **Number of Infra nodes : 40e**
- **Test List**
  - **PER**
  - **Round-Trip-Delay**
  - **Retransmission**
  - **Throughput**
  - **Etc**

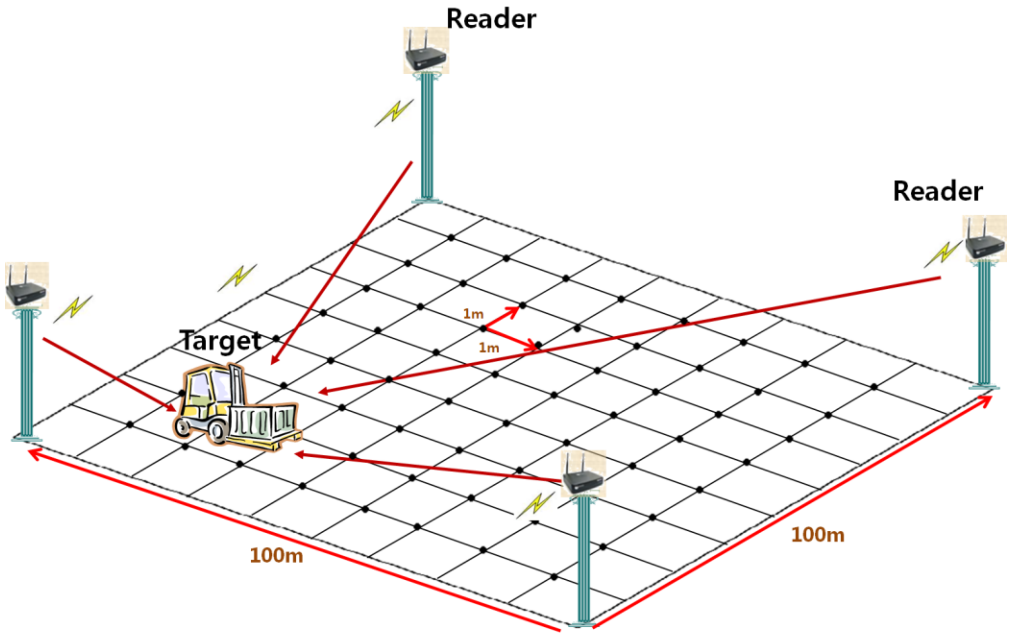


USN Performance Test - proximity RTLS

- **Special Feature**
  - **Debugging Tool**
    - **Dump program memory from sensor nodes while running**
    - **Overwrite data into program memory while running**
    - **All of this action is done by Background Server**
  - **Every infra node is controlled by Background Server while they are running**
  - **What we can do with this special feature?**
    - **Downloading binary image simultaneously**
    - **Changing specific variables while running time**

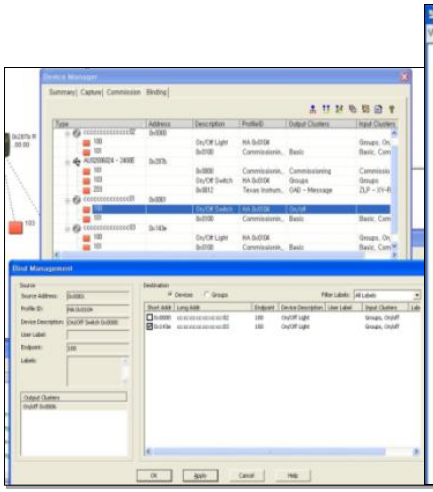
USN Performance Test - zone RTLS

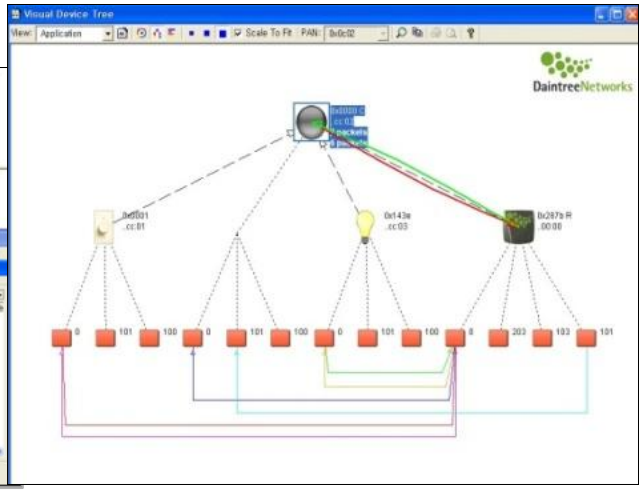
- **Target**
  - RTLS based on zone algorithm, like using triangulated algorithm
  - Ex) ISO 24730, AeroScout products, etc
- **System Overview**
  - Size : 100m x 100m
- **Test List**
  - Location Accuracy
  - Time Delay for Movement



Network Performance Test

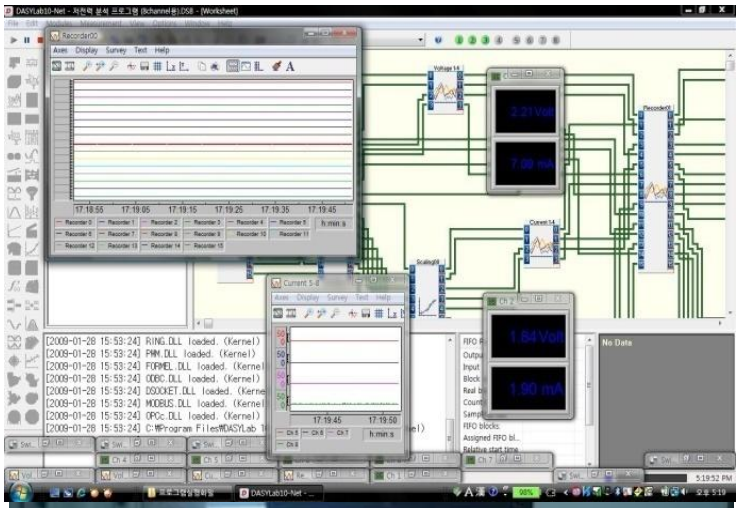
- **Target**
  - **Every protocol which includes non-standard based on IEEE 802.15.4**
- **Test List**
  - **PER : Routing & Source Routing**
  - **OTA(Over-The-Air)**
  - **LQI(Link Quality Indication)**
  - **Round-Trip-Delay**
  - **Retransmission**
  - **Throughput**
  - **Etc**





Low Power Performance Test

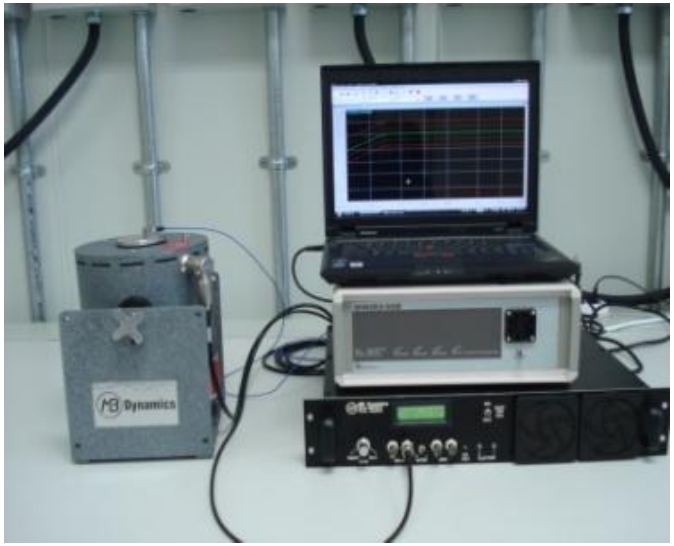
- Target
  - Battery powered USN node
- Test List
  - Lifetime Test
    - Estimation of exact lifetime
  - Analysis Test
    - Analyze performance of low power protocol
- Feature of Tester
  - Precision ADC Converter(RogaDAQ16)
  - Sampling Rate : 40 μs
  - Unlimited time of data logging



Sensor Data Accuracy Test

- **Target**
  - **Sensors for**
    - **Temperature and Humidity**
    - **Acceleration and Vibration**
    - **Hydraulic and Pneumatic**

< Temp & Humi >



< Accel & Vib >

< Hydraulic & Pneumatic >

Content

I. Experiments for test specification

II. USN performance test in NIPA

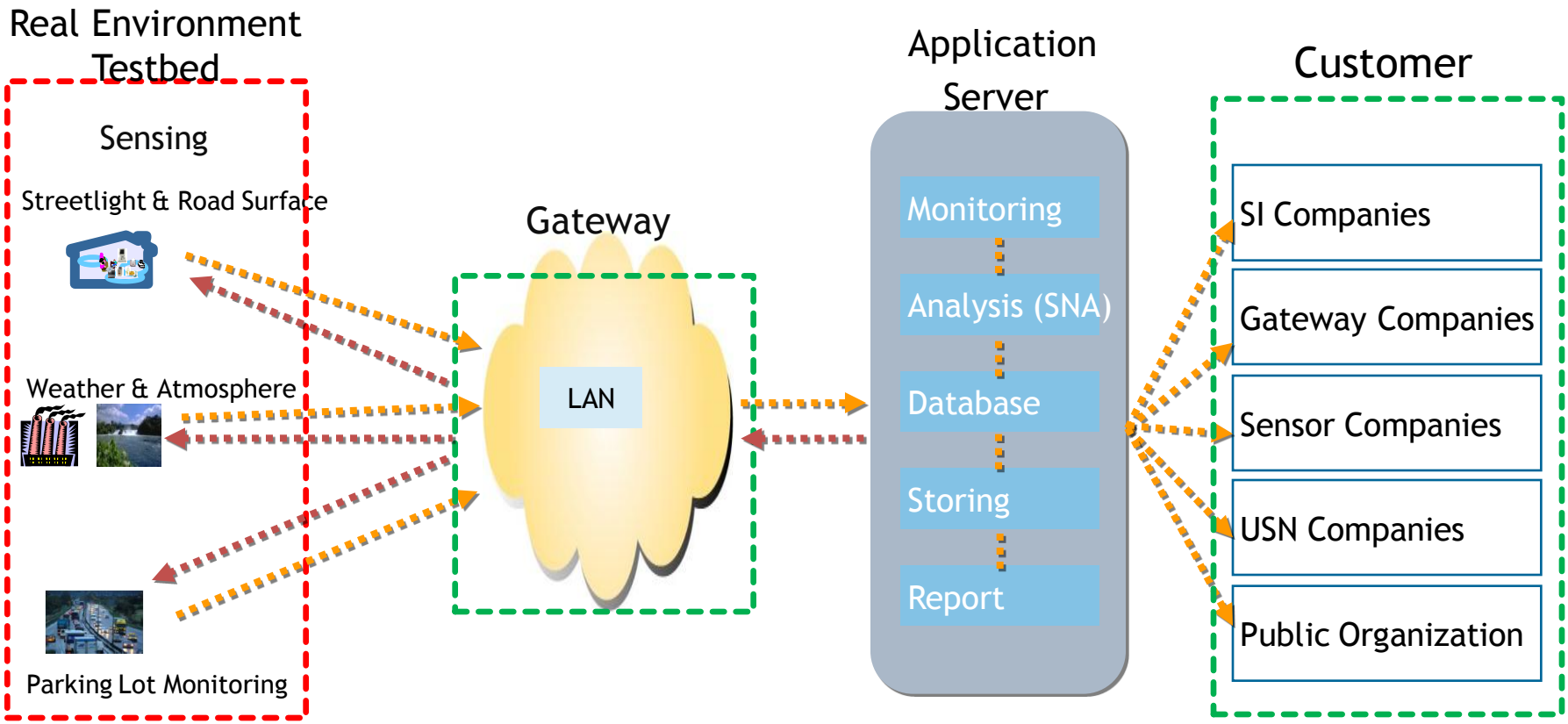
III. USN Testbed

IV. Demo

Introduction

- **Verifying the Performance of WSN at Real Environment**
  - **Reliability test for specific application**
  - **Wide range test of outdoor field**
  - **Higher density of WSN nodes**
- **Comfortable Field Test for Development**
  - **Well constructed LAN & Power infra at outdoor**
  - **Providing automatic control & management system**
- **Application Model**
  - **Parking Lot Management**
  - **Road Surface Monitoring**
  - **Streetlight Management**
  - **Weather & Atmosphere Monitoring**

Overview


Real Environment Testbed
Sensing
Streetlight & Road Surface
Weather & Atmosphere
Parking Lot Monitoring
Gateway
LAN
Application Server
Monitoring
Analysis (SNA)
Database
Storing
Report
Customer
SI Companies
Gateway Companies
Sensor Companies
USN Companies
Public Organization

USN Test beds in RUC Overview

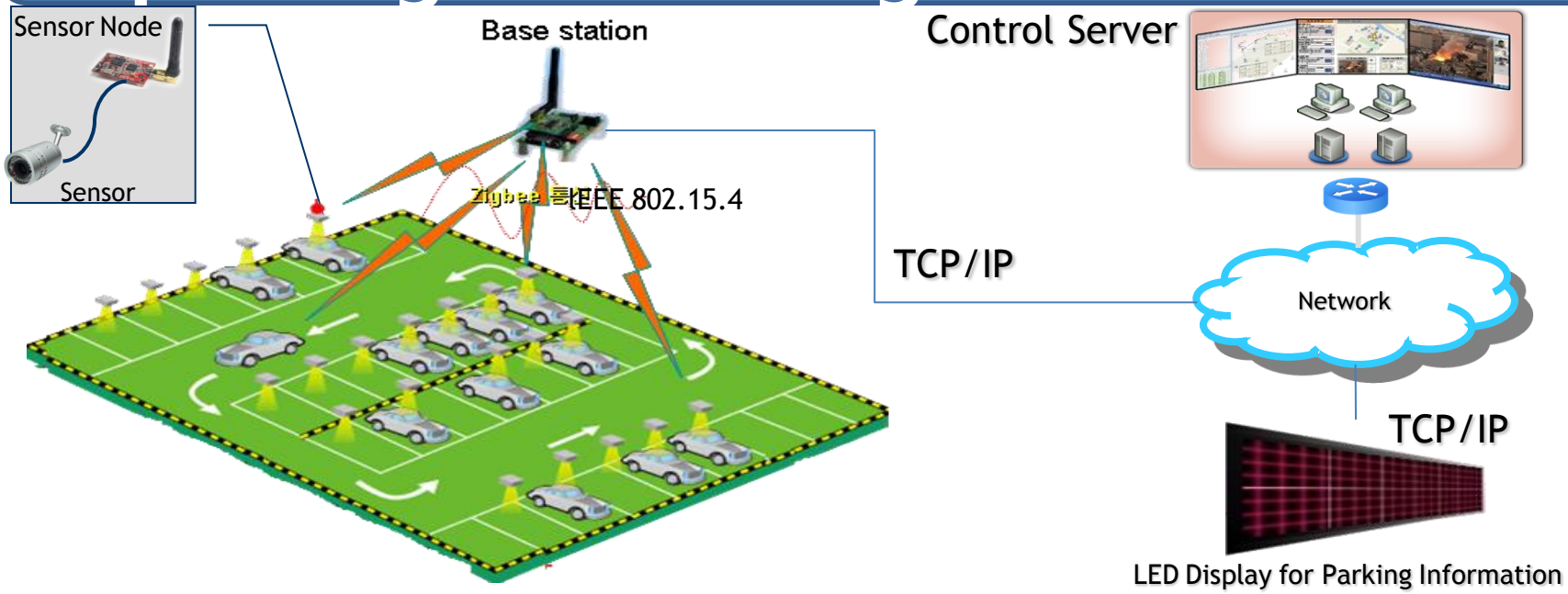
- **Sensor Nodes**
  - IEEE 802.15.4 Compliant RF module
  - 2.4GHz bandwidth
  - Mesh Network
  - Provide Battery, LQI, Parent Address information

- **Gateway**
  - Deliver data packets between monitoring server and sink node
  - Web access with TCP/IP

Functional Tasks of Testbed

Task	Feature	Content
Sensor Monitoring	✓ Graphical Display ✓ User Map upload	▪ Display sensor network topology on user map ▪ Display a status of parking lot, weather, atmosphere, streetlight, etc… ▪ Display the information of each sensors on time domain ▪ Record every information on DB
Sensor Nodes Performance Monitoring	✓ Network Status ✓ System Status	▪ Display LQI, RSSI, Packet Loss Rate ▪ Display the amount of battery charge ▪ Record every information on DB
Sensor Nodes Management	✓ Over-The-Air ✓ Command Query ✓ Management ✓ Deployment	▪ Network reprogramming over the air ▪ Control of sensor node's H/W like LED's On/Off, reboot, modifying RF channel ▪ Control of sensor node's S/W like modifying Node ID, PAN ID, Group ID ▪ Display multihop route path(Mesh Networks) ▪ Display the amount of battery charge ▪ Display sensor node's network information like LQI ▪ Insert or delete sensor node information as it appears or disappear on network
Database	✓ Middleware ✓ DB Backup	▪ Store every sensing data on DB ▪ Provide data on real time for application server ▪ Data backup on schedule(daily)
User Interface	✓ Usage of Testbed ✓ Verification Report	▪ GUI : User Map, Network Topology, LQI, RSSI, Battery, Packet Loss Rate, etc… ▪ Management of USN Testbed's status ▪ Record performance of USN products like performance of RF, Network Protocol, MAC Protocol, sensed data, command query, etc ▪ Report verification result on paper

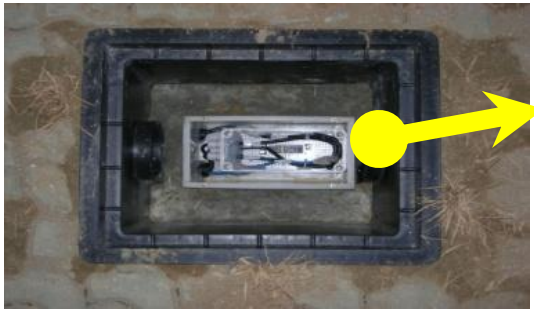
USN Test beds in RUC parking Lot management



- Magnetic sensor which located underground senses existence of car for each parking lot
- Sensor nodes are networked each other with USN technology(IEEE 802.15.4, CTP Routing Algorithm, etc…)
- Base station is gathering all portion of parking lot's information from each sensor nodes
- The information gathered by base node transfer USN Parking Lot Management Server(TCP/IP)
- Companies, developers can install and test their own sensors, base stations and etc.

USN Test beds in RUC
Parking Lot management

- The case of sensor node is shielded to protect from rain, typhoon, shock and etc.
- Magnetic sensors which detect car existence are buried in the ground
- Each of Sensor node cases has power source, LAN connector and RS232 p
- S connected with magnetic sensor by RS23
lc car.



Parking Lot management

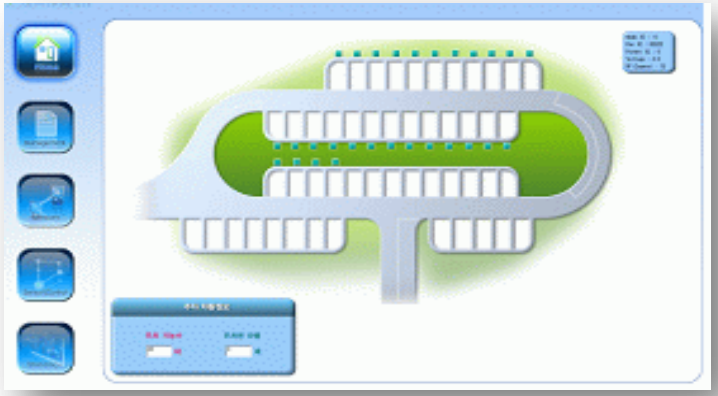
[Test and Analysis Items]

- Application Layer Performance
  - Accuracy of car existence sensing data at time domain
  - Reliability of received data packet(application layer)
  - Reliability of command query(source routing)
  - Tolerance limit against data traffic
- Network Layer Performance
  - Accuracy of received network layer packet(ex: routing packet)
  - Reliability of source routing packet
  - Analysis for multi-hop network topology
  - Monitoring the cost of routing protocols
  - Tolerance limit against data traffic
- Functions of WSN Test bed
  - Status of LQI, battery, parent's address, route path etc
  - Over-The-Air
  - Command query(source routing)
  - Ping message
  - Reboot message
  - Changing RF channel

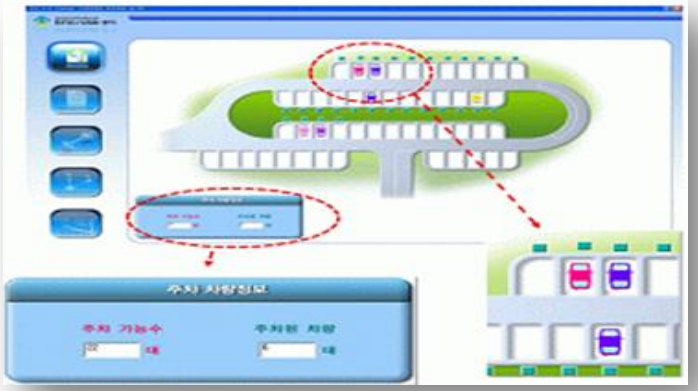
Parking Lot management

[Monitoring SW]

- Application menu shows existence of car information

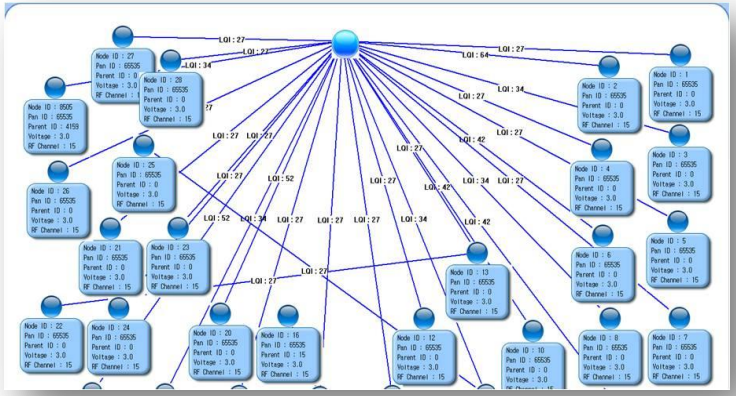


No car detected



Detecting 3 cars

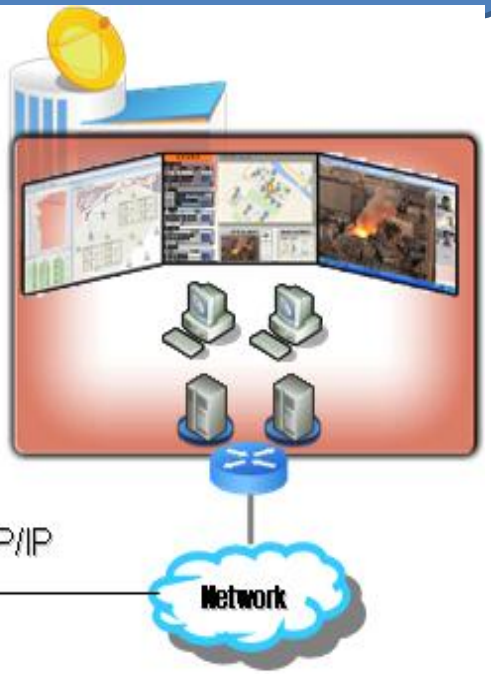
- Network menu shows route path information

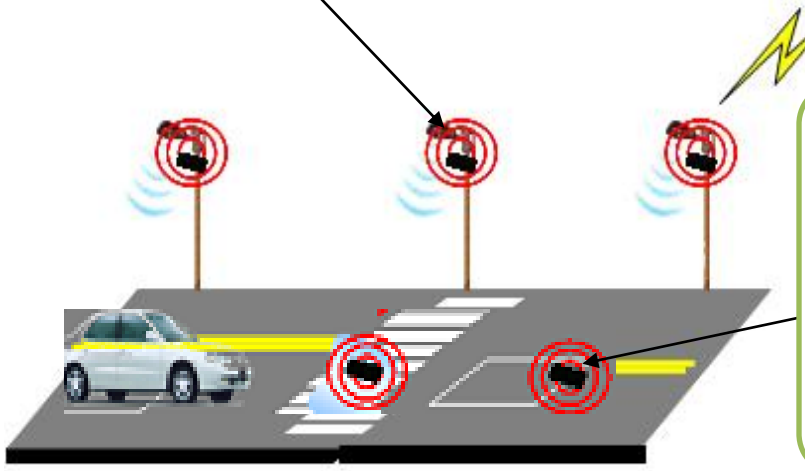


Road Surface and Streetlight Management

Streetlight Management System

- ❖ Streetlight Monitoring
  - Sensor senses the state of Streetlight(ON/OFF)
  - Sensor nodes transfer the information to gateway
  - Gateway delivers gathered information to Server
- ❖ Streetlight Management
  - Management Server turns On/Off every Streetlight





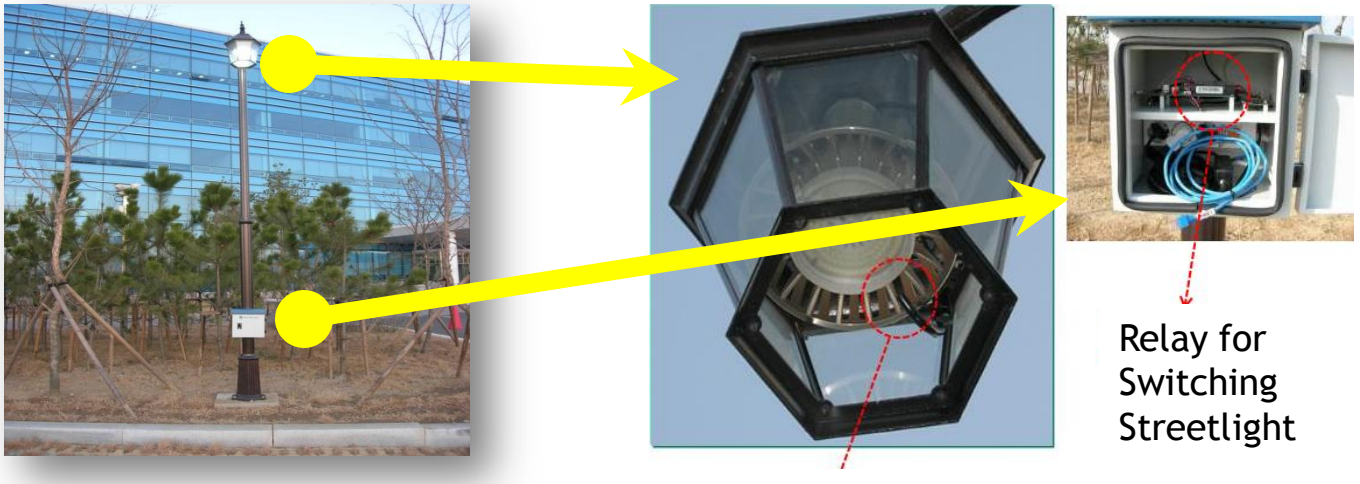
Road Surface Monitoring System

- ❖ Sensing Status of Road Surface
- Sensor senses the state of road surface
- Sensor nodes transfer the information to gateway
- Gateway delivers gathered information to Server

Road Surface and Streetlight Management

- Scenario of Streetlight Management System

  - Light sensor under a streetlight senses brightness
  - The brightness implies streetlight's status
  - Sensor node transfer sensing data to management server
  - Management server checks brightness value for management
  - Management server turns on the streetlight whose brightness value implies turning off
  - Relays settled in the streetlight makes possible switching streetlight turns on/off

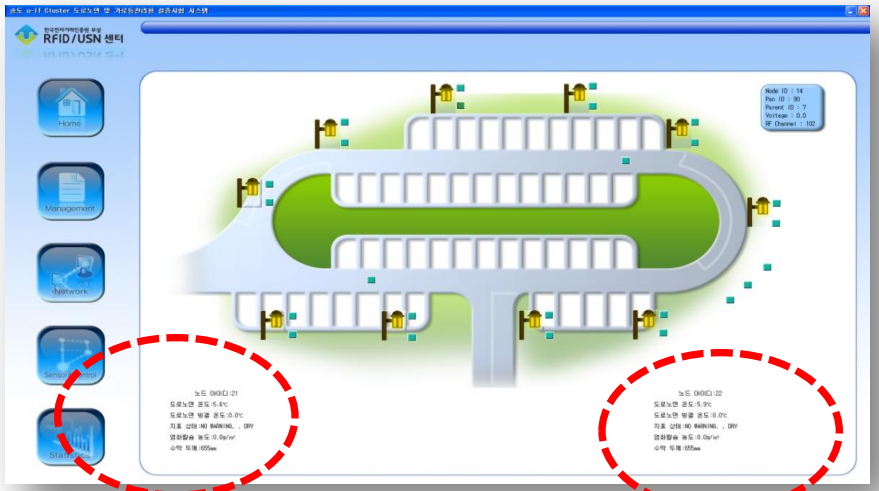


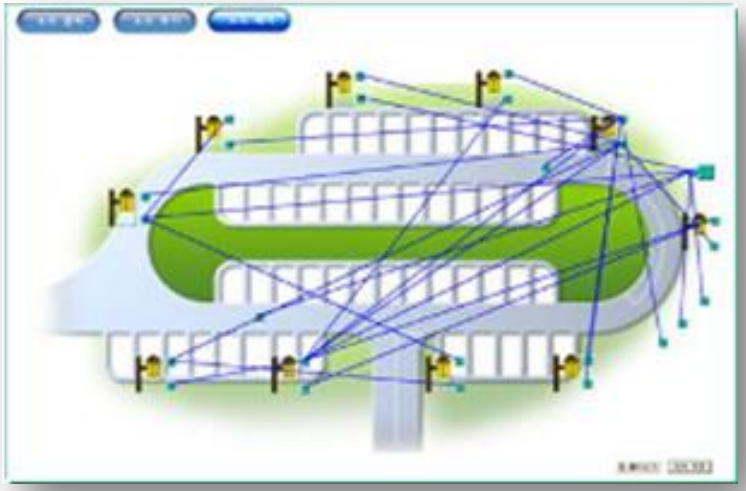
Road Surface and Streetlight Management

- Application Layer Performance
  - Accuracy of road surface sensing data at time domain
  - Accuracy of streetlight sensing data at time domain
  - Reliability of received data packet(application layer)
  - Reliability of command query(source routing)
  - Reliability of switching streetlight On/Off
  - Tolerance limit against Data Traffic
- Network Layer Performance
  - Accuracy of received network layer packet(ex: routing packet)
  - Reliability of source routing packet
  - Analysis for multihop network topology
  - Monitoring the cost of routing protocols
  - Tolerance limit against data traffic
- Functions
  - Status of LQI, battery, parent's address, route path etc
  - Over-The-Air
  - Command query(source routing)
  - Ping message
  - Reboot message
  - Changing RF channel

Road Surface and Streetlight Management

- Monitoring S/W



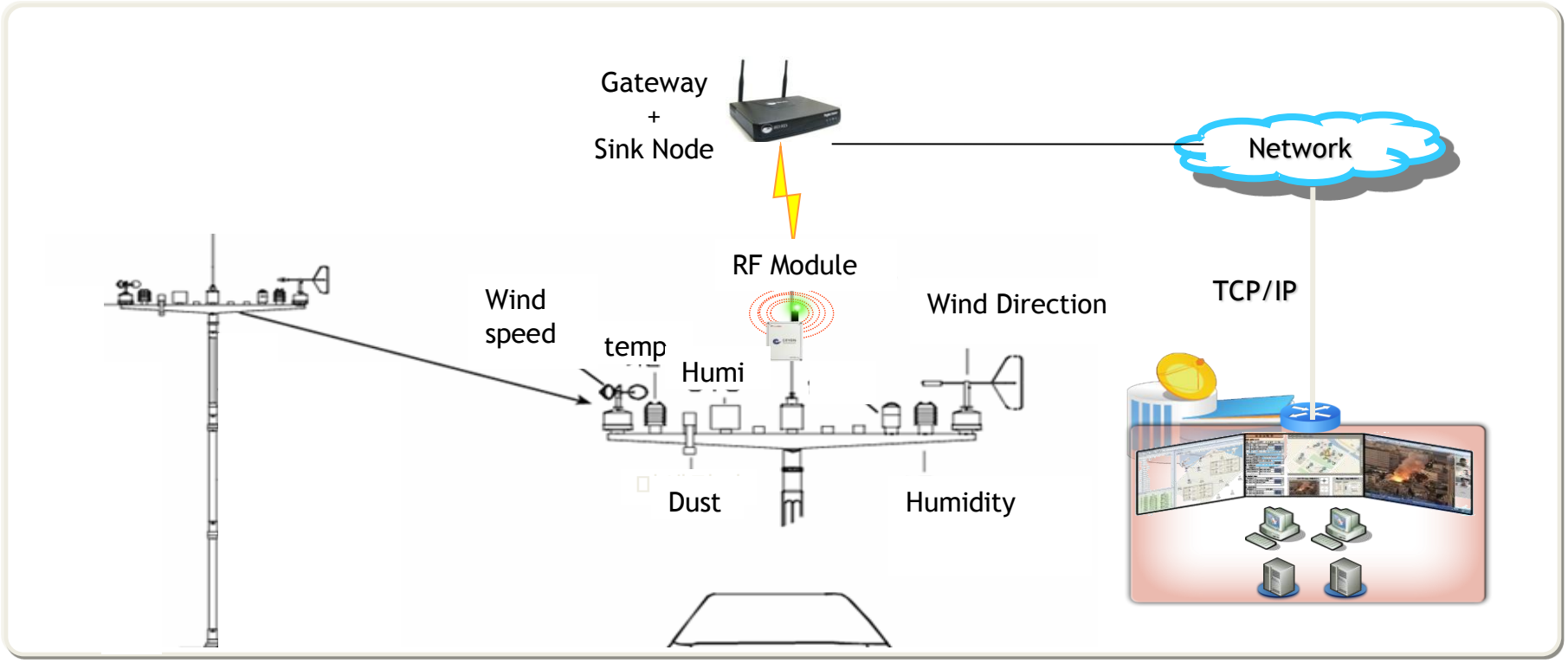


Node ID : 21
Road Temp : 5.6℃
Road Icing Temp : 0.0℃
Surface : No warning, Dry
Calcium Chloride : 0.0g/m

Node ID : 22
Road Temp : 5.9℃
Road Icing Temp : 0.0℃
Surface : No warning, Dry
Calcium Chloride : 0.0g/m

- Application menu shows road surface's wear and streetlight's On/Off status
- Management menu shows topology of Mesh Networks in Test bed

Weather & Atmosphere Monitoring System



- Weather & atmosphere monitoring system acquire temperature, dust, humidity, wind speed and wind direction information from the sensor nodes
- Developer can test their products by exchanging elements of test bed

Weather & Atmosphere Monitoring System

- Actual photos of Weather & Atmosphere monitoring System

Temperature & Humidity sensor

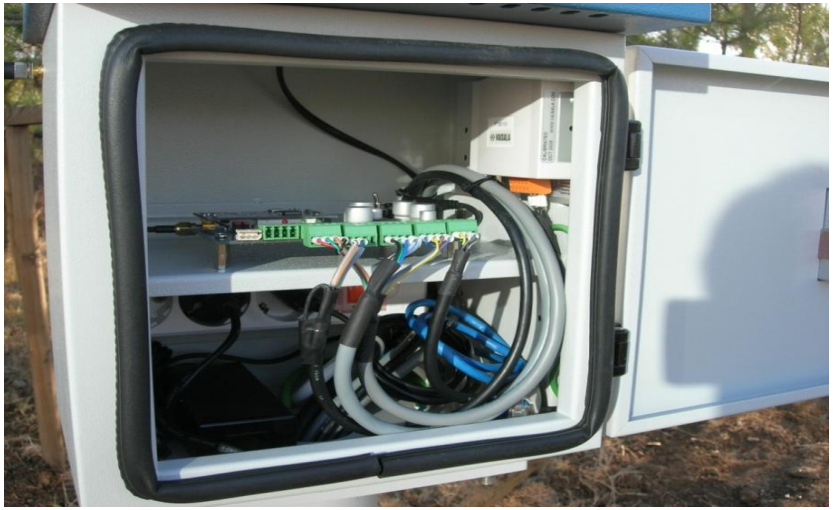
Rainfall sensor

Wind Speed/Direction Sensor

Rainfall sensor

Pole for sensors

Case of Sensor Nodes



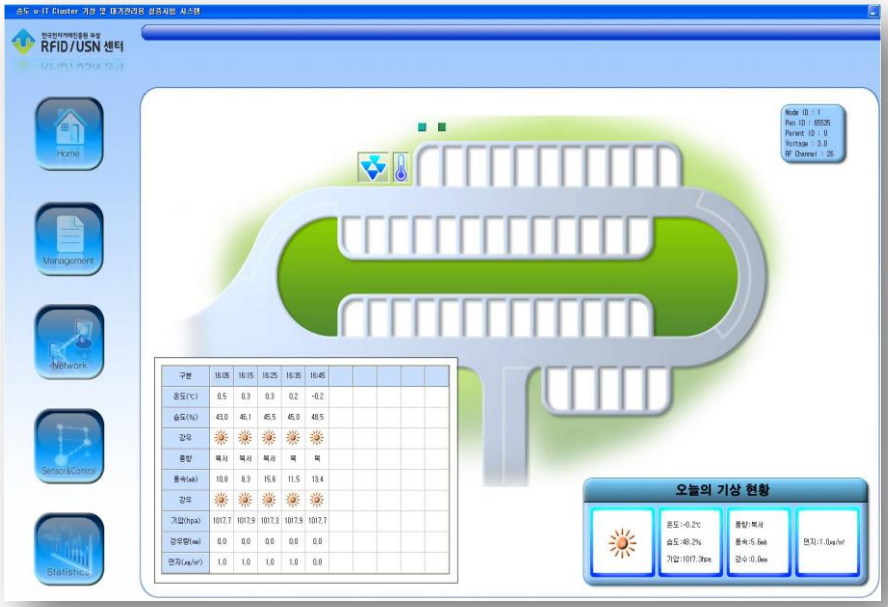
Case of Sensor Nodes

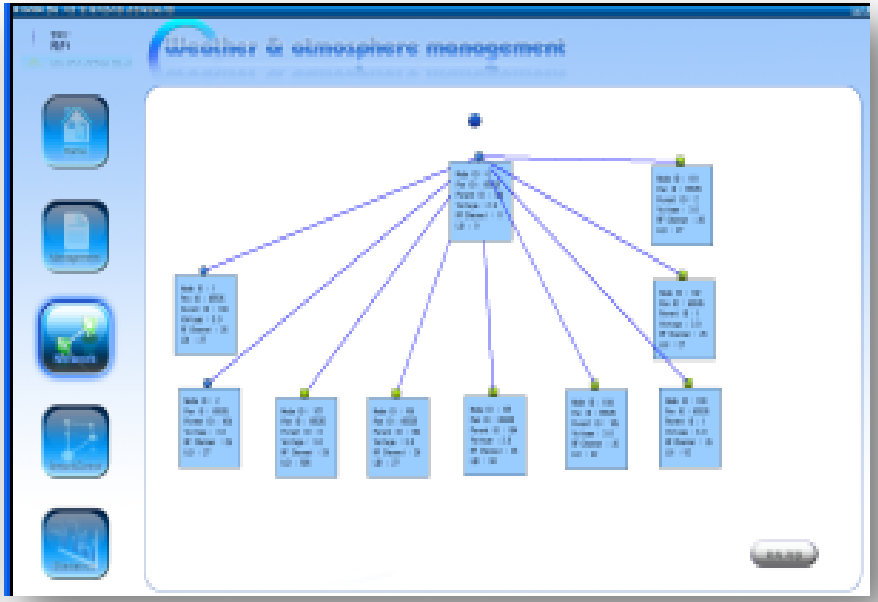
Weather & Atmosphere Monitoring System

- Application Layer Performance
  - Accuracy of weather & atmosphere sensing data at time domain
  - Reliability of received data packet(application layer)
  - Reliability of command query(source routing)
  - Tolerance limit against Data Traffic
- Network Layer Performance
  - Accuracy of received network layer packet(ex: routing packet)
  - Reliability of source routing packet
  - Analysis for multihop network topology
  - Monitoring the cost of routing protocols
  - Tolerance limit against data traffic
- Functions
  - Status of LQI, battery, parent's address, route path etc
  - Over-The-Air
  - Command query(source routing)
  - Ping message
  - Reboot message
  - Changing RF channel

Weather & Atmosphere Monitoring System

- Monitoring S/W





- Application menu shows temperature, dust, humidity, rainfall, wind speed and wind direction status
- Network menu shows topology of route path information

Content

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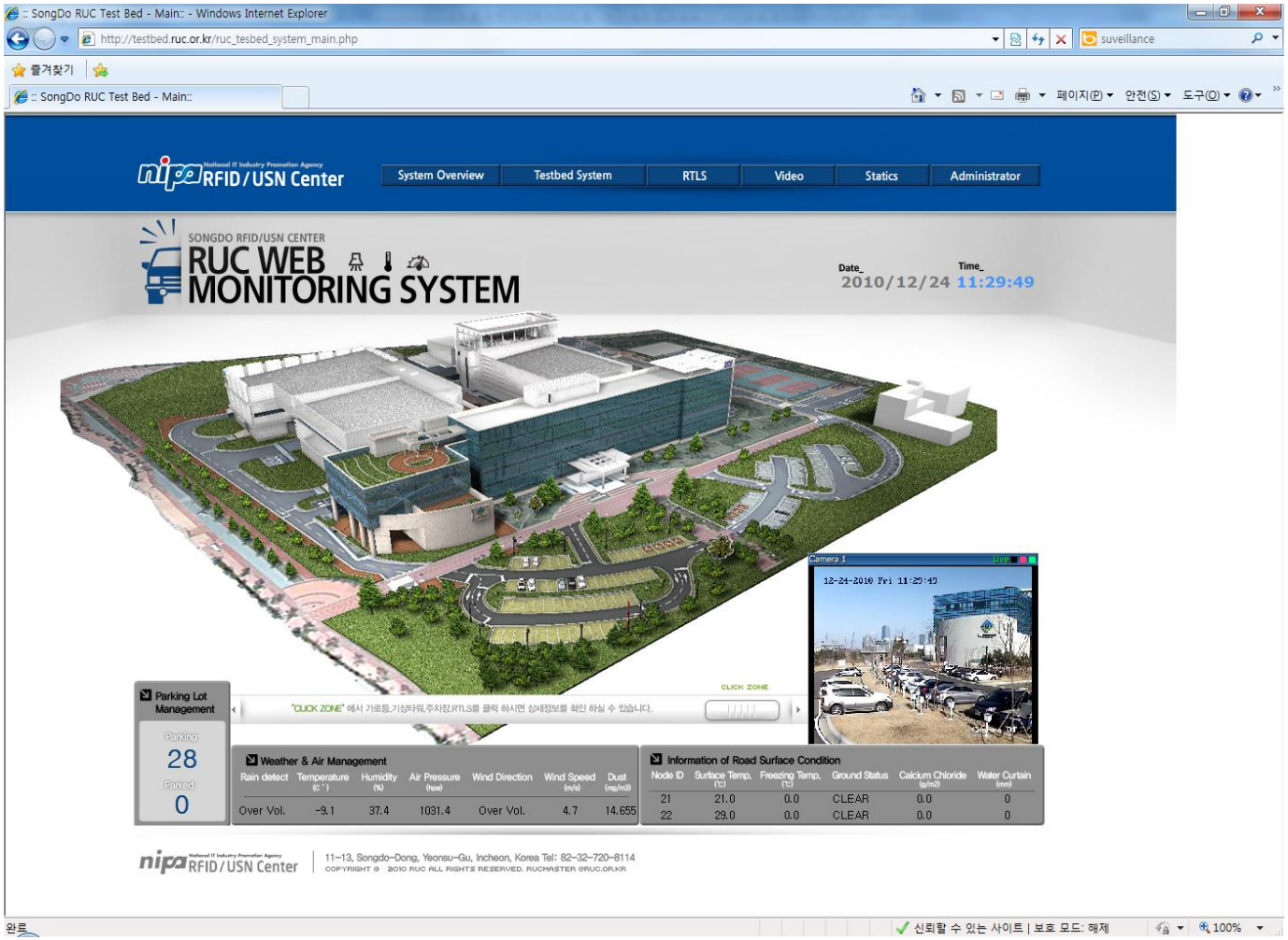
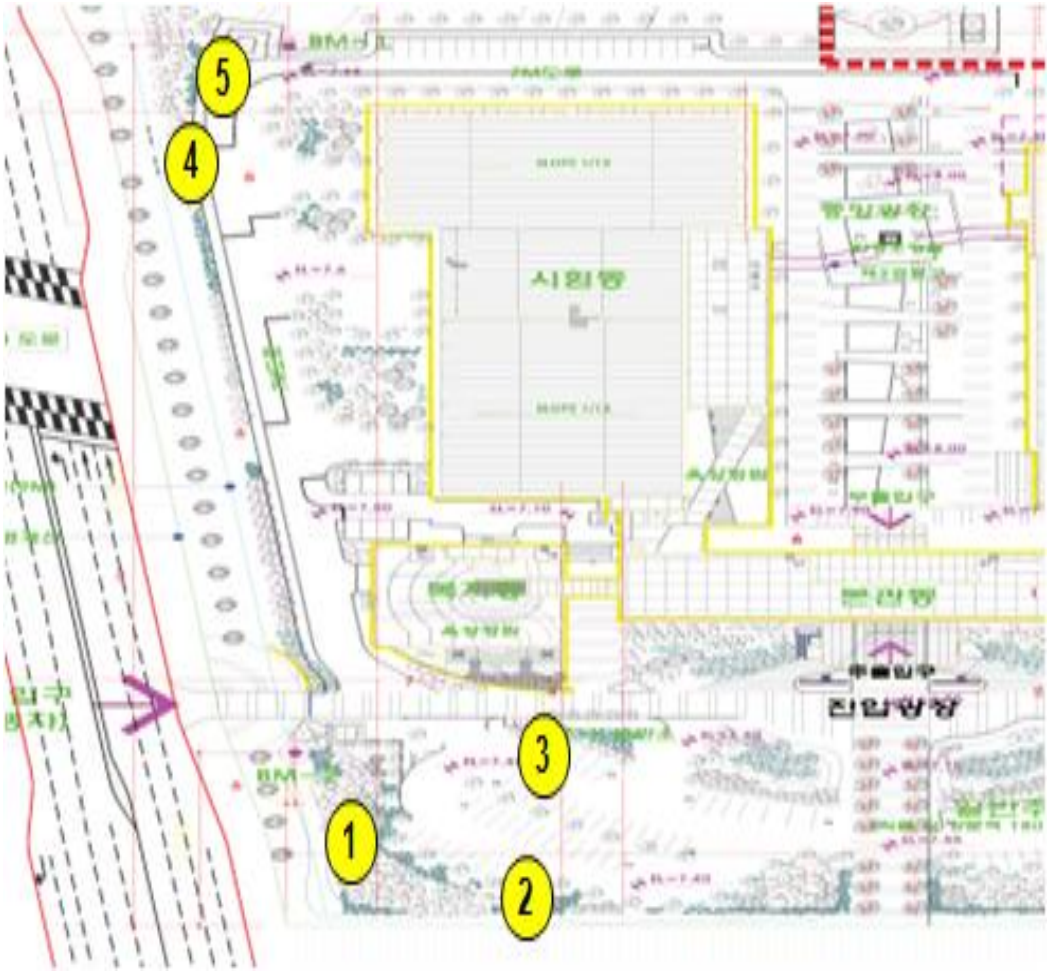
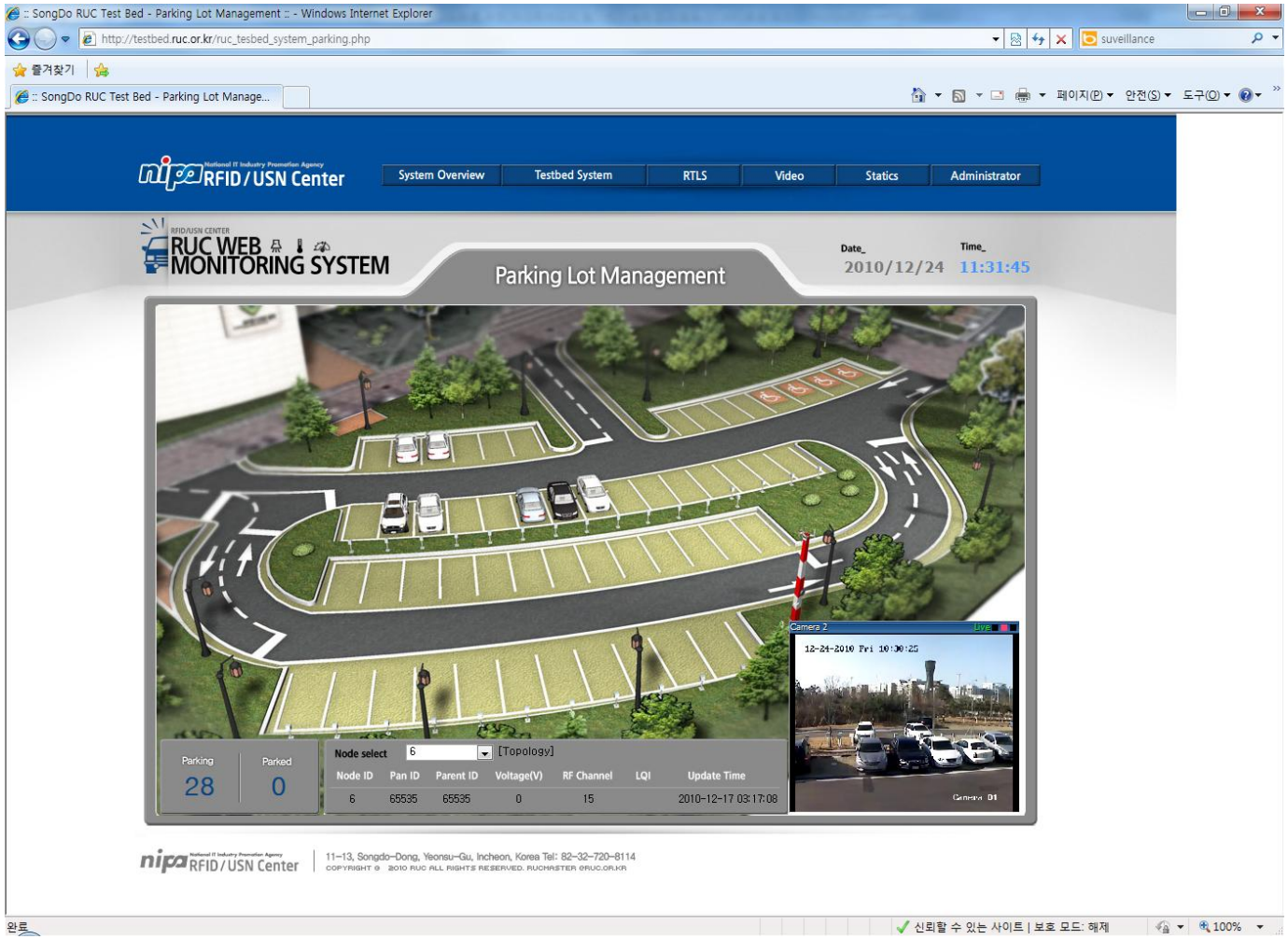
USN Testbed


:: SongDo RUC Test Bed - Main:: - Windows Internet Explorer
http://testbed.ruc.or.kr/ruc_tesbed_system_main.php
:: SongDo RUC Test Bed - Main::
RFID / USN Center
System Overview
Testbed System
RTLS
Video
Statics
Administrator
SONGDO RFID/USN CENTER
RUC WEB MONITORING SYSTEM
Date_ 2010/12/24
Time_ 11:29:49
Camera 1
12-24-2010 Fri 11:29:49
Parking Lot Management
Parking
28
Parked
0
"CLICK ZONE" 에서 가로등,가상타워,주차장,RTLS를 클릭 하시면 상세정보를 확인 하실 수 있습니다.
Weather & Air Management
Rain detect | Temperature (C°) | Humidity (%) | Air Pressure (hpa) | Wind Direction | Wind Speed (m/s) | Dust (mg/m3)
Over Vol. | -9.1 | 37.4 | 1031.4 | Over Vol. | 4.7 | 14.655
Information of Road Surface Condition
Node ID | Surface Temp. (°C) | Freezing Temp. (°C) | Ground Status | Calcium Chloride (g/m2) | Water Curtain (ml)
21 | 21.0 | 0.0 | CLEAR | 0.0 | 0
22 | 29.0 | 0.0 | CLEAR | 0.0 | 0
RFID / USN Center
11-13, Songdo-Dong, Yeonsu-Gu, Incheon, Korea Tel: 82-32-720-8114
COPYRIGHT © 2010 RUC ALL RIGHTS RESERVED. RUCMASTER @RUC.OR.KR
완료
신뢰할 수 있는 사이트 | 보호 모드: 해제
100%

USN Testbed



USN Testbed


:: SongDo RUC Test Bed - Parking Lot Management :: - Windows Internet Explorer
http://testbed.ruc.or.kr/ruc_tesbed_system_parking.php
:: SongDo RUC Test Bed - Parking Lot Manage...
RFID / USN Center
System Overview
Testbed System
RTLS
Video
Statics
Administrator
RUC WEB MONITORING SYSTEM
Parking Lot Management
Date_ 2010/12/24
Time_ 11:31:45
Parking 28
Parked 0
Node select 6 [Topology]
Node ID | Pan ID | Parent ID | Voltage(V) | RF Channel | LQI | Update Time
6 | 65535 | 65535 | 0 | 15 | 2010-12-17 03:17:08
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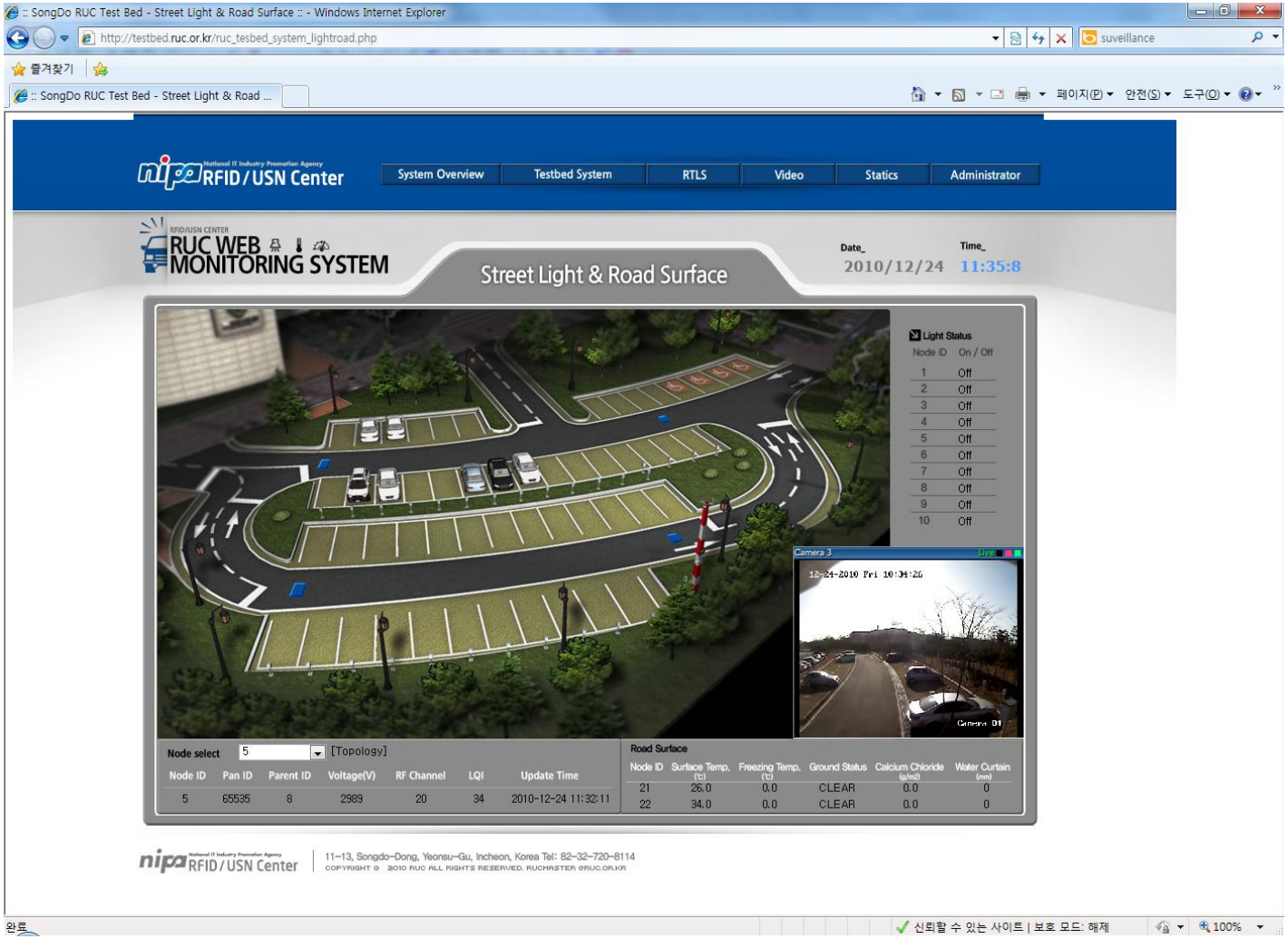
100%

USN Testbed


:: SongDo RUC Test Bed - Street Light & Road Surface :: - Windows Internet Explorer
http://testbed.ruc.or.kr/ruc_tesbed_system_lightroad.php
:: SongDo RUC Test Bed - Street Light & Road ...
RFID / USN Center
System Overview
Testbed System
RTLS
Video
Statics
Administrator
RUC WEB MONITORING SYSTEM
Street Light & Road Surface
Date_ 2010/12/24
Time_ 11:35:8
Light Status
Node ID On / Off
1 Off
2 Off
3 Off
4 Off
5 Off
6 Off
7 Off
8 Off
9 Off
10 Off
Camera 3
Node select 5 [Topology]
Node ID Pan ID Parent ID Voltage(V) RF Channel LQI Update Time
5 65535 8 2989 20 34 2010-12-24 11:32:11
Road Surface
Node ID Surface Temp. (℃) Freezing Temp. (℃) Ground Status Calcium Chloride (g/m2) Water Curtain (mm)
21 26.0 0.0 CLEAR 0.0 0
22 34.0 0.0 CLEAR 0.0 0
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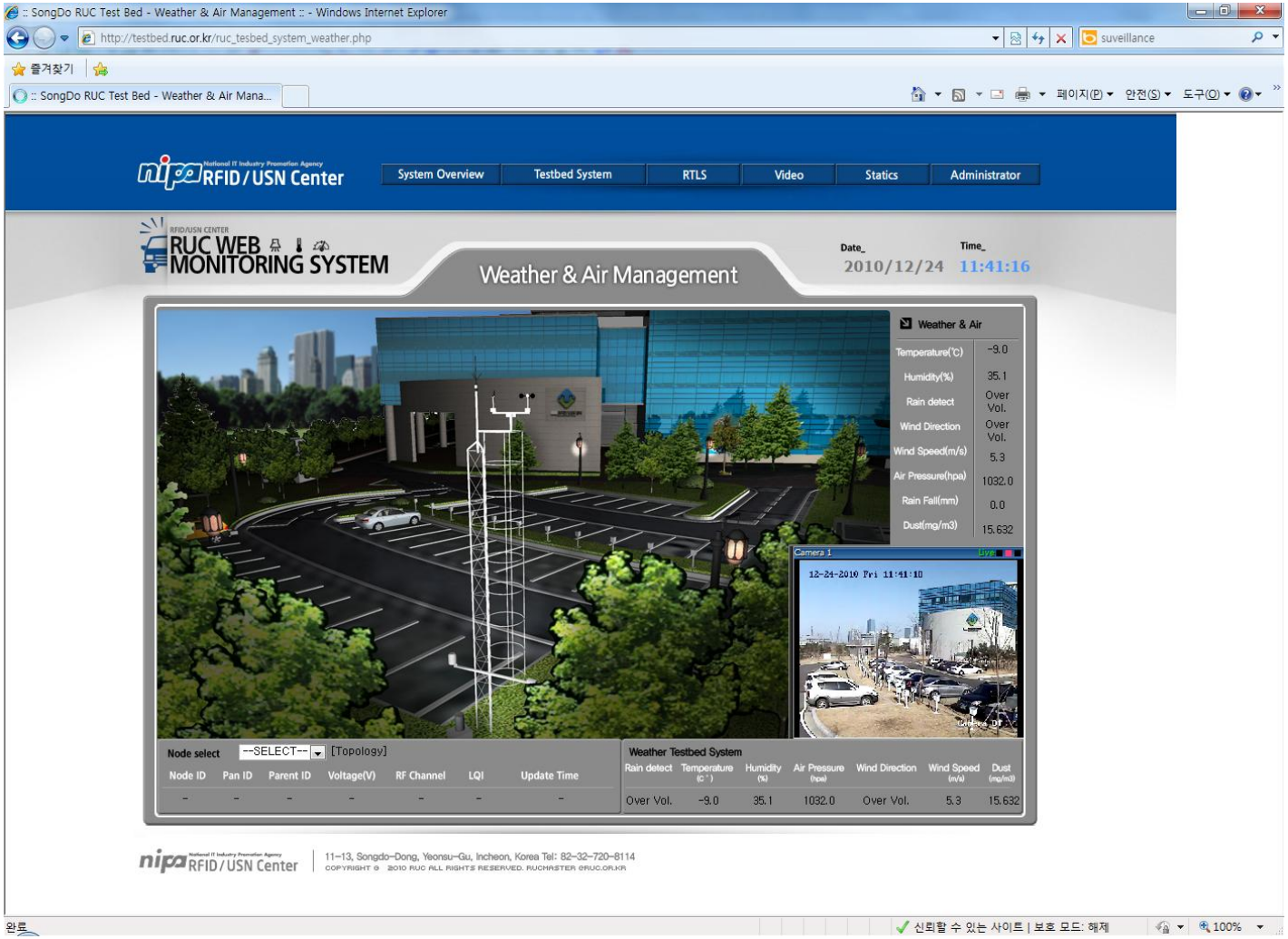
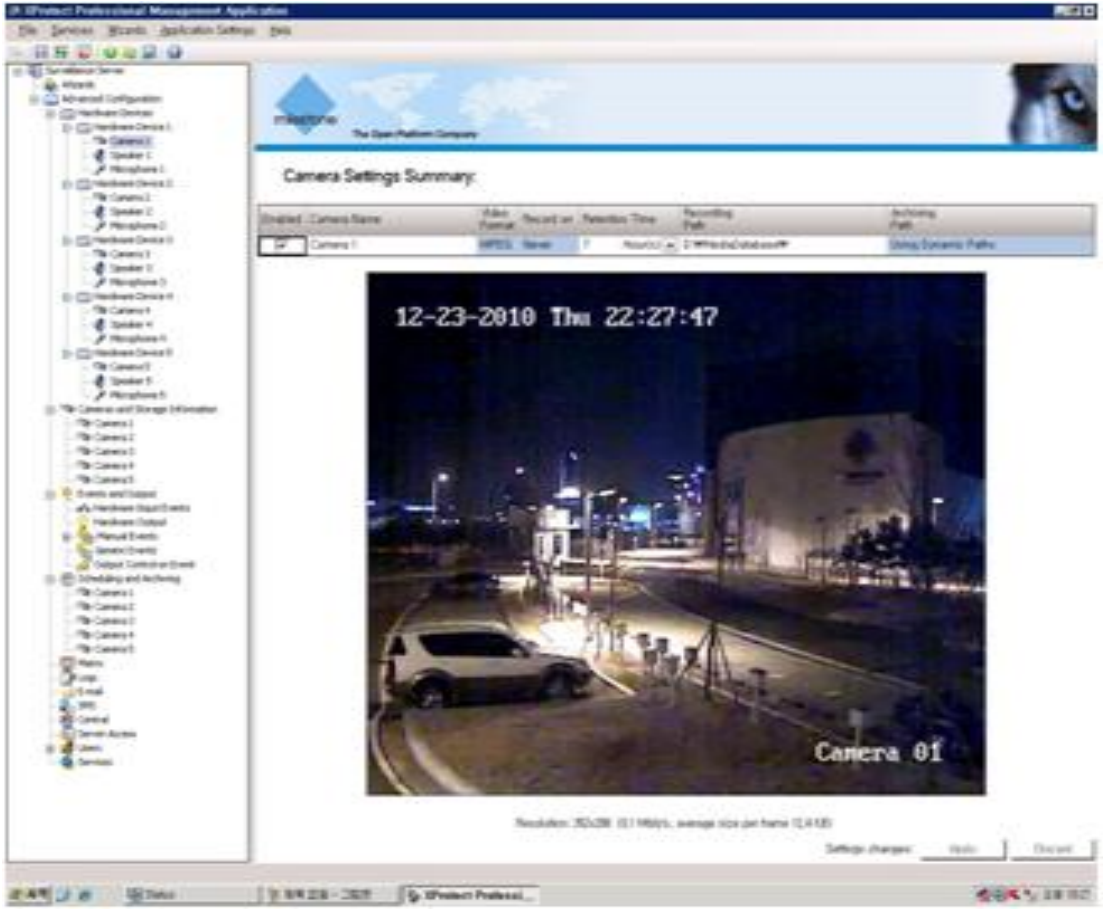
100%

USN Testbed


:: SongDo RUC Test Bed - Weather & Air Management :: - Windows Internet Explorer
http://testbed.ruc.or.kr/ruc_tesbed_system_weather.php
RFID / USN Center
System Overview
Testbed System
RTLS
Video
Statics
Administrator
RUC WEB MONITORING SYSTEM
Weather & Air Management
Date_ 2010/12/24
Time_ 11:41:16
Weather & Air
Temperature(℃) -9.0
Humidity(%) 35.1
Rain detect Over Vol.
Wind Direction Over Vol.
Wind Speed(m/s) 5.3
Air Pressure(hpa) 1032.0
Rain Fall(mm) 0.0
Dust(mg/m3) 15.632
Camera 1
12-24-2010 Fri 11:41:10
Node select --SELECT-- [Topology]
Node ID Pan ID Parent ID Voltage(V) RF Channel LQI Update Time
Weather Testbed System
Rain detect Temperature Humidity Air Pressure Wind Direction Wind Speed Dust
Over Vol. -9.0 35.1 1032.0 Over Vol. 5.3 15.632
11-13, Songdo-Dong, Yeonsu-Gu, Incheon, Korea Tel: 82-32-720-8114

USN Testbed

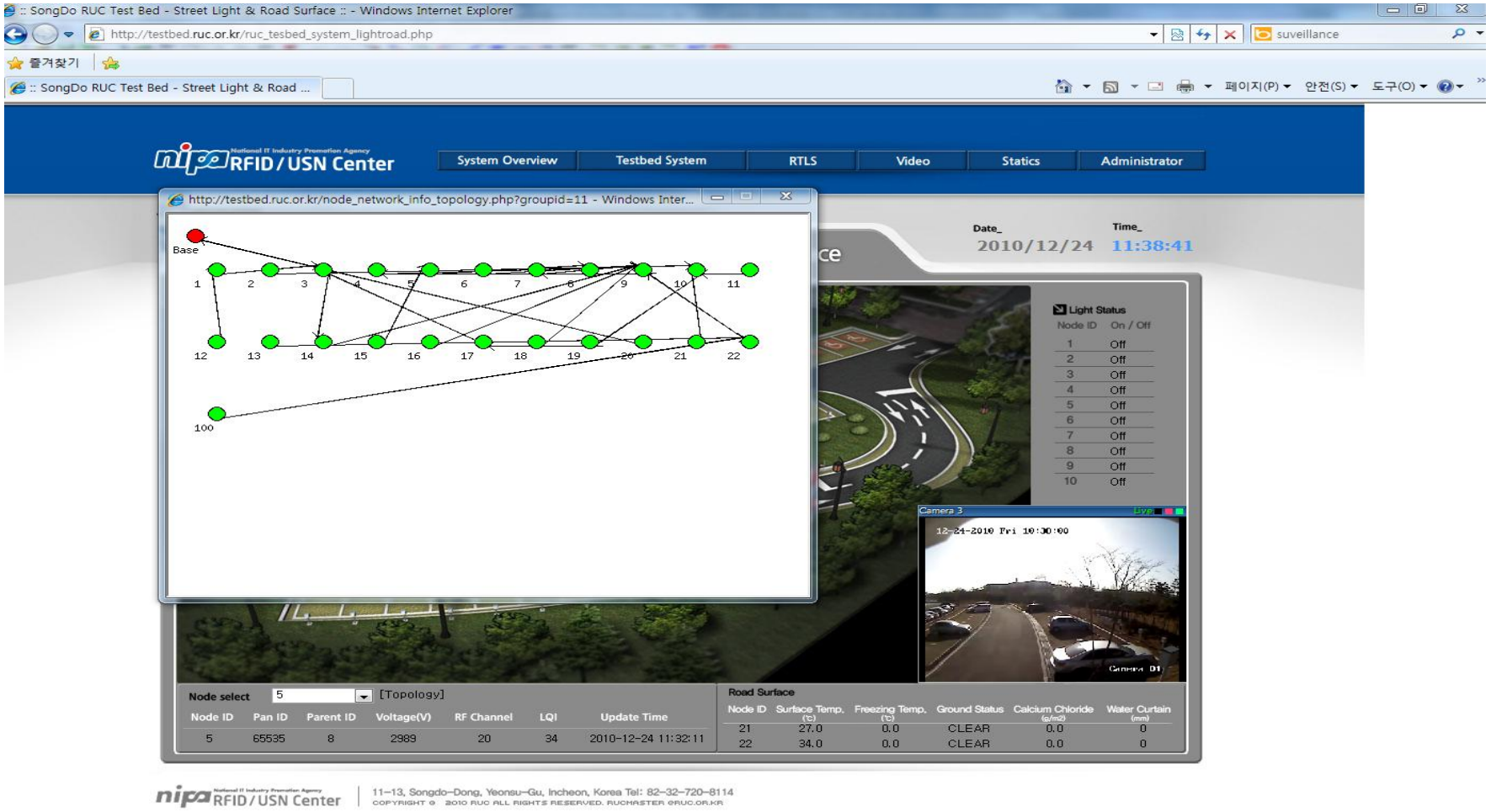

Camera Settings Summary
12-23-2010 Thu 22:27:47
Camera 01


Status
Server
Camera 1
Camera 2
Camera 3
Camera 4
Camera 5
Close

USN Testbed


12-22-2010 Wed 14:24:31
Camera 01
12-22-2010 Wed 14:23:58
Camera 01

USN Testbed


:: SongDo RUC Test Bed - Street Light & Road Surface :: - Windows Internet Explorer
http://testbed.ruc.or.kr/ruc_tesbed_system_lightroad.php
:: SongDo RUC Test Bed - Street Light & Road ...
RFID / USN Center
System Overview
Testbed System
RTLS
Video
Statics
Administrator
http://testbed.ruc.or.kr/node_network_info_topology.php?groupid=11 - Windows Inter...
Base
1 2 3 4 5 6 7 8 9 10 11
12 13 14 15 16 17 18 19 20 21 22
100
Date_ 2010/12/24
Time_ 11:38:41
Light Status
Node ID On / Off
1 Off
2 Off
3 Off
4 Off
5 Off
6 Off
7 Off
8 Off
9 Off
10 Off
Camera 3
12-24-2010 Fri 10:30:00
Node select 5 [Topology]
Node ID Pan ID Parent ID Voltage(V) RF Channel LQI Update Time
5 65535 8 2989 20 34 2010-12-24 11:32:11
Road Surface
Node ID Surface Temp. (℃) Freezing Temp. (℃) Ground Status Calcium Chloride (g/m2) Water Curtain (mm)
21 27.0 0.0 CLEAR 0.0 0
22 34.0 0.0 CLEAR 0.0 0
RFID / USN Center
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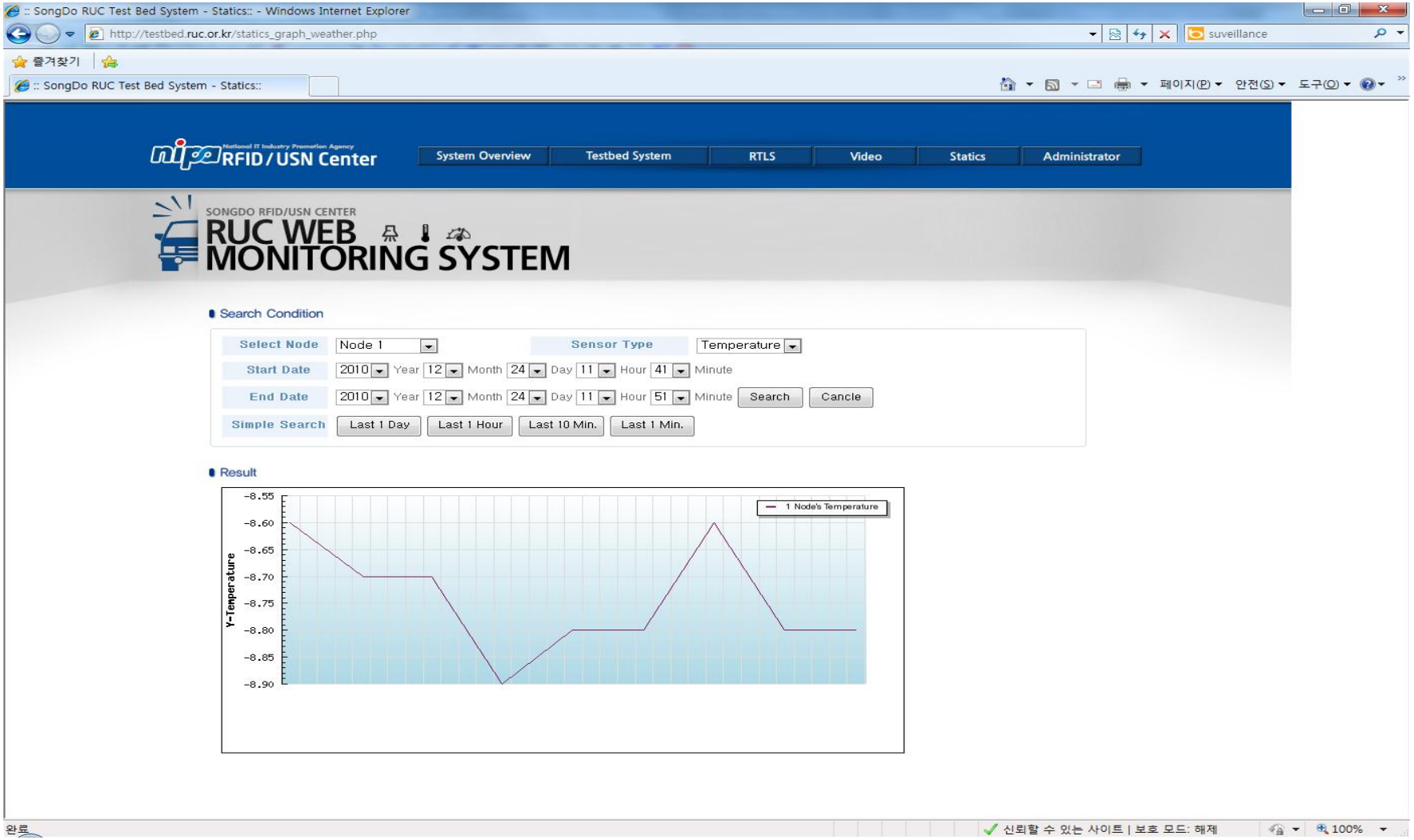
USN Testbed


:: SongDo RUC Test Bed System - Statics:: - Windows Internet Explorer
http://testbed.ruc.or.kr/statics_graph_weather.php
suveillance
:: SongDo RUC Test Bed System - Statics::
RFID / USN Center
System Overview
Testbed System
RTLS
Video
Statics
Administrator
SONGDO RFID/USN CENTER
RUC WEB MONITORING SYSTEM
Search Condition
Select Node
Node 1
Sensor Type
Temperature
Start Date
2010 Year 12 Month 24 Day 11 Hour 41 Minute
End Date
2010 Year 12 Month 24 Day 11 Hour 51 Minute
Search
Cancle
Simple Search
Last 1 Day
Last 1 Hour
Last 10 Min.
Last 1 Min.
Result
1 Node's Temperature
Y-Temperature
-8.55
-8.60
-8.65
-8.70
-8.75
-8.80
-8.85
-8.90

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