USN 서비스 기술

2005. 11. 25

박 우출

wcpark@keti.re.kr

Korea Electronics Technology Institute (KETI)

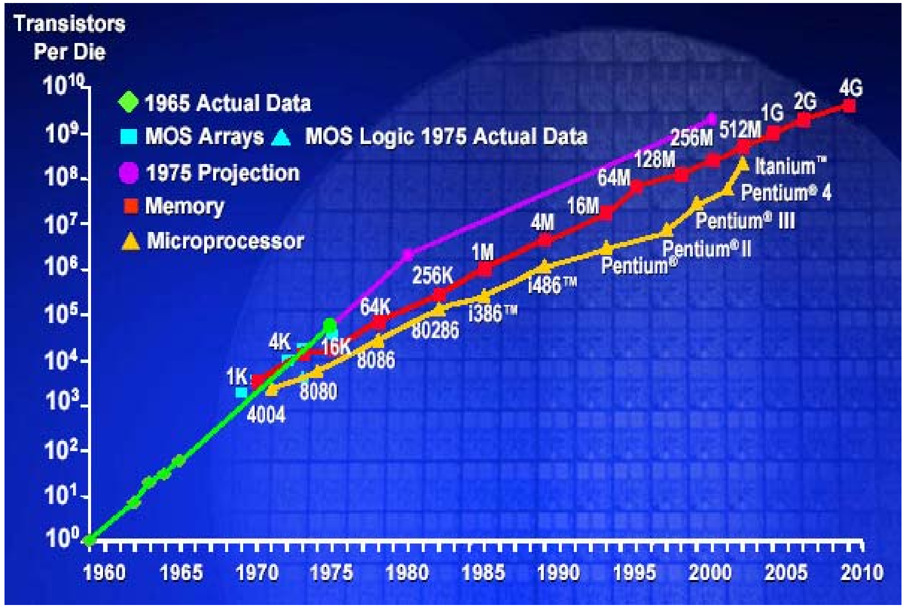
전자부품연구원

목 차

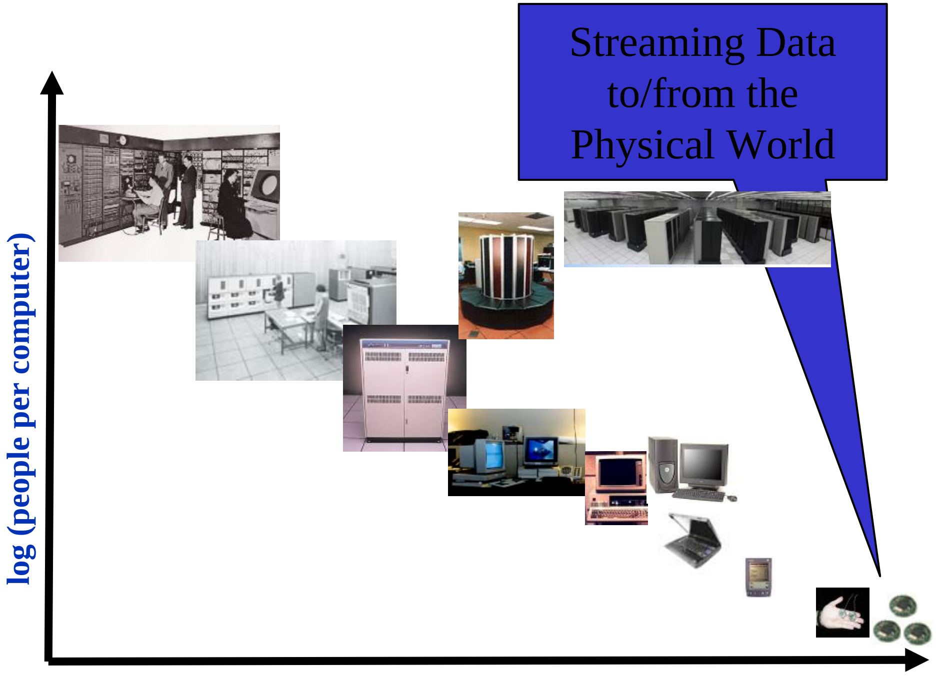
1. Ubiquitous Sensor Network Applications

Trends – Faster, Smaller, Numerous

- Moore's Law
  - "Stuff" (transistors, etc) doubling every 1-2 years



- Bell's Law
  - New computing class every 10 years

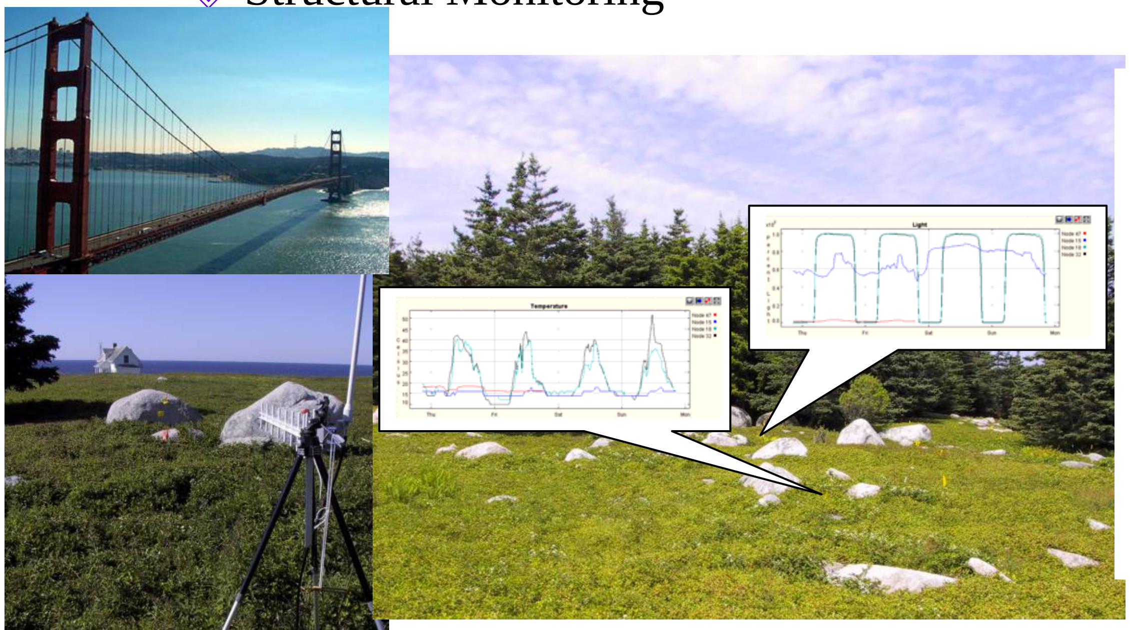


USN Applications

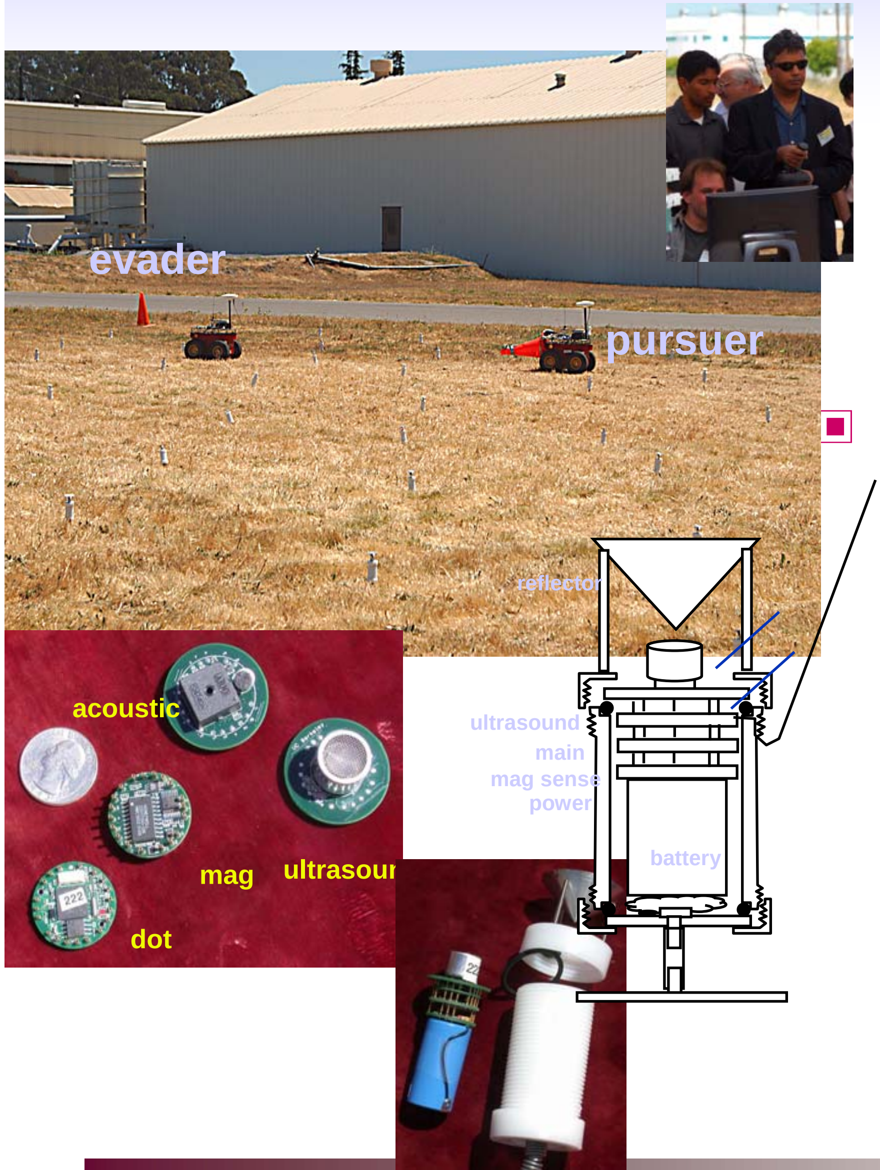
Density & Scale

Sample Rate & Precision

- **Environmental Monitoring**
  - Habitat Monitoring
  - Integrated Biology
  - Structural Monitoring
- **Interactive and Control**
  - Digital Home
  - Security/Automation



NEST Pursuer/Evader



Problem: detect vehicle entering sensitive area, track using magnetics, pursue and capture by UGV.

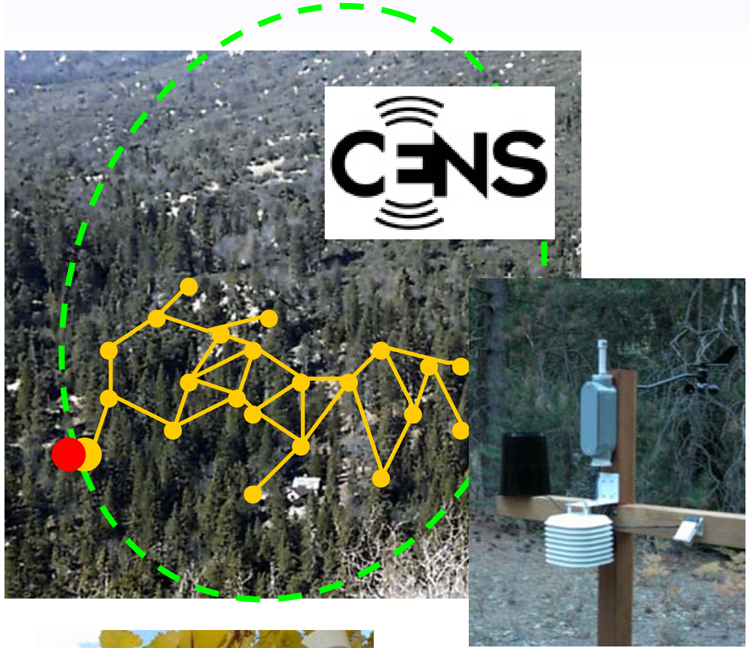
Components

- 10x10 array of robust wireless, self-localizing sensors over 400 m^2 area
- Low cost, robust ‘mote’ device: magnetometer, microcontroller, radio network, ultrasonic transceiver
- Evader: human controlled Rover
- Pursuer: autonomous rover with mote, embedded PC, GPS

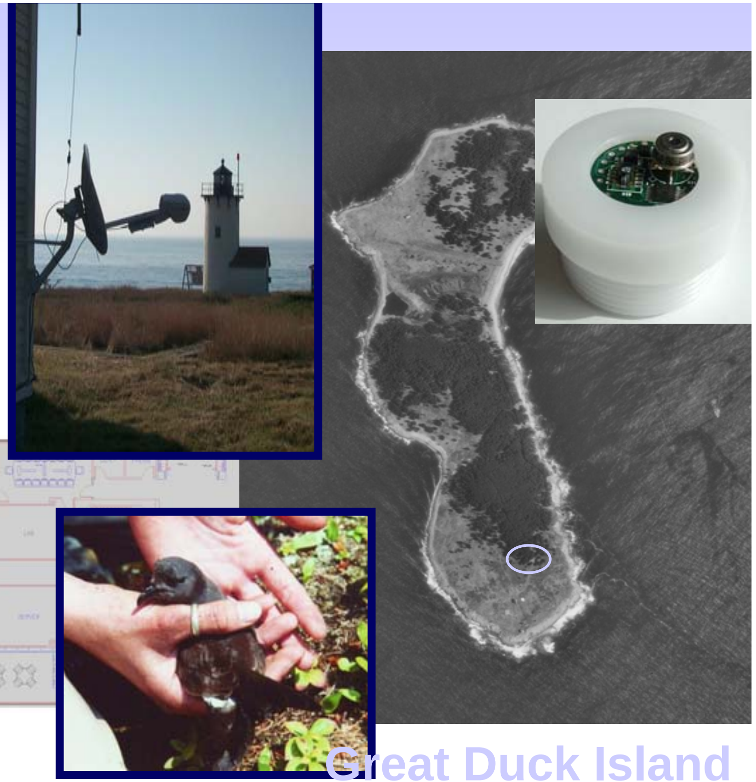
Operation

- Nodes inter-range (Ultrasonic) and self localize from few anchors, correct for earth mag, go into low-power ‘sentry’ state
- Detect entry and track evader
  - Local mag signal processing determines event and announces to neighbors
  - Neighborhood aggregates and estimates position
  - Network routes estimate from leader to tracker (multihop)
- Pursuer enters and navigates to intercede
  - Motes detect and estimate multiple events
  - Route to mobile Pursuer node
  - Disambiguates events to form map
  - Closed inner-loop navigation control
  - Closed information-driven pursuit control
  - Capture when within one meter

Monitoring Space

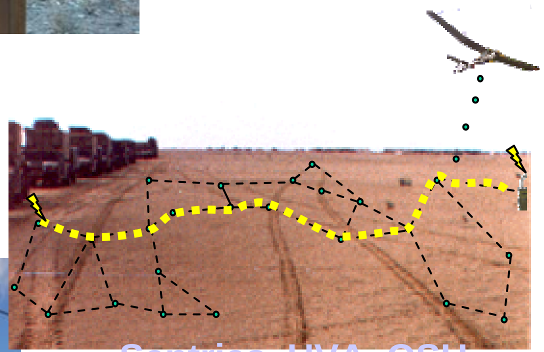


Building Comfort,
Smart Alarms

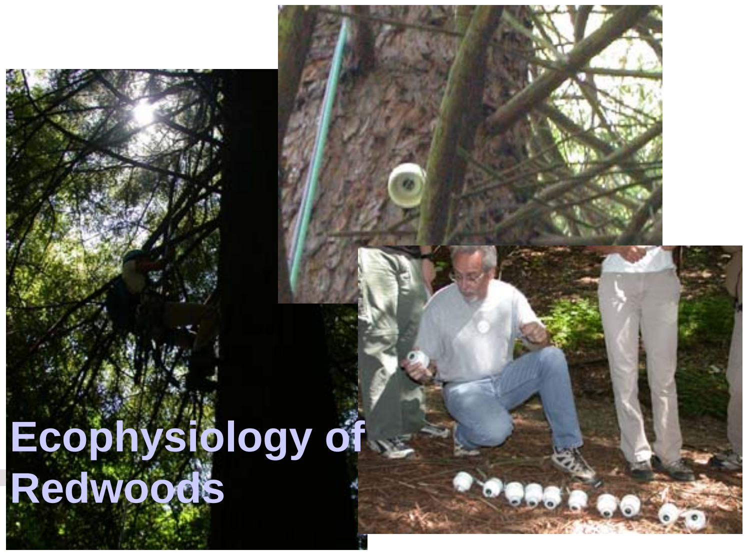


Great Duck Island

Vineyards
BC

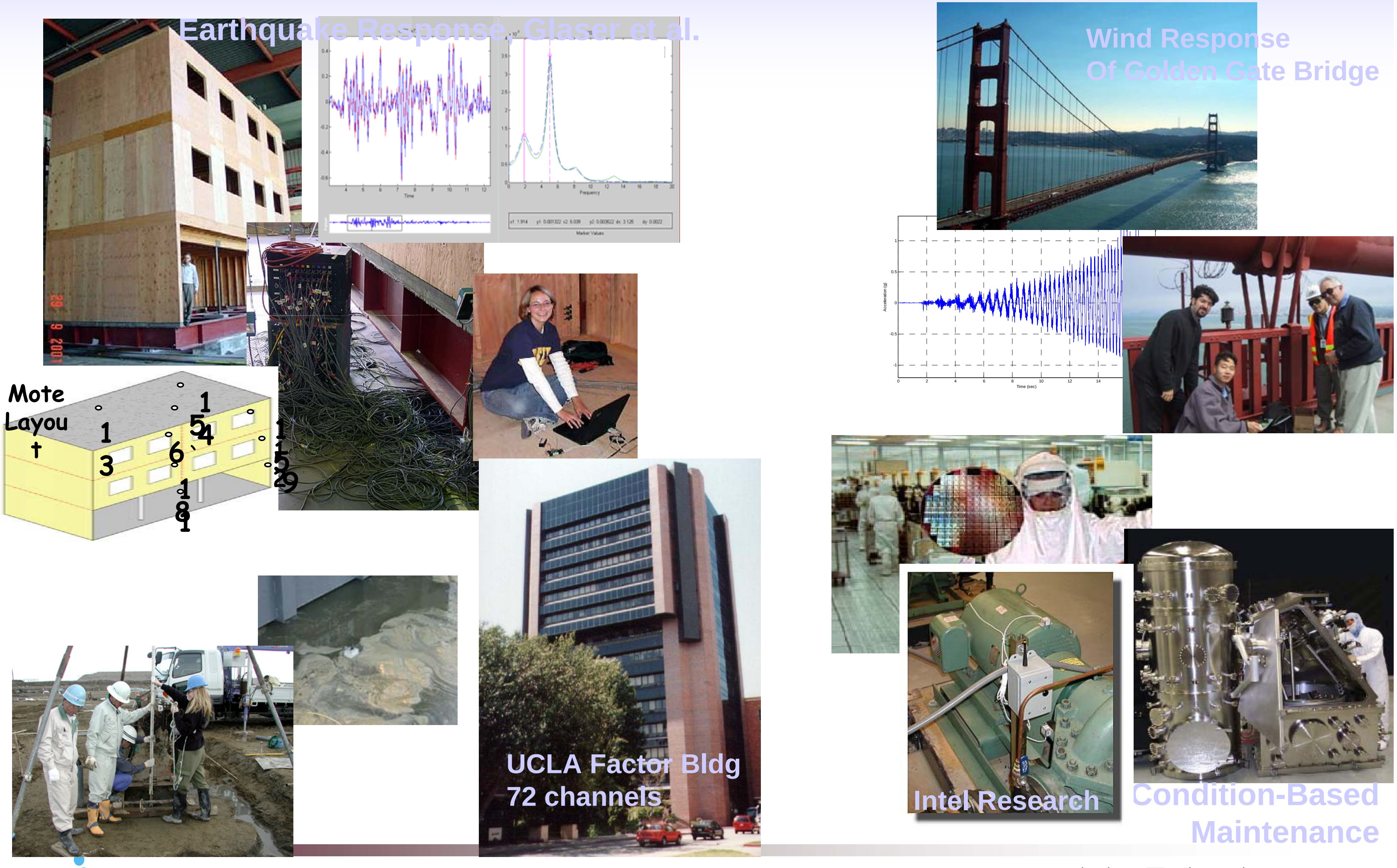


Sentries, UVA, OSU



Ecophysiology of
Redwoods

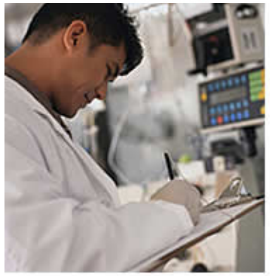
Monitoring Things



Interactions of Space and Things

ElderCare

Sensor Augmented Fire Response

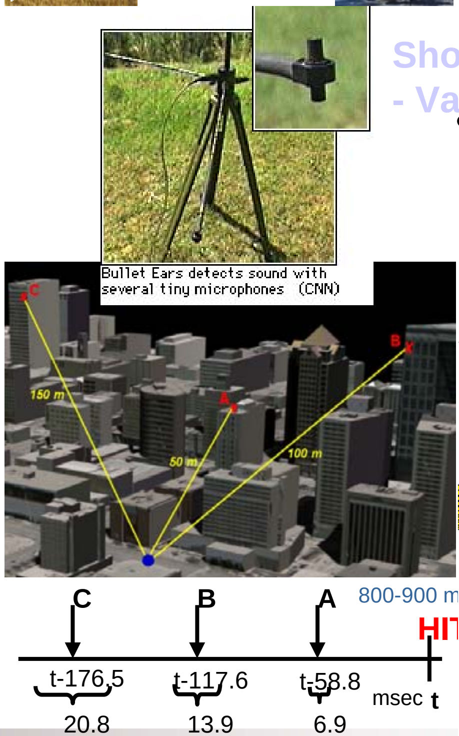


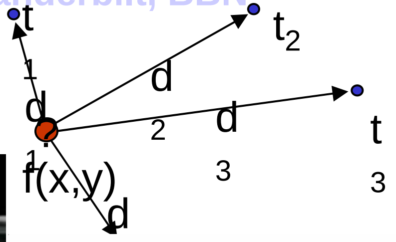
Clinical Management

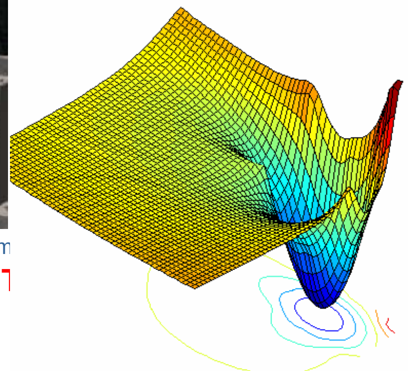
Manufacturing

Asset Management

Shooter Localization
- Vanderbilt, BBN

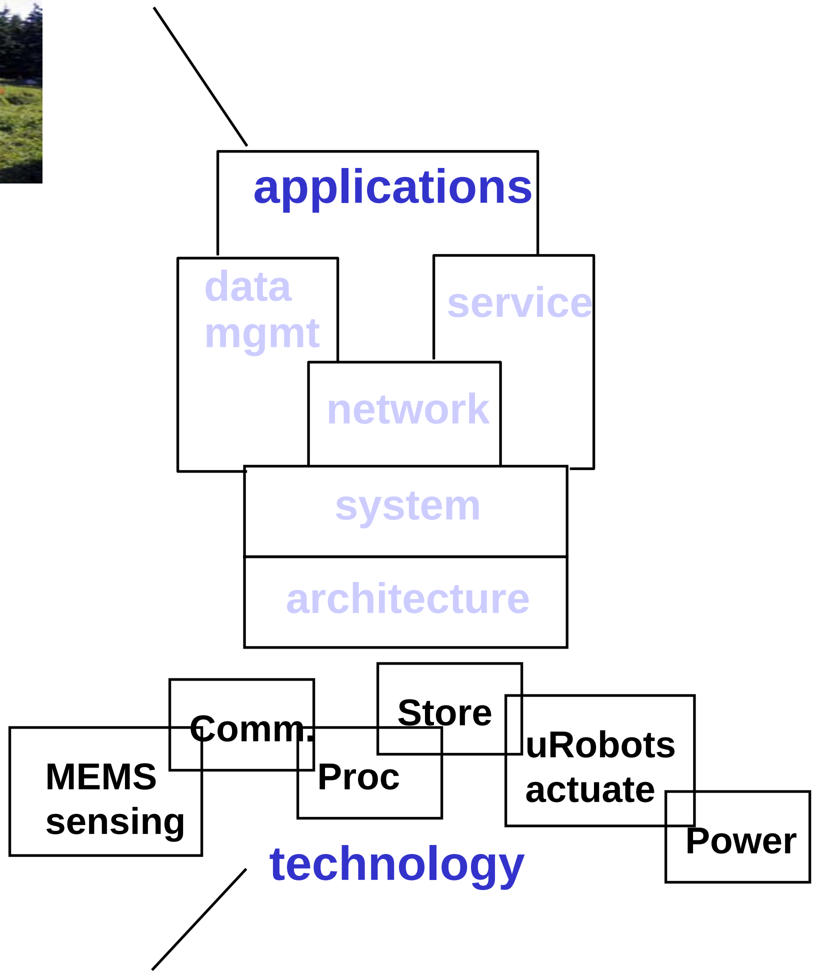


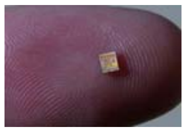


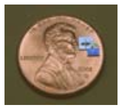


Resolving The Systems Challenge

Monitoring & Managing Spaces and Things





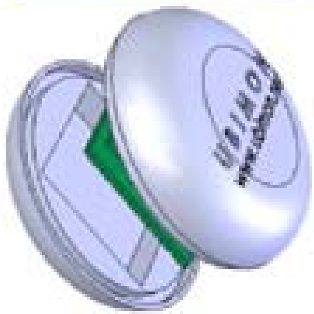


Miniature, low-power connections to the physical world

Body Sensor Nodes

- CC2430 (MCU + RF)
  - 25mm * 25mm Size

- Body Sensor Networks Applications
  - Health Care
  - Ambulatory Monitoring of Patients
  - Context Awareness
  - Human Activity Monitoring
  - Sensors Plugged onto the nodes



MAS-net:

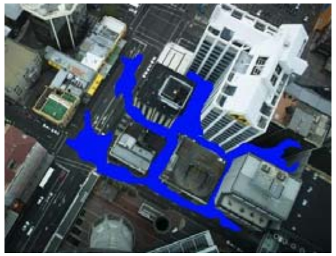
A sensor network to serve the society

1. Pollution plume event.

2. Unmanned Aerial Vehicles (UAVs) are deployed.

3. UAVs enter the plume, send sensor data to base station in real-time.

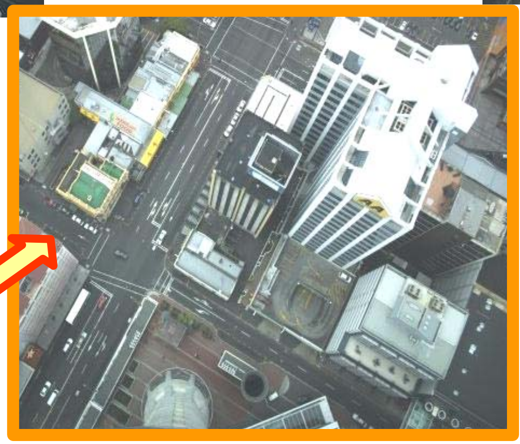
Estimation



Prediction

4. The base station estimates the plume boundary in real-time, predicts its future shape, and commands UAVs accordingly.

5. UAVs release anti-agents and update the data.



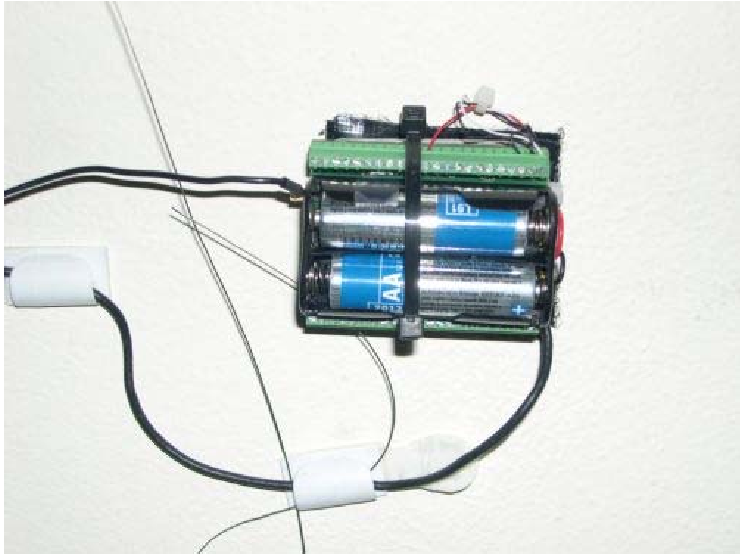
6. Pollution plume is eliminated.

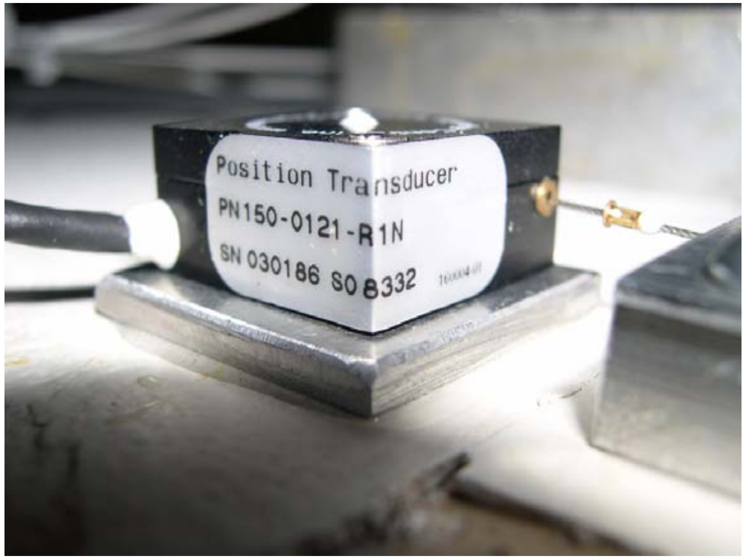
MAS-net Platform


WIRE
TRANSDUCERS

Components of the WDA System

- Remote Nodes
  - Crossbow Mica2 Mote
  - MDA300 Analog Sensor Board
  - SpaceAge Control Series 150 Displacement Potentiometer



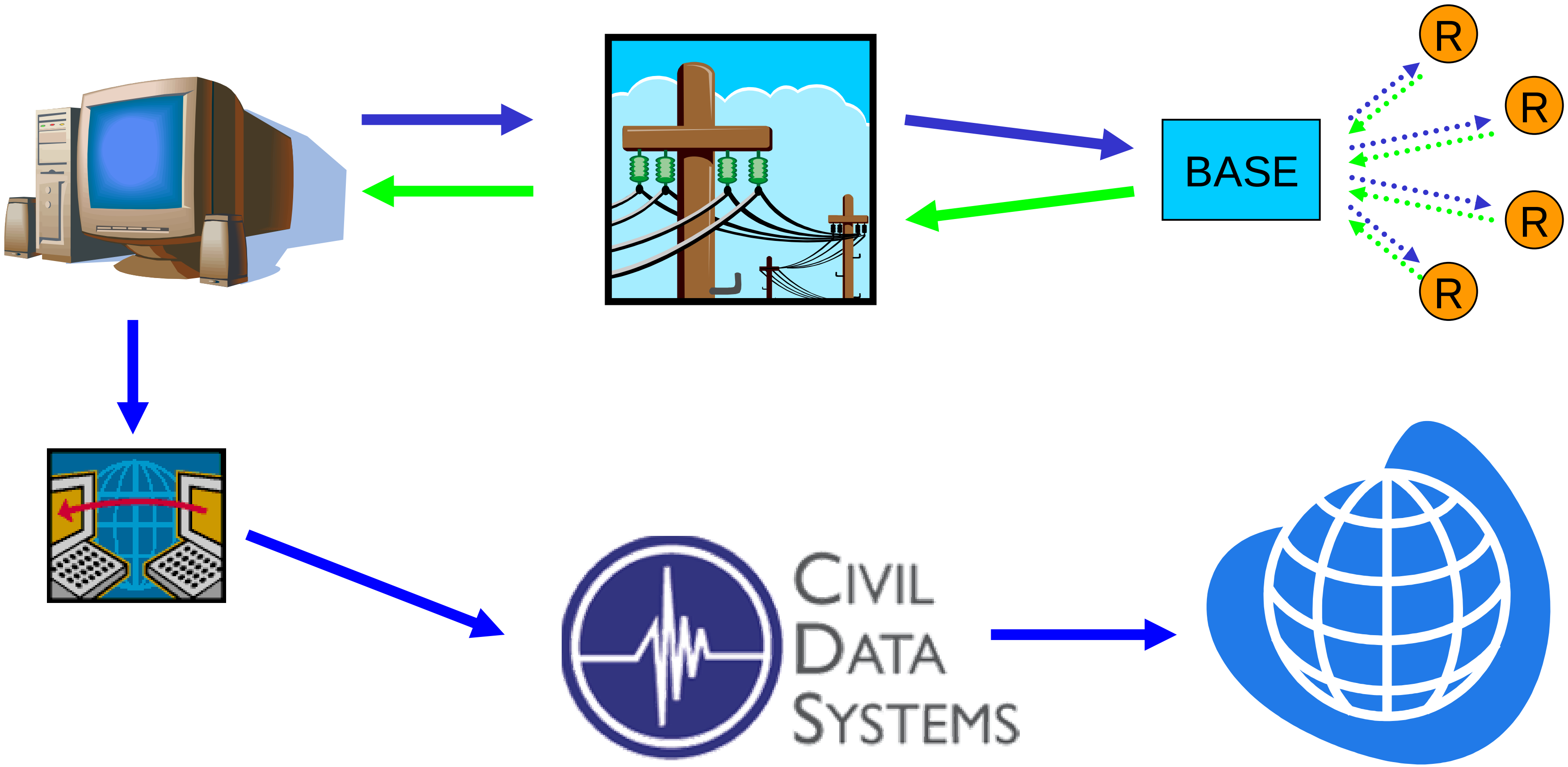


Components of WDA System

- Base Node

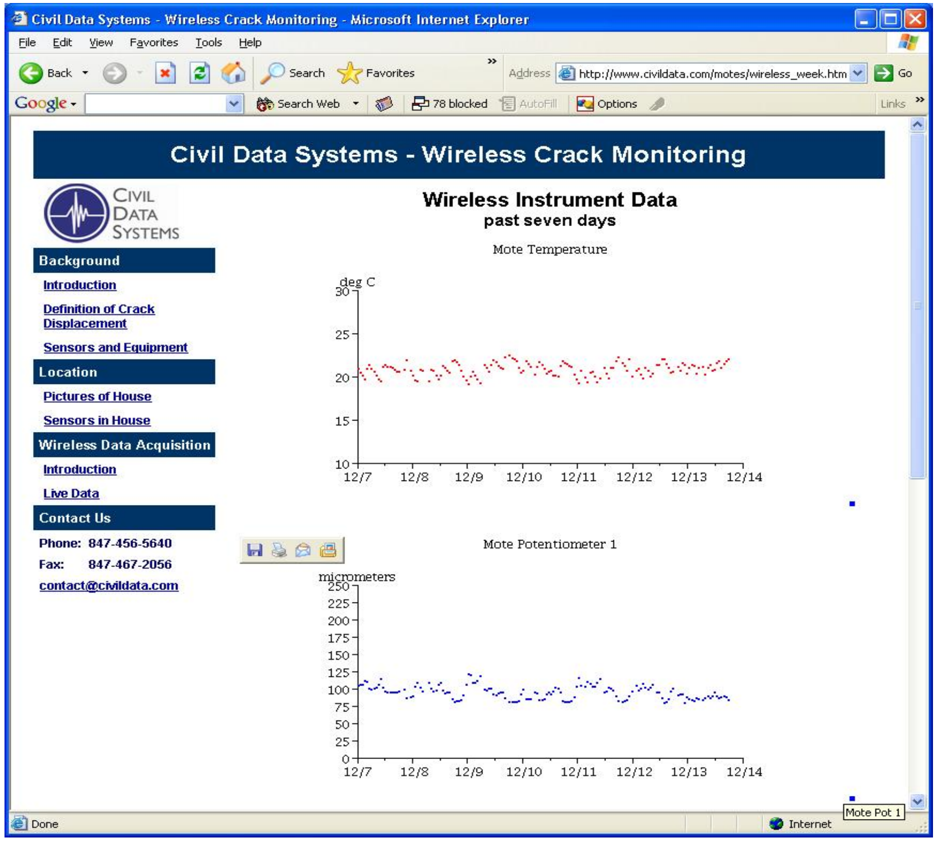
Communication

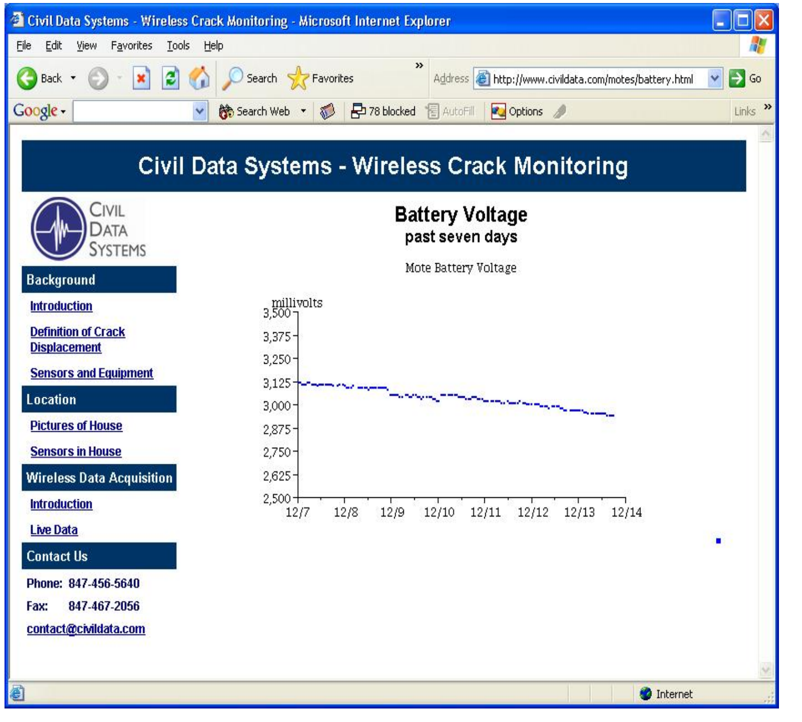
WDA Process



WDA in Action: Crack Monitoring

http://www.civildata.com/motes





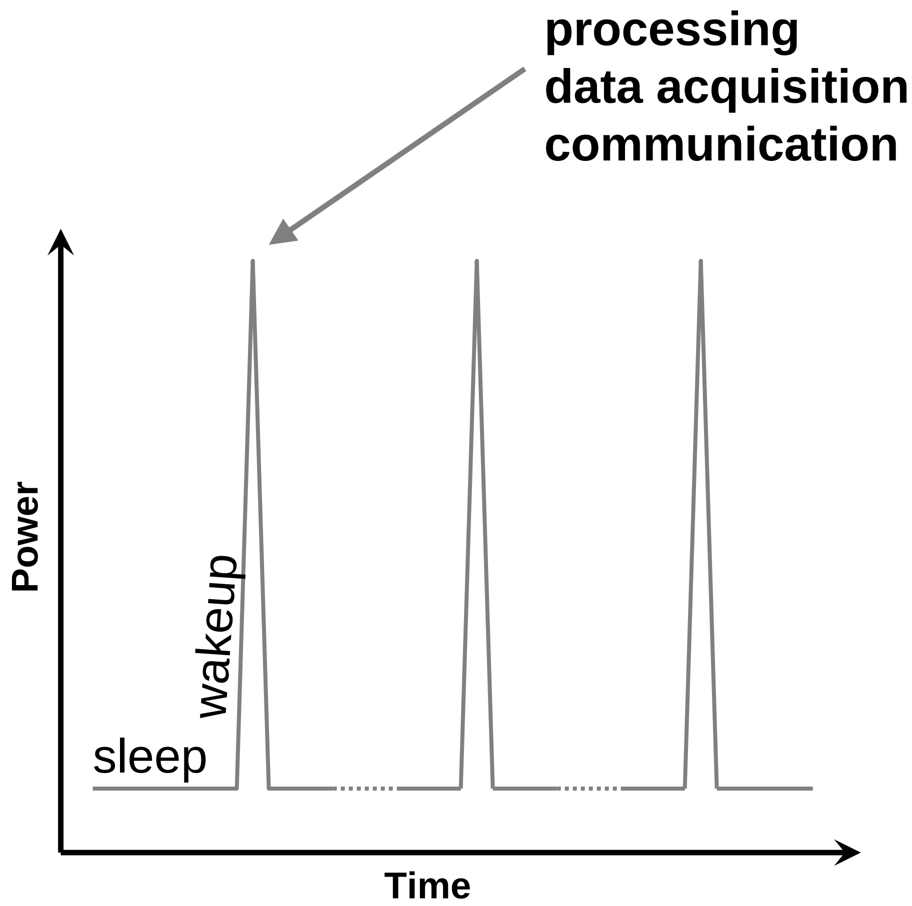
2. USN Node Technology

Low Power Operation

- Efficient Hardware
  - Selectable Power States (Off, Sleep, Standby)
  - Operate at low voltages and low current
    - Run to cut-off voltage of power source
- Efficient Software
  - Fine grained control of hardware
  - Utilize wireless broadcast medium
  - Aggregate

Typical Sensor Network Application

- Periodic
  - Data Collection
  - Network Maintenance
  - *Majority of operation*
- Triggered Events
  - Detection/Notification
  - *Infrequently occurs*
    - *But… must be reported quickly and reliably*
- Long Lifetime
  - Months to Years without changing batteries
  - Power management is the key to WSN success



Design Principles

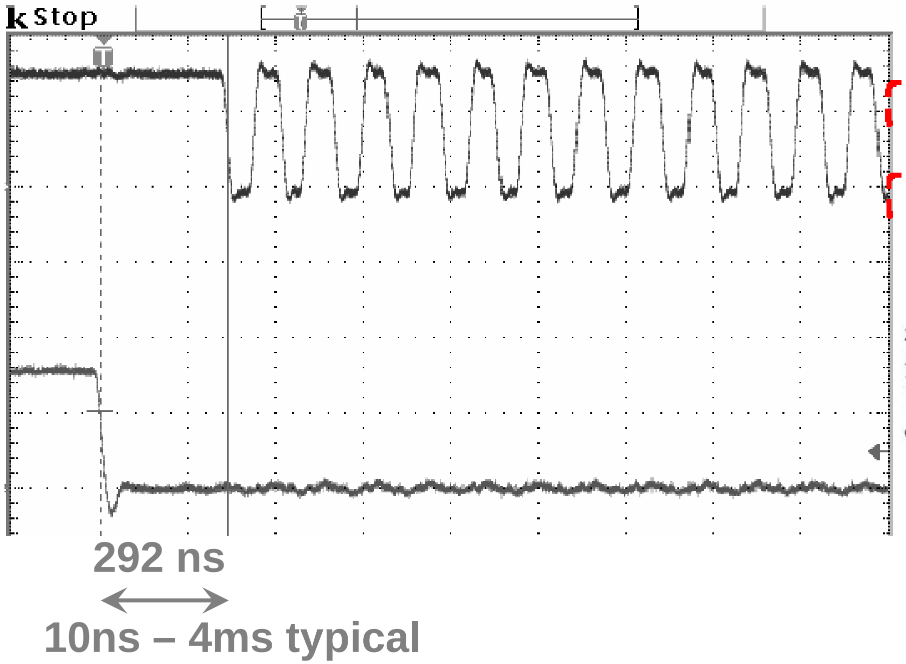
- Key to Low Duty Cycle Operation:
  - Sleep – majority of the time
  - Wakeup – quickly start processing
  - Active – minimize work & return to sleep

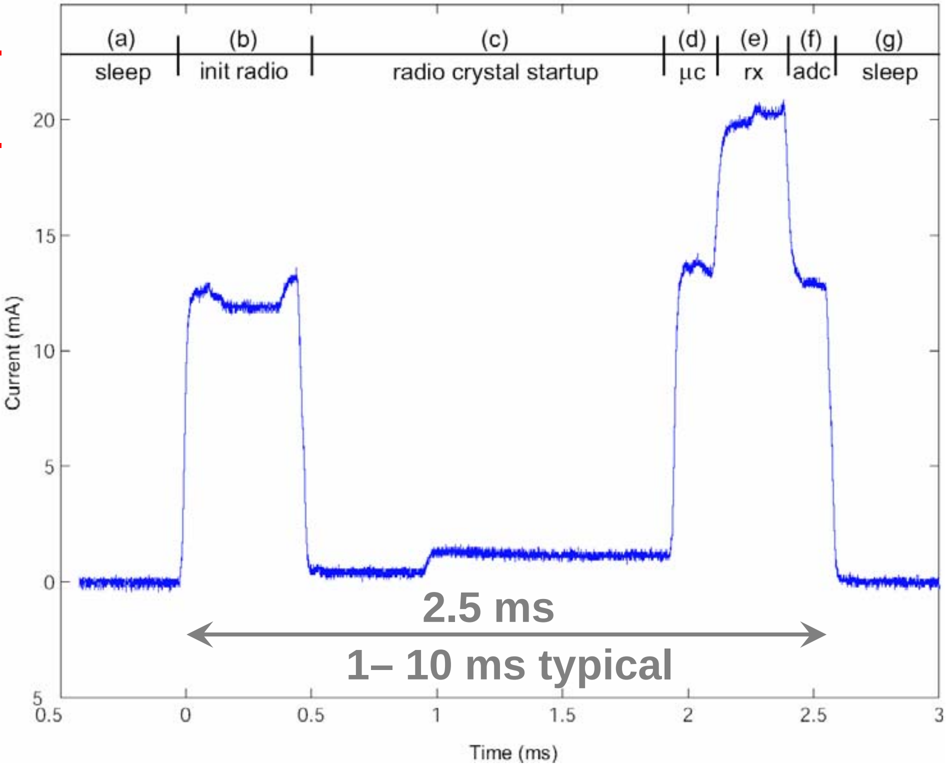
Sleep

- Majority of time, node is asleep
  - >99%
- Minimize sleep current through
  - Isolating and shutting down individual circuits
  - Using low power hardware
    - Need RAM retention
- Run auxiliary hardware components from low speed oscillators (typically 32kHz)
  - Perform ADC conversions, DMA transfers, and bus operations while microcontroller core is stopped

Wakeup

- Overhead of switching from Sleep to Active Mode
- Microcontroller
- Radio (FSK)





Active

- Microcontroller
  - Fast processing, low active power
  - Avoid external oscillators
- Radio
  - High data rate, low power tradeoffs
  - Narrowband radios
    - Low power, lower data rate, simple channel encoding, faster startup
  - Wideband radios
    - More robust to noise, higher power, high data rates
- External Flash (stable storage)
  - Data logging, network code reprogramming, aggregation
  - High power consumption
  - Long writes
- Radio vs. Flash
  - 250kbps radio sending 1 byte
    - Energy : 1.5μJ
    - Duration : 32μs
  - Atmel flash writing 1 byte
    - Energy : 3μJ
    - Duration : 78μs

TinyOS Mote Platform

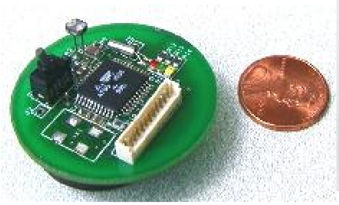
Services

Networking

TinyOS

Telos 4/04
Robust
Low Power
250kbps
Easy to use

WeC 99
“Smart Rock”



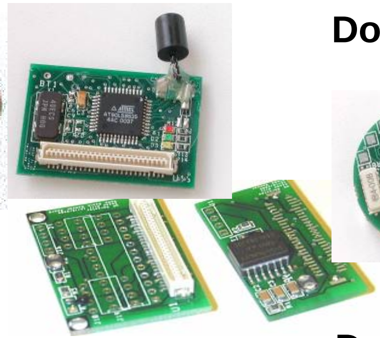
Small microcontroller
8 kB code
512 B data

Simple, low-power radio
10 kbps ASK

EEPROM (32 KB)

Simple sensors

Rene 11/00



Designed for experimentation

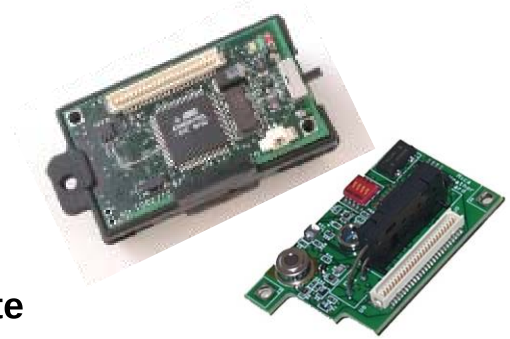
-sensor boards

-power boards

Dot 9/01

Demonstrate scale

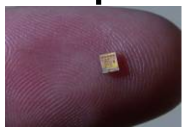
Mica 1/02



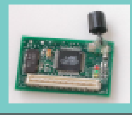
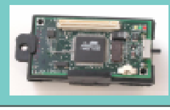
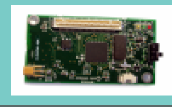
NEST open exp. Platform
128 kB code, 4 kB data
40kbps OOK/ASK radio
512 kB Flash

Mica2 12/02
38.4kbps radio
FSK

Spec 6/03
“Mote on a chip”



Mote History

Mote Type Year	*WeC* 1998	*René* 1999	*René 2* 2000	*Dot* 2000	*Mica* 2001	*Mica2Dot* 2002	*Mica 2* 2002	*Telos* 2004
								
Microcontroller								
Type	AT90LS8535		ATmega163		ATmega128			TI MSP430
Program memory (KB)	8		16		128			60
RAM (KB)	0.5		1		4			2
Active Power (mW)	15		15		8		33	3
Sleep Power (μW)	45		45		75		75	6
Wakeup Time (μs)	1000		36		180		180	6
Nonvolatile storage								
Chip	24LC256				AT45DB041B			ST M24M01S
Connection type	I^2C				SPI			I^2C
Size (KB)	32				512			128
Communication								
Radio	TR1000				TR1000	CC1000		CC2420
Data rate (kbps)	10				40	38.4		250
Modulation type	OOK				ASK	FSK		O-QPSK
Receive Power (mW)	9				12	29		38
Transmit Power at 0dBm (mW)	36				36	42		35
Power Consumption								
Minimum Operation (V)	2.7		2.7		2.7			1.8
Total Active Power (mW)	24				27	44	89	41
Programming and Sensor Interface								
Expansion	none	51-pin	51-pin	none	51-pin	19-pin	51-pin	10-pin
Communication	IEEE 1284 (programming) and RS232 (requires additional hardware)							USB
Integrated Sensors	no	no	no	yes	no	no	no	yes

Telos Platform

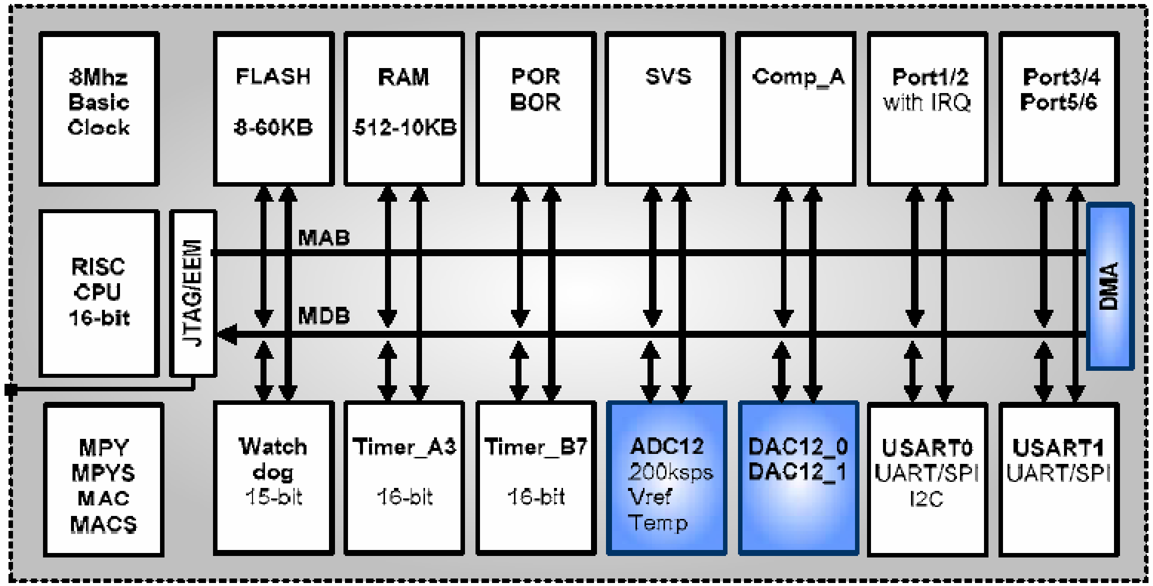
- A new platform for low power research
  - Monitoring applications:
    - Environmental
    - Building
    - Tracking
- Long lifetime, low power, low cost
- Built from application experiences and low duty cycle design principles
- Robustness
  - Integrated antenna
  - Integrated sensors
  - Soldered connections

- Standards Based
  - IEEE 802.15.4
  - USB
- IEEE 802.15.4
  - CC2420 radio
  - 250kbps
  - 2.4GHz ISM band
- TI MSP430
  - Ultra low power
    - 1.6μA sleep
    - 460μA active
    - 1.8V operation

Open embedded platform with open source tools, operating system (TinyOS), and designs.

Operation Characteristics

- TI MSP430 -- Advantages over previous motes
  - 16-bit core
  - 12-bit ADC
    - 16 conversion store registers
    - Sequence and repeat sequence programmable
  - < 50nA port leakage (vs. 1mA for Atmels)
  - Double buffered data buses
  - Interrupt priorities
  - Calibrated DCO
- Buffers and Transistors
  - Switch on/off each sensor and component subsystem



Minimizing Power Consumption

- Compare to MicaZ: a Mica2 mote with AVR mcu and 802.15.4 radio

- Sleep
  - Majority of the time
  - Telos: 2.4mA
  - MicaZ: 30mA

- Wakeup
  - As quickly as possible to process and return to sleep
  - Telos: 290ns typical, 6ms max
  - MicaZ: 60ms max internal oscillator, 4ms external

- Active
  - Get your work done and get back to sleep
  - Telos: 4-8MHz 16-bit
  - MicaZ: 8MHz 8-bit

Power Calculation Comparision

- **Mica2 (AVR)**
  - 0.2 ms wakeup
  - 30 μW sleep
  - 33 mW active
  - 21 mW radio
  - 19 kbps
  - 2.5V min
    - 2/3 of AA capacity
- **MicaZ (AVR)**
  - 0.2 ms wakeup
  - 30 mW sleep
  - 33 mW active
  - 45 mW radio
  - 250 kbps
  - 2.5V min
    - 2/3 of AA capacity
- **Telos (TI MSP)**
  - 0.006 ms wakeup
  - 2 μW sleep
  - 3 mW active
  - 45 mW radio
  - 250 kbps
  - 1.8V min
    - 8/8 of AA capacity

Supporting mesh networking with a pair of AA batteries reporting data once every 3 minutes using synchronization (<1% duty cycle)

453 days 328 days 945 days

*** Reference: Joseph Polastre, Robert Szewczyk, Cory Sharp, David Culler in Proceedings of Hot Chips 16: A Symposium on High Performance Chips. August 22-24, 2004.**

3. International Standards:

IEEE 802.15.4 Characteristics

	2.4 GHz	868 MHz	915 MHz
Data Rate	250 Kbps	20 Kbps	40 Kbps
Channel	11~26 channel	1 channel	10 channel
DSSS	32-chip PN codes	15-chip PN codes	
Chip Modulation	O-QPSK	BPSK	
Symbol Rate	62.5 Ksym/s	20 Ksym/s	40 Ksym/s
Chip Rate	2.0 Mchips/s	300 Kchips/s	600 Kchips/s
Sensitivity	-85 dBm	-92 dBm	
RF Linearity	- 10 dBm(IIP3), -4 dBm (Output P1dB)		
Trasmit Power	0 dBm(1mW)		
Adjacent Channel Rejection	0 dB		
Alternating Channel Rejection	30 dB		

IEEE 802.15.4a

IEEE 802.15.4a

- IEEE 802.15.4의 PHY 대체 -> Pulse Radio
- 1미터 이내의 정확도 갖는 위치 정보를 제공
- 1Kbps에서 1Mbps Data 전송 속도
- 통신 거리의 확장
- 저전력 소모
- 2004년 7월 CFP 발행
- 표준화 초안 2005년 3월 발표 예정
- 최종 규격 완료 2006년 2/4 분기

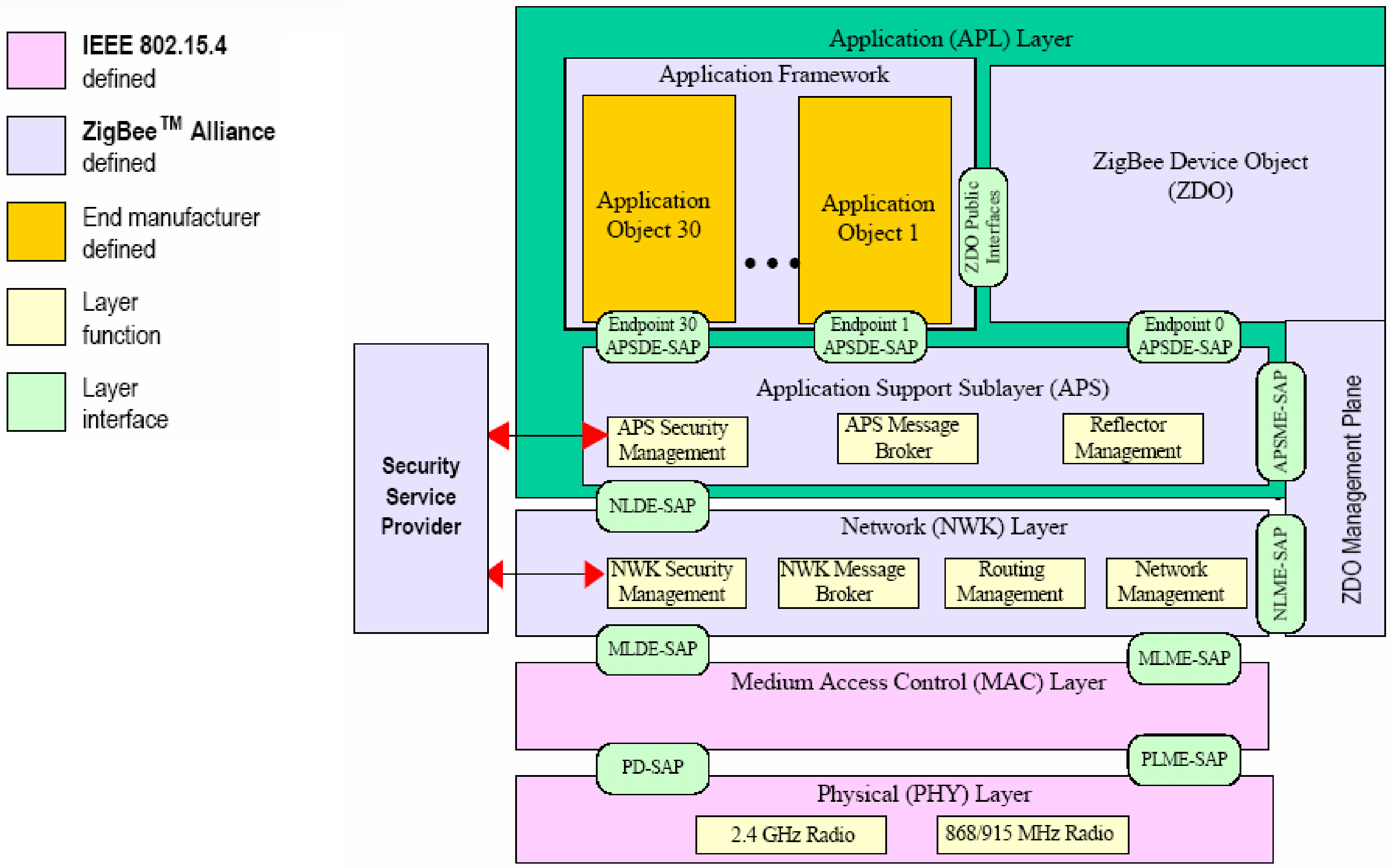
IEEE 802.15.4b

- IEEE 802.15.4b
  - IEEE 802.15.4 모호성 해결을 위함
  - 불필요한 표준의 복잡함을 간소화
  - 보안 키 활용의 유연성 보강
  - 862 ~ 868의 새로운 주파수 대역 채택 논의
  - 2004년 5월 CFP 발행

IEEE 802.15.5

- IEEE 802.15.5
  - Mesh 네트워크 지원하기 위한 15.4의 PHY 및 MAC 구조 보강
  - IEEE 802.15.4의 PHY 구조에서 통신거리 확장(출력 및 수신감도 동일)
  - 라우팅 기능의 신뢰성 보강
  - 네트워크 구성의 편리성 보강
  - 재전송 기능의 최소화를 통해 배터리 동작 시간을 연장

ZigBee

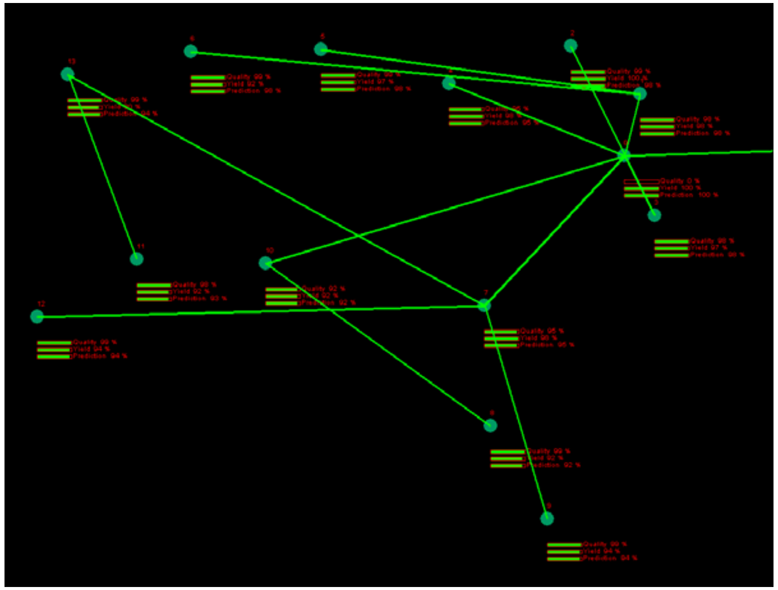


IEEE 802.15.4 defined
ZigBee TM Alliance defined
End manufacturer defined
Layer function
Layer interface
Application (APL) Layer
Application Framework
Application Object 30
Application Object 1
ZDO Public Interfaces
ZigBee Device Object (ZDO)
Endpoint 30 APSDE-SAP
Endpoint 1 APSDE-SAP
Endpoint 0 APSDE-SAP
Application Support Sublayer (APS)
APS Security Management
APS Message Broker
Reflector Management
APSME-SAP
Security Service Provider
NLDE-SAP
Network (NWK) Layer
NWK Security Management
NWK Message Broker
Routing Management
Network Management
NLME-SAP
ZDO Management Plane
MLDE-SAP
MLME-SAP
Medium Access Control (MAC) Layer
PD-SAP
PLME-SAP
Physical (PHY) Layer
2.4 GHz Radio
868/915 MHz Radio

ZigBee-Ready Chip Vendor

Company	Frenquency	Product Name	Configuration	Market Time
ZMD	900MHz	ZMD44101	RF Transceiver BB + RF	N/A
AMI Semiconductor	900MHz	ASTRX1	RF Transceiver BB + RF	Q3/2004
FreeScale	2.4GHz	AT86RF210 AT86ZL3201	RF Transceiver BB+MAC+MCU	Q3/2004
Chipcon	2.4GHz	CC2420	RF Transceiver BB+RF	Q1/2004
Ember	2.4GHz	EM2420	RF Transceiver BB+RF	Q2/2004
RadioPulse	2.4GHz 868/915MHz	Mango	Full Single Chip BB+RF+MAC+MCU	Q1/2005 (Estimation)
KETI	900MHz	UbiChip	RF Transceiver (RF+BB+ MAC)	N/A

IEEE 802.15.4 Compliant CC2420 Radio



- CC2420
  - Fast data rate, robust signal
    - 250kbps : 2Mchip/s : DSSS
    - 2.4GHz : Offset QPSK : 5MHz
    - 16 channels in 802.15.4
    - -94dBm sensitivity
  - Low Voltage Operation
    - 1.8V minimum supply
  - Software Assistance for Low Power Microcontrollers
    - 128byte TX/RX buffers for full packet support
    - Automatic address decoding and automatic acknowledgements
    - Hardware encryption/authentication
    - Link quality indicator (assist software link estimation)
      - samples error rate of first 8 chips of packet (8 chips/bit)

ZigBee Certification

- ZigBee Certification Introduction (ZigBee Meeting, Seoul, 12/04)
  - Cable Modem, DOCIS Qualification Program
  - Qualification Working Group
  - ZigBee Platform Compliance
  - End Product Certification

ZigBee Platform Compliance

- ZigBee Platform Compliance
  - Chip, Module, Protocol, Profile 통합한 Platform에 Certification
  - Bluetooth의 Certification 프로그램의 상호 호환성에 한계
  - ZigBee에 대한 Total Solution 요구
- End Product Certification
  - After ZigBee Platform Compliance
  - ZigBee Profile 준용 여부
  - 타사 제품 2-3와 Interoperability Testing
  - ZigBee Logo 부여

Certification Institute & Cost

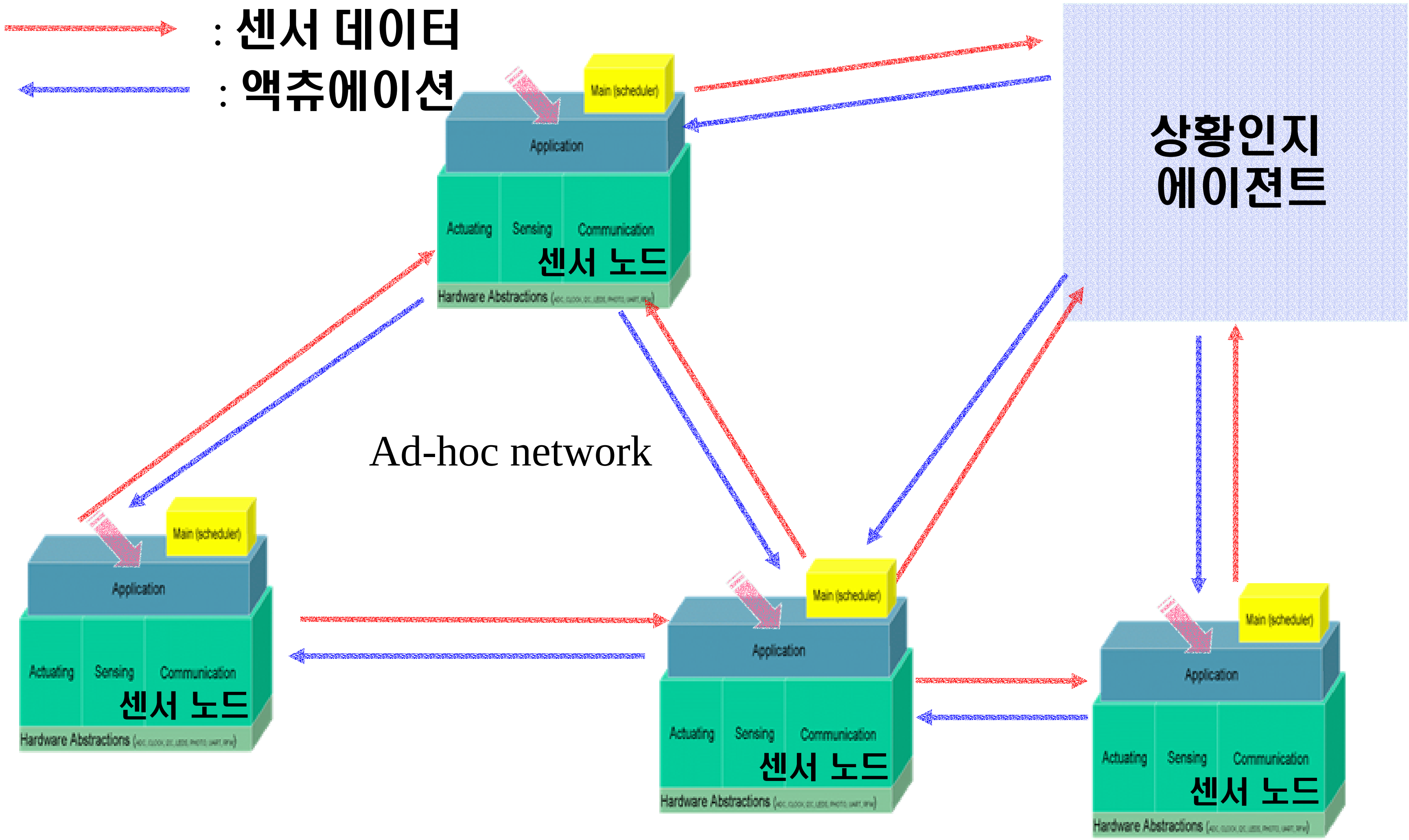
- Certification 기관: TUV America, NTS
- Certification단계
  - 제품 디자인 및 사내 테스트(ZigBee Spec.)
  - ZigBee Certification/Compliance 리뷰 신청 및 Certification 서류 제출
  - Certification 테스트 실행
  - Certification 승인 및 로고 라이센스 계약 체결
  - Certification Maintenance
- Certification Documents
  - ZigBee Certification Application,
  - ZigBee Conformance Checklist
  - ZigBee Interoperability Checklist
  - Product Documentation
  - Logo Licence documents

ZigBee Certification

- Certification testing documents 공개 예정
- ZigBee Certification : 2005년 1분기
- 2005년 하반기 : ZigBee Logo 제품 시장 등장 예정
- 칩 개발자 + 프로토콜 스택 또는 프로토콜 소프트웨어 솔류션 개발자간의 협력 요구

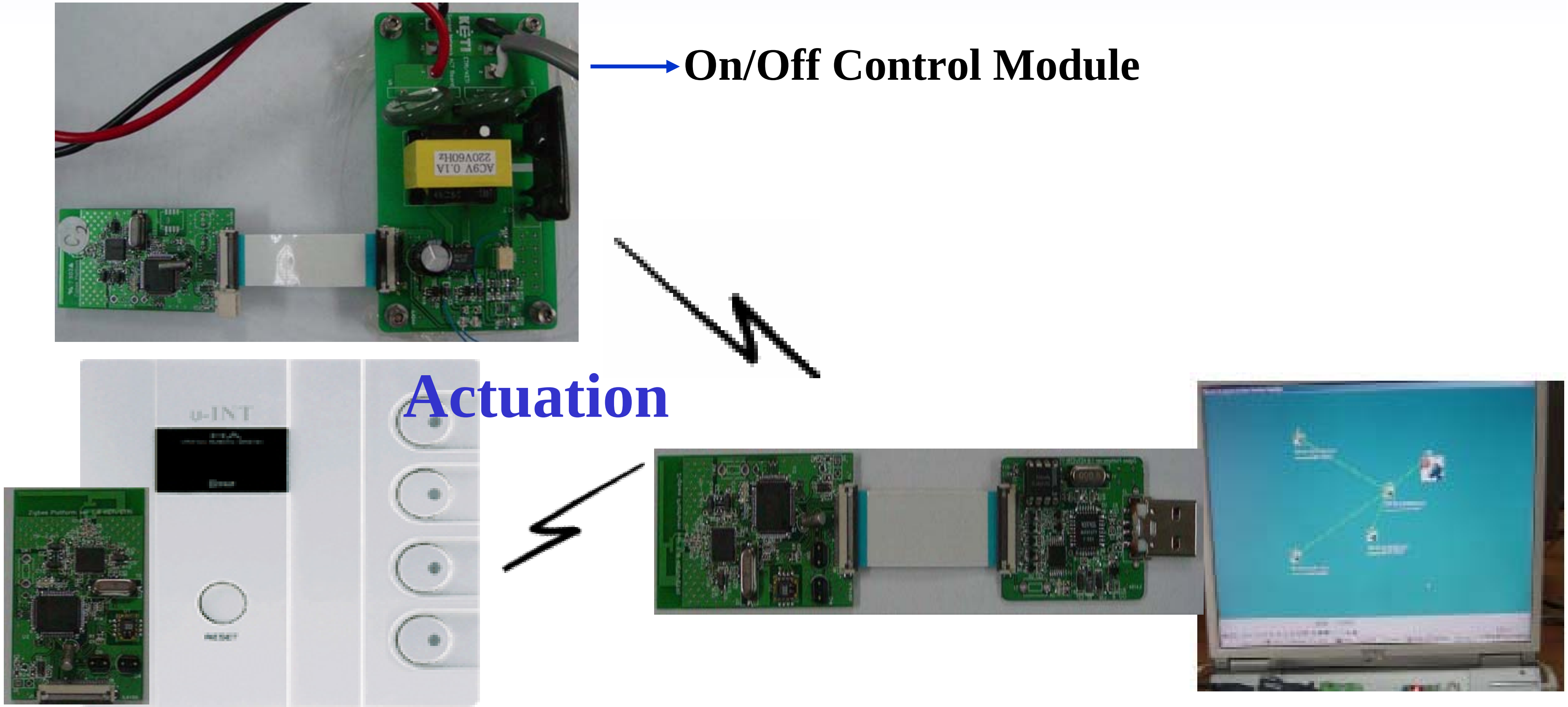
4. Our Works:

중점 개발 내용



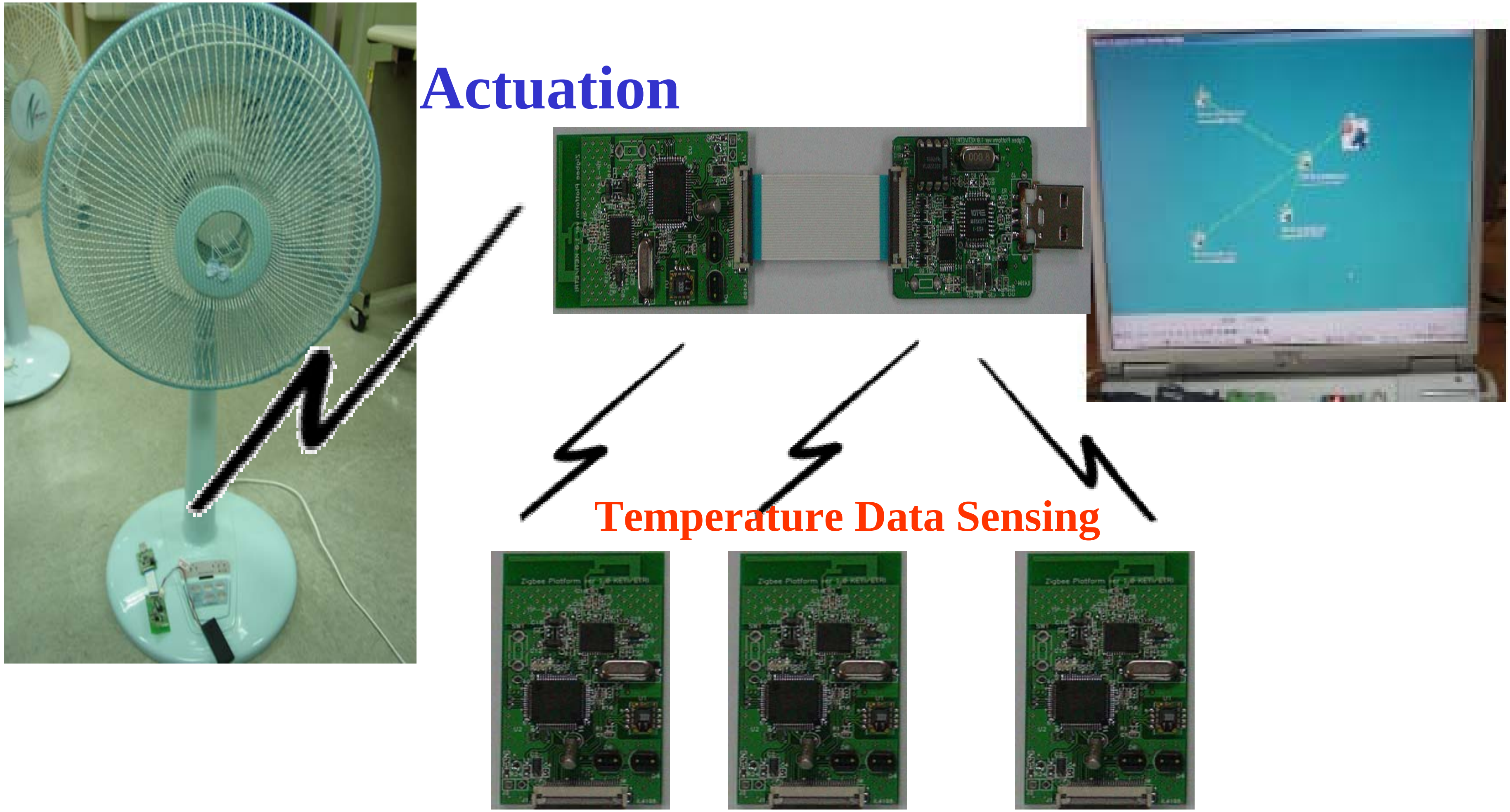
: 센서 데이터
: 액츄에이션
Main (scheduler)
Application
Actuating
Sensing
Communication
센서 노드
Hardware Abstractions
상황인지 에이전트
Ad-hoc network

IEEE 802.15.4 기반 가전제어



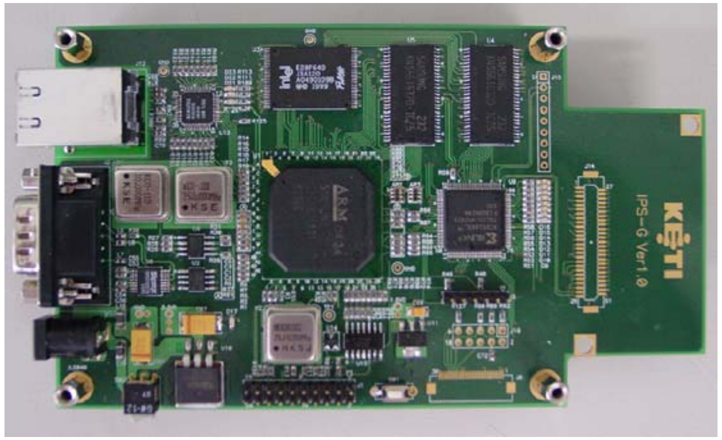
- Photo, Temperature, Humidity 모니터링
    - Threshold 설정 및 변경
- Sending Actuation Command

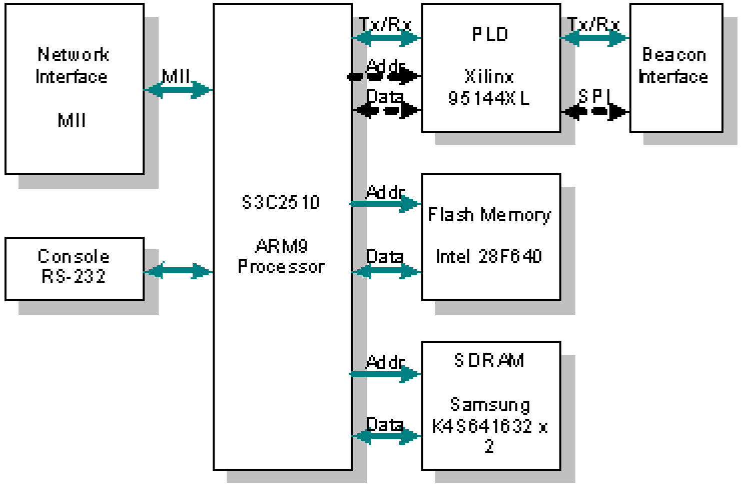
IEEE 802.15.4 기반 선풍기 제어



Indoor Positioning System
: H/W 결과물 – (IPS-G)

- Hardware Spec.
  - ARM9 Core Processor
    - Samsung S3C2510
  - 512Mbit SDRAM
    - 32Bit Data Bus
  - 64Mbit Flash Memory
    - 16Bit Data Bus
  - Xilinx 95144XL
  - 10/100MBps Ethernet
- Function
  - Embedded Linux 동작
  - IPS-M Remote Upgrade
    - FTP, TFTP
  - Command
    - Pass : Ethernet → Serial
  - Data
    - Pass : Serial → Ethernet
    - IPS-M Gathering Data
    - Sensor Value (Temp. Sensor)

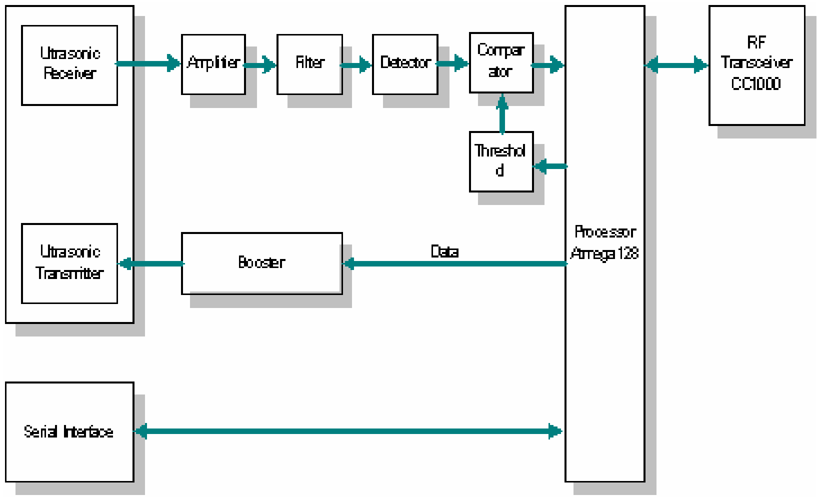




• IPS-G : Indoor Positioning System – Gateway

Indoor Positioning System
: H/W 결과물 – (IPS-M)

- Hardware Spec.
  - ATmega128L
  - CC1000
    - 915MHz RF Transceiver
  - Serial EEPROM
    - 환경변수 저장
  - Ultrasonic Sensor
    - Murata MA40 Series
    - Other Ultrasonic Sensor Compatible
  - Voltage Booster
    - Output Voltage : 2 x Source Voltage
    - Min. Size (No Transformer)
  - Serial Interface
    - Controller Program
    - Status Monitoring
  - Sensor
    - Temp. Sensor
    - Photo. Sensor
      - 2 Axis
  - Power
    - 2 x 1.5V Battery
    - 5V Adapter



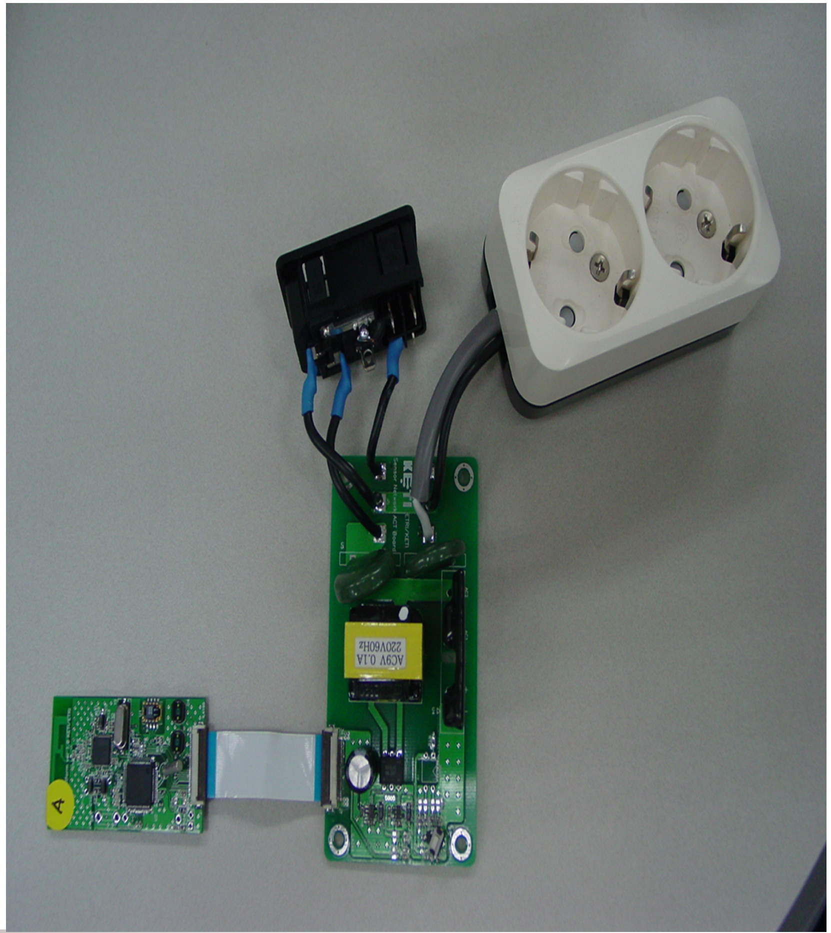
H/W 결과물 – ZigBee 기반 가전제어 엑츄에이터

■ 용도

- ZigBee 기반의 가전제어 용도

■ Hardware Spec.

- 통신 모듈
  - ◆ TI MSP430
  - ◆ CC2420
    - – 2.4Ghz RF Transceiver
- 엑츄에이션 모듈
  - ◆ Opto-Coupler On/Off



S/W - 위치 인지 알고리즘 (Ver. 1.0)

Listener Start

주기적 타이머 핸들러 호출

Beacon Start

Radio Send

라디오 메시지 전송

Radio Receive

Ultrasound Send

초음파 전송

Ultrasound Receive

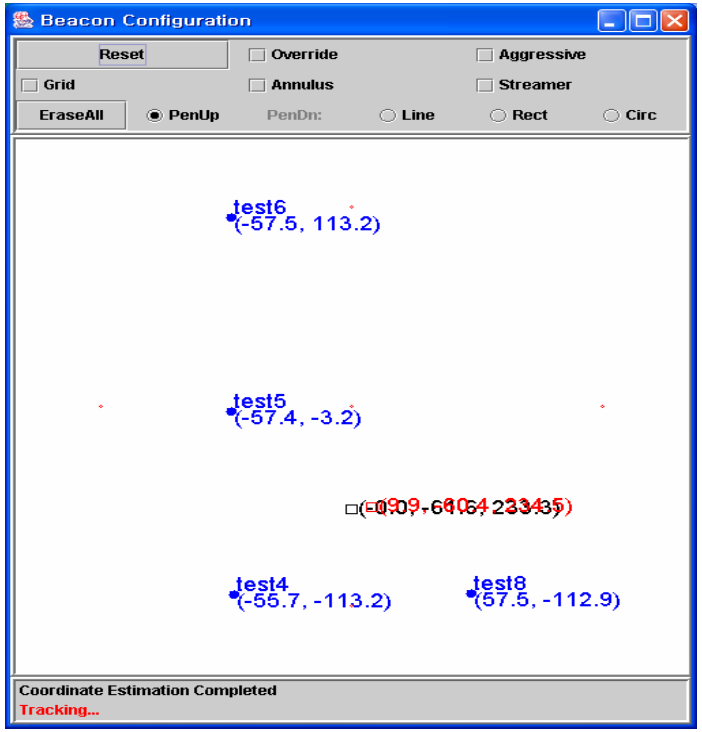
RF와 초음파의 time-of-flight 계산하여 Beacon과 Listener 거리계산

UART로 Beacon 정보 출력

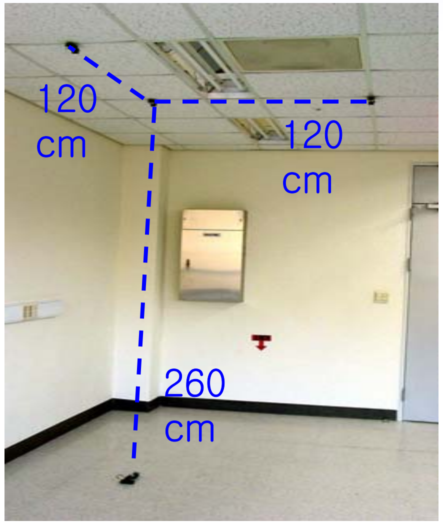
■ 본 알고리즘의 단점
- 유선을 통한 시리얼 통신 연결
- 비콘 노드들의 배터리 소모가 큼
- 위치 인지 값을 계산하는데 지연 현상이 발생함

S/W 결과물 – (Ver. 1.0)

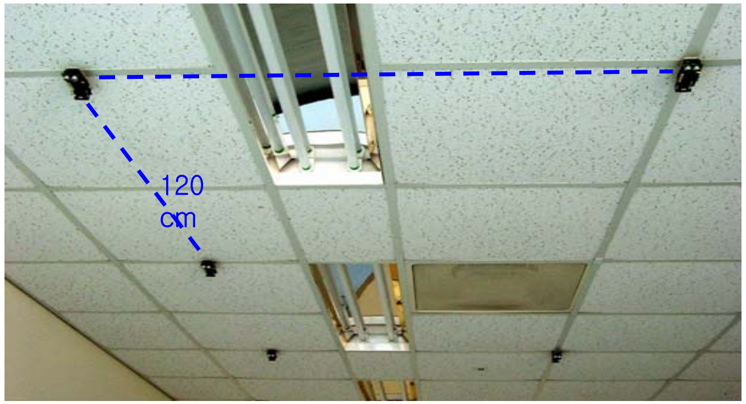
테스트베드 및 모니터링 정보



모니터링 정보

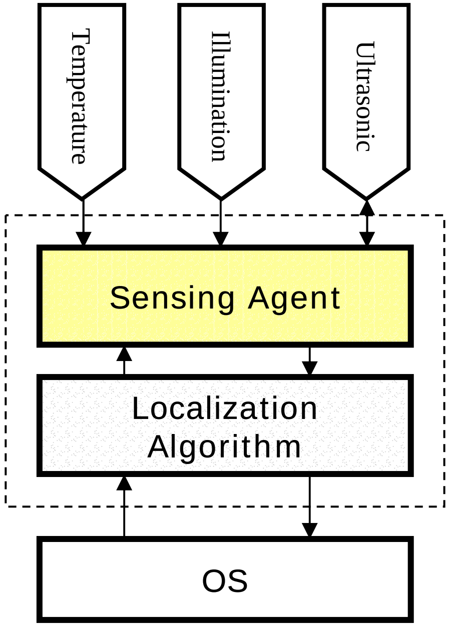


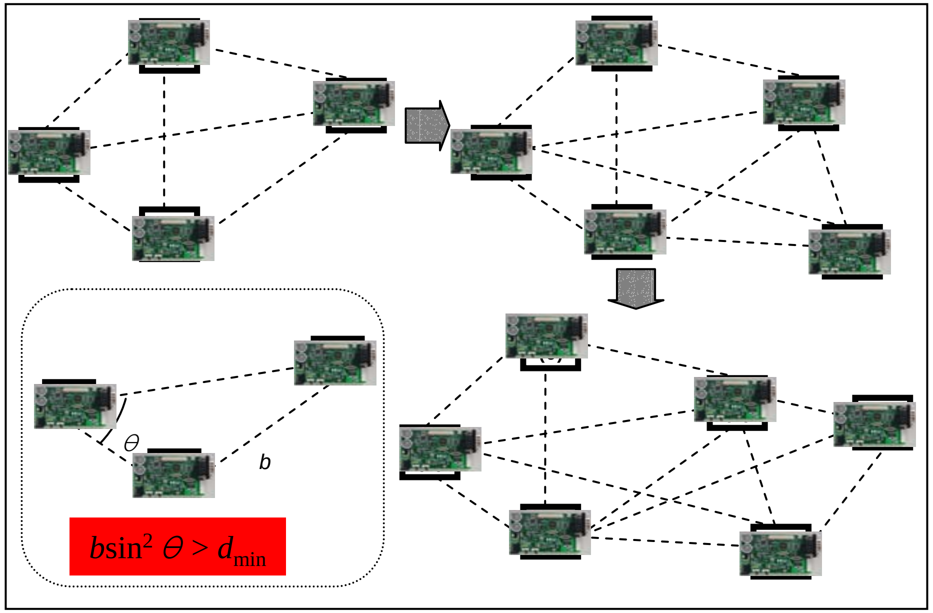
테스트베드



S/W 결과물: Robust quad 기반 삼각측량 알고리즘(Ver. 2.0)

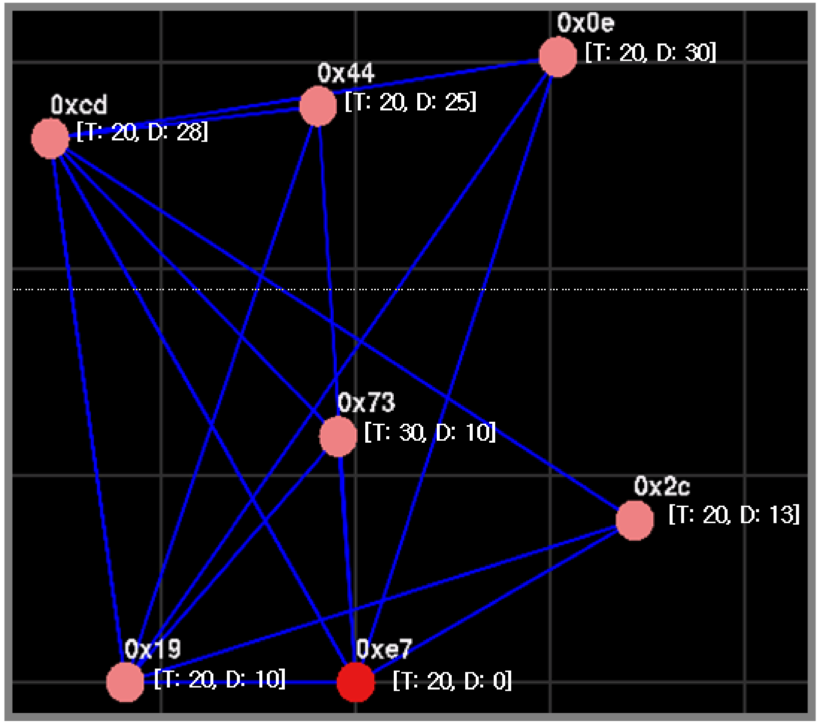
1. 노드 4개의 사각형 형성
2. 그 중 3개의 노드들을 이용하여 삼각형 기반의 노드 거리 및 각도 측정
3. 삼각형 기반 노드 및 각도 값을 서로 보정

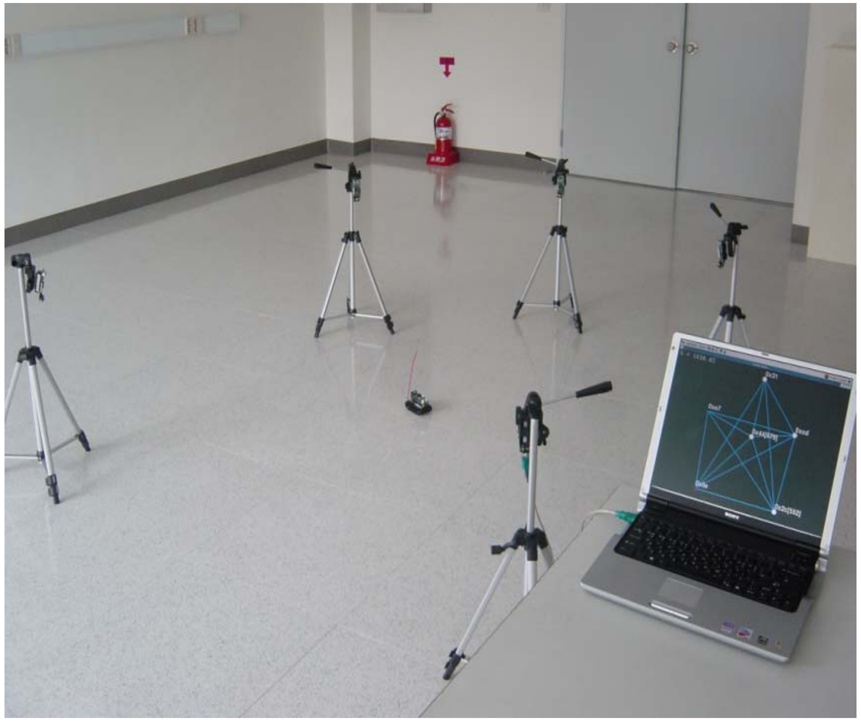




S/W 결과물:
Robust quad 기반 삼각측량 알고리즘(Ver. 2.0)

테스트베드 및 모니터링 정보

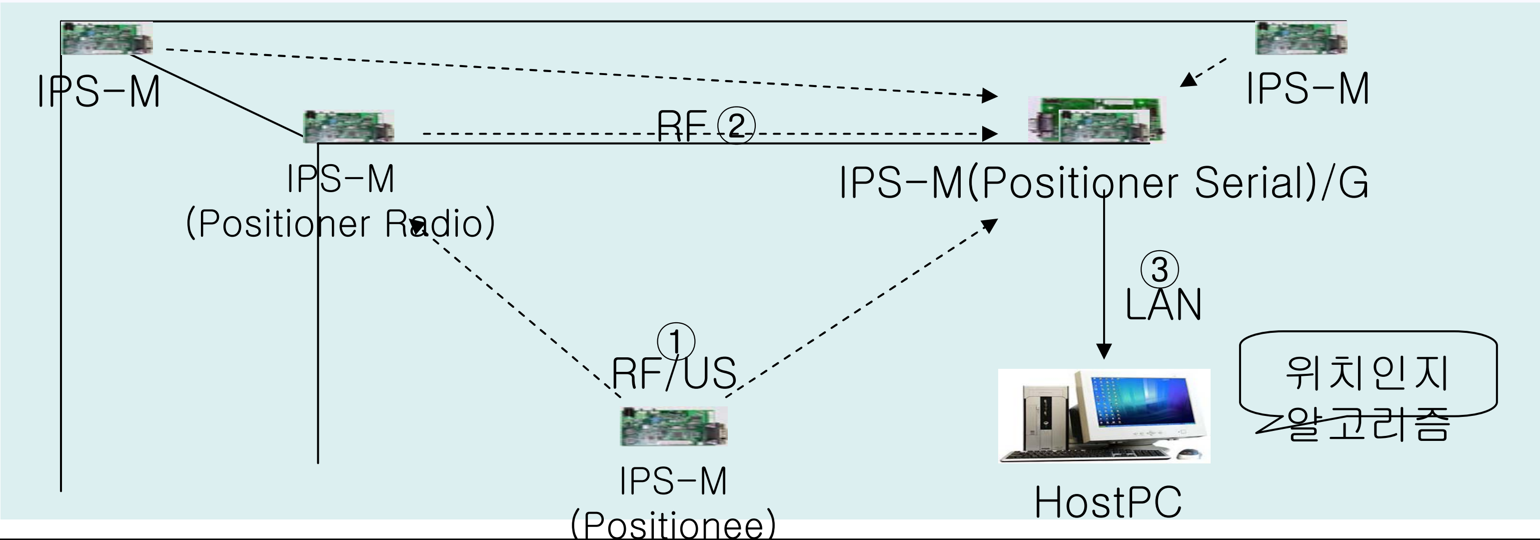




노드들의 모니터링 정보

테스트베드

S/W 결과물 –
(위치 인지 알고리즘 Ver. 3.0)

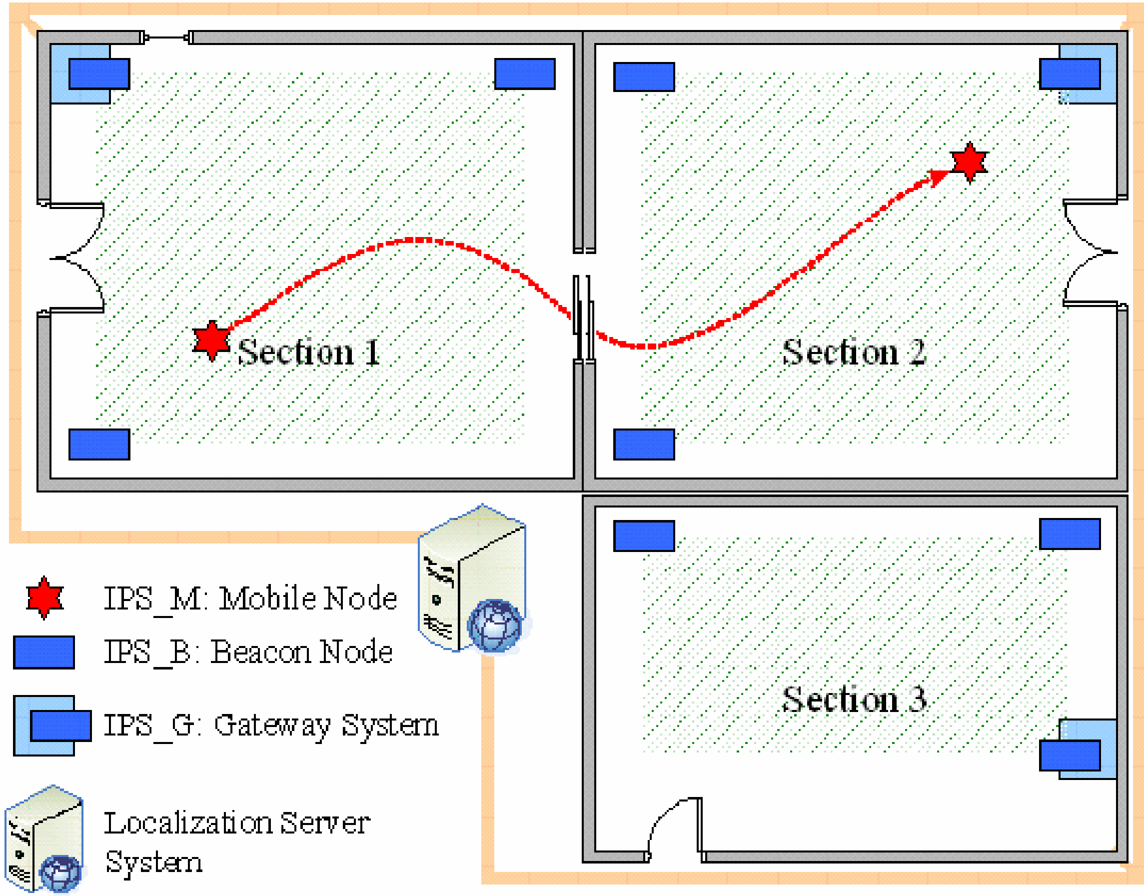


① IPS-M (Positionee)에서 주기적으로 RF 메시지와 초음파 발생.
② IPS-M (Positioner)는 IPS-M (Positionee)과의 거리를 구하고 RF 메시지를 전송하여 IPS-M/G에게 이를 알린다.
③ IPS-G는 IPS-M으로부터 거리정보를 넘겨받아 HostPC로 이더넷 망을 통해 전송한다.

■ 본 알고리즘의 장점
- 비콘노드의 배터리 소모량을 감소시킴
- 이더넷을 통하여 정보 수집 가능
- 위치 인지 서버 시스템에서 가장 최상의 3개의 비콘 노드을 선택하여 위치값을 계산함

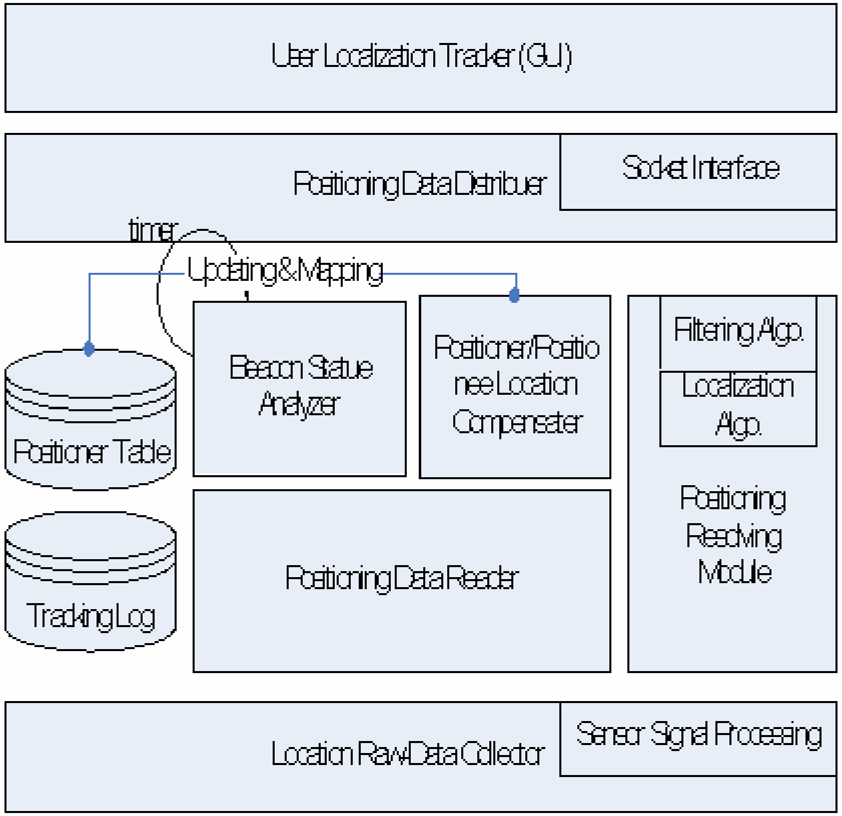
S/W 결과물 – (위치 인지 서버 시스템)

전체 시스템 구성도



S/W 결과물 – (위치 인지 서버 시스템)

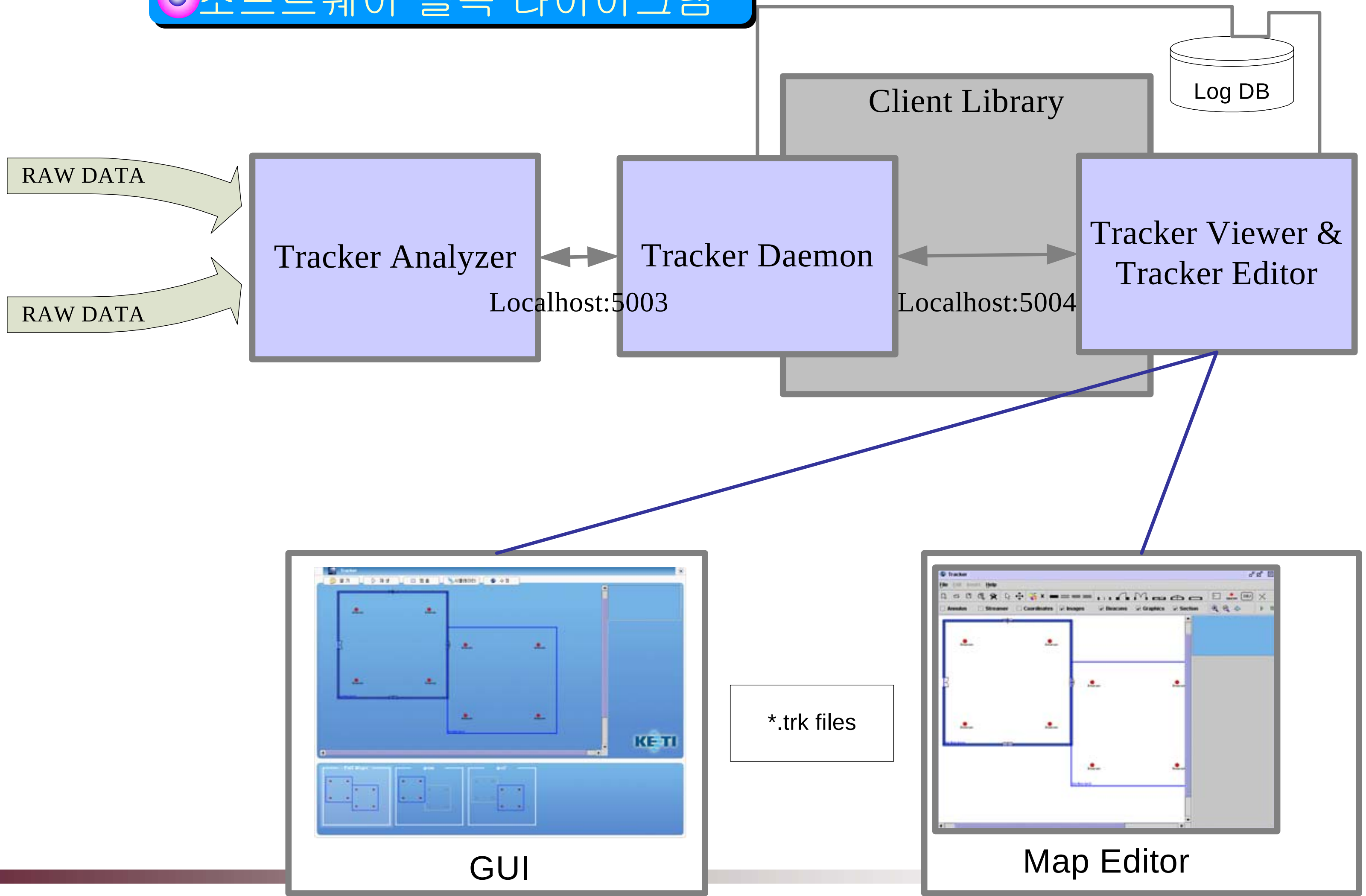
- 위치 인지 서버 시스템 개요
  - IPS-M 위치계측
    - IPS-G로부터 Raw-Data 수집
    - 수집된 Raw-Data를 이용하여 사용자 위치계산 및 Tracking
  - 위치기반 Actuator 제어
    - 계측된 사용자의 위치를 actuator에게 주기적으로 Notify



위치 인지 서버 시스템 S/W구성도

S/W 결과물 – (위치 인지 서버 시스템)

소프트웨어 블록 다이어그램



전시장/박물관

- 전시장/박물관에서 사용자 위치에 따른 안내 및 설명 서비스

헬스 케어

▣ 치매 위험성이 있는 노인들의 활동량을 모니터링 하여 의사에게 데이터 전달

데모 시나리오

위치인지 기법을 사용한 가전제어 구현