

Wireless Sensor Network and IOT in Precision Agriculture

- Recent Development and Future Trend



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Kansas State University**

**For 5th Continuous Professional Development (CPD) Event
THE SOUTH AFRICAN INSTITUTE OF AGRICULTURAL ENGINEERS
September 28, 2010
Pretoria, Gauteng, South Africa**

Where is KSU?



Kansas State University



- **Founded in 1863**
- **Morrill Act of 1862; “Education of the Children of the Working Class”**
- **“Land-grant” University**

Emphases:

- **Agriculture**
- **Engineering**
- **Domestic Arts**
- **Arts and Letters**



Kansas State University



- 19,500 undergraduate students
- 2,500 graduate students
- 1,300 faculty
- 2,700 support staff

Kansas State University



2010 Season
4 wins!

We are “Wildcats”



An African wildcat

This is how we look during work



This is how we look after work



Topics

- ❑ Introduction
 - ❑ Wireless Sensor Network
 - ❑ Internet of Things
 - ❑ M2M
- ❑ Application Examples
- ❑ Issues

Recent National/Local News

Philippine precision farming gets a mobile upgrade

Joel D. Adriano

21 July 2010 | EN

[MANILA] Rice farmers in the Philippines will be able to dial a specialised service on their mobile phones to obtain tailored advice on fertiliser use when they plant their crops in September.

Scientists at the Philippine-based International Rice Research Institute (IRRI), officials of the Philippine Department of Agriculture, and local private telecommunications firm Globe, have joined together to create the service that will enable poor farmers to tap into sophisticated 'precision agriculture' techniques commonly used in developed countries. These include technologies such as remote sensing, not often available to Asian farmers.



Dialling a mobile number could provide a quick fertilisation advice

Flickr/limasia

Recent National/Local News

Precision agriculture is recognised as being important for maximising yields while reducing environmental damage. Under the IRRI scheme, the farmer becomes the 'sensor'. After calling a toll free number, the farmer answers a menu of questions, such as whether the farm is upland or lowland, the variety of rice they plant, and the previous season's yield, simply by pressing the appropriate number on the phone keypad.

Their responses determine the advice they receive on fertiliser amounts, timing and sourcing, provided within minutes from a computer-based calculation developed by IRRI called Site Specific Nutrient Management.

Roland Buresh, principal scientist at IRRI, told *SciDev.Net* they have chosen to address fertiliser use because it is the second largest expense in rice farming after labour, and proper application is critical in determining yield.

Wireless Sensor Network

WSN: A large number of **networked, low-cost, low-power, multifunctional**, and **small, intelligent** sensor nodes.

- Radio-frequency transceiver
- Sensors
- Microcontroller
- Power source

Available Technologies

Wireless communication is one of the fastest growing, cutting-edge technologies:

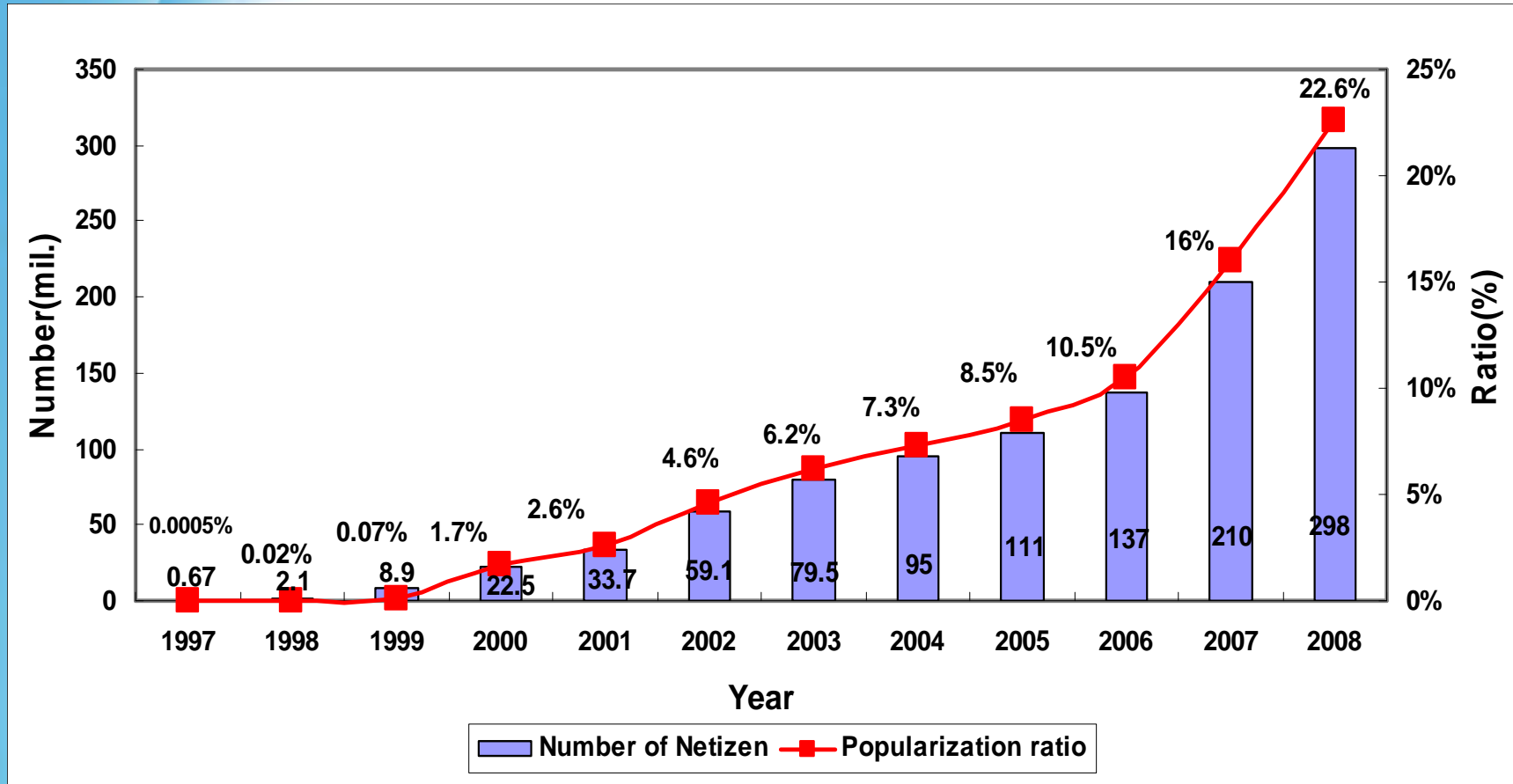
- ❑ Mobile phone users (Frost and Sullivan, 2006)
 - ❑ Global: 2 billions
 - ❑ Asia: 800 millions (40%)
 - ❑ U.S: 160 millions

- ❑ 21% increase from 3-rd quarter, 2005, to 3-rd quarter, 2006

Available Technologies

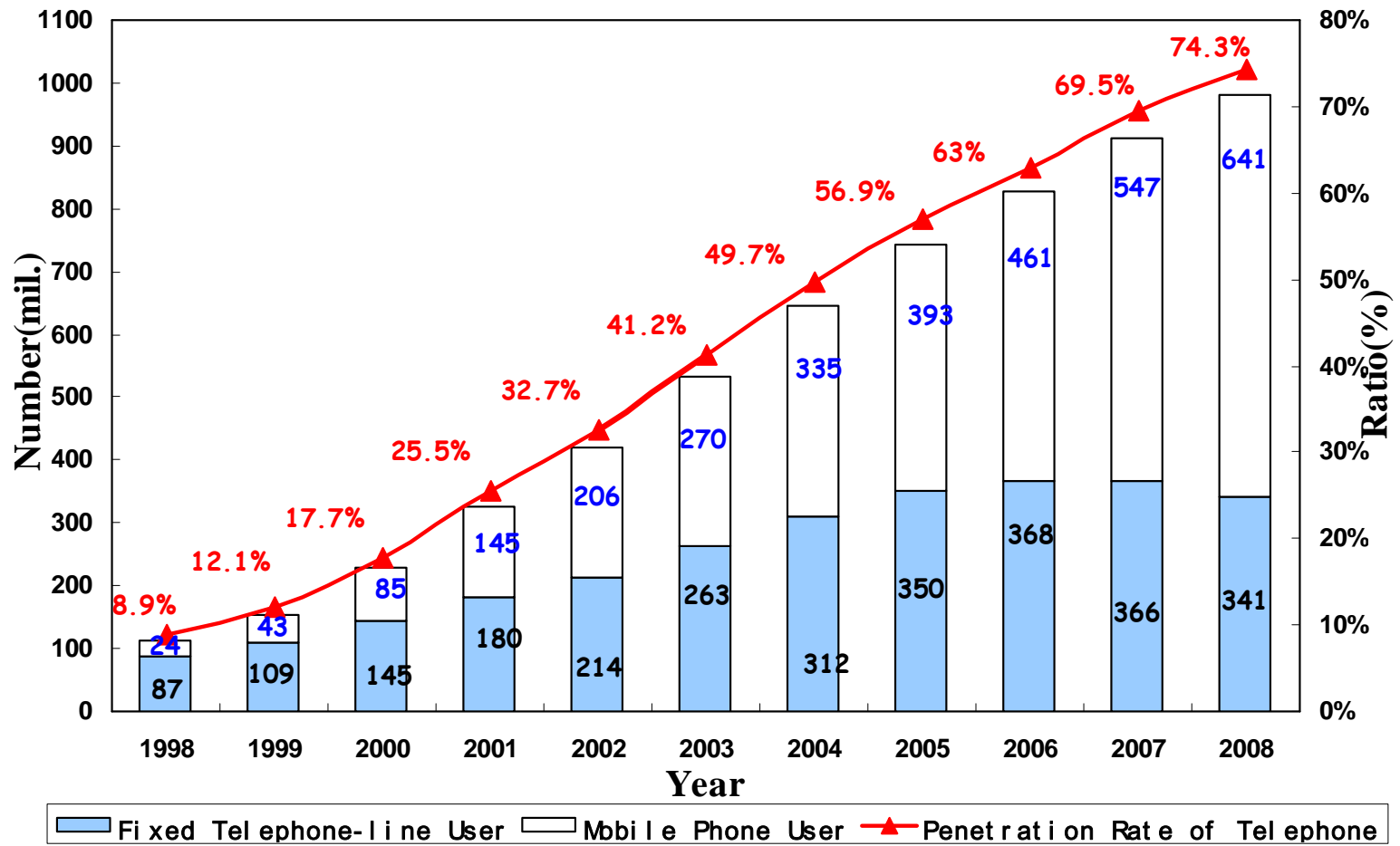
- 3G, International Mobile Telecommunication-2000
 - GSM EDGE
 - CDMA2000
- Services
 - voice
 - video
 - data
- Features
 - Simultaneous voice and data services
 - high data rate
 - 14 Mbit/s downlink
 - 5.8 Mbit/s uplink

Internet Access in China



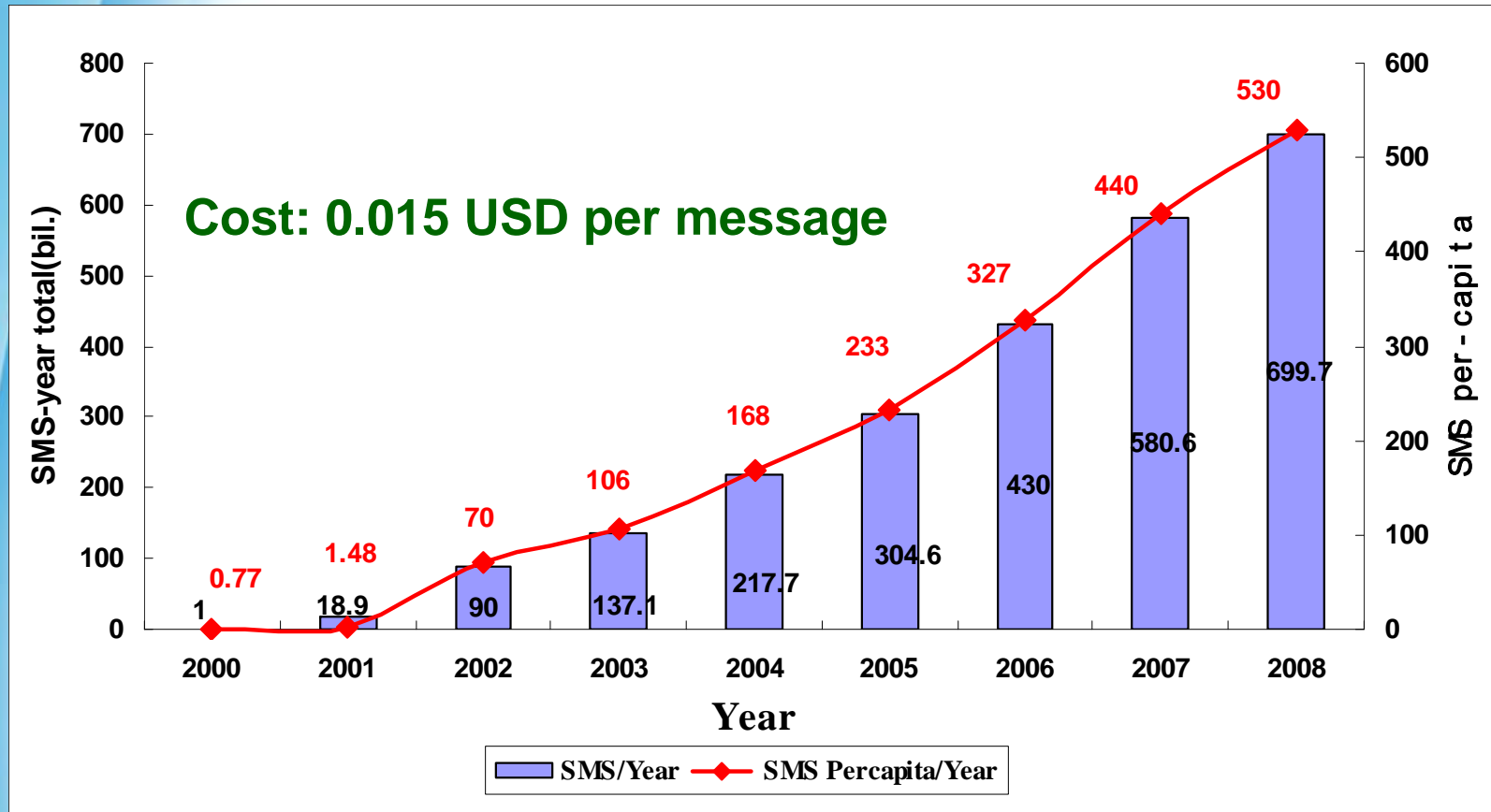
**Totally 298 mil. Internet users (22.6 % population),
>97% township have Internet access.**

Telephone Users in China



74.3 % population and 99.5% rural villages have telephone access, 2008.

Text Messages sent in China



The first mobile phone was used in 1987. It reached 531 million users by 2008.

In 2008, 770 billions short messages were sent; the “per capita” was 530.

Recent National/Local News

The need

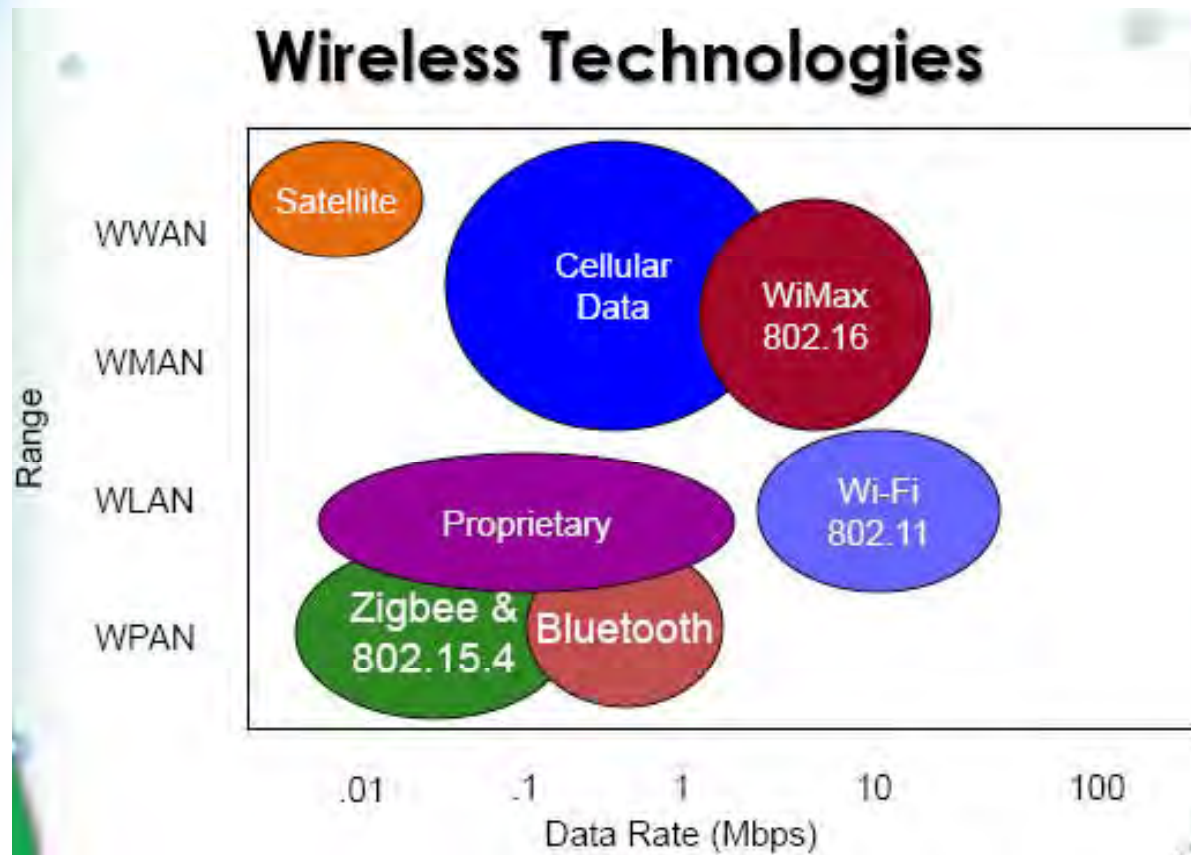
LOS BANOS, 12 August 2010 (IRIN) - Nonilan Sulibat, a rice farmer in Laguna Province, never knows how much fertilizer to use on his 4ha field. "I'm just never sure. I always have questions," the 56-year-old father of six told IRIN.

Technology availability

"In this case, the farmer is the 'sensor'. In this way, we can reach even the smallest farmer," Buresh said. And in a country described as the text messaging capital of the world, with an estimated one billion text messages sent daily, he might be right.

"Filipinos use their cell phones a lot so this is just the kind of technology we should be using. I'm sure it would work well elsewhere in Asia," said Pam Mappala of the Department of Agriculture's Agricultural Training Institute.

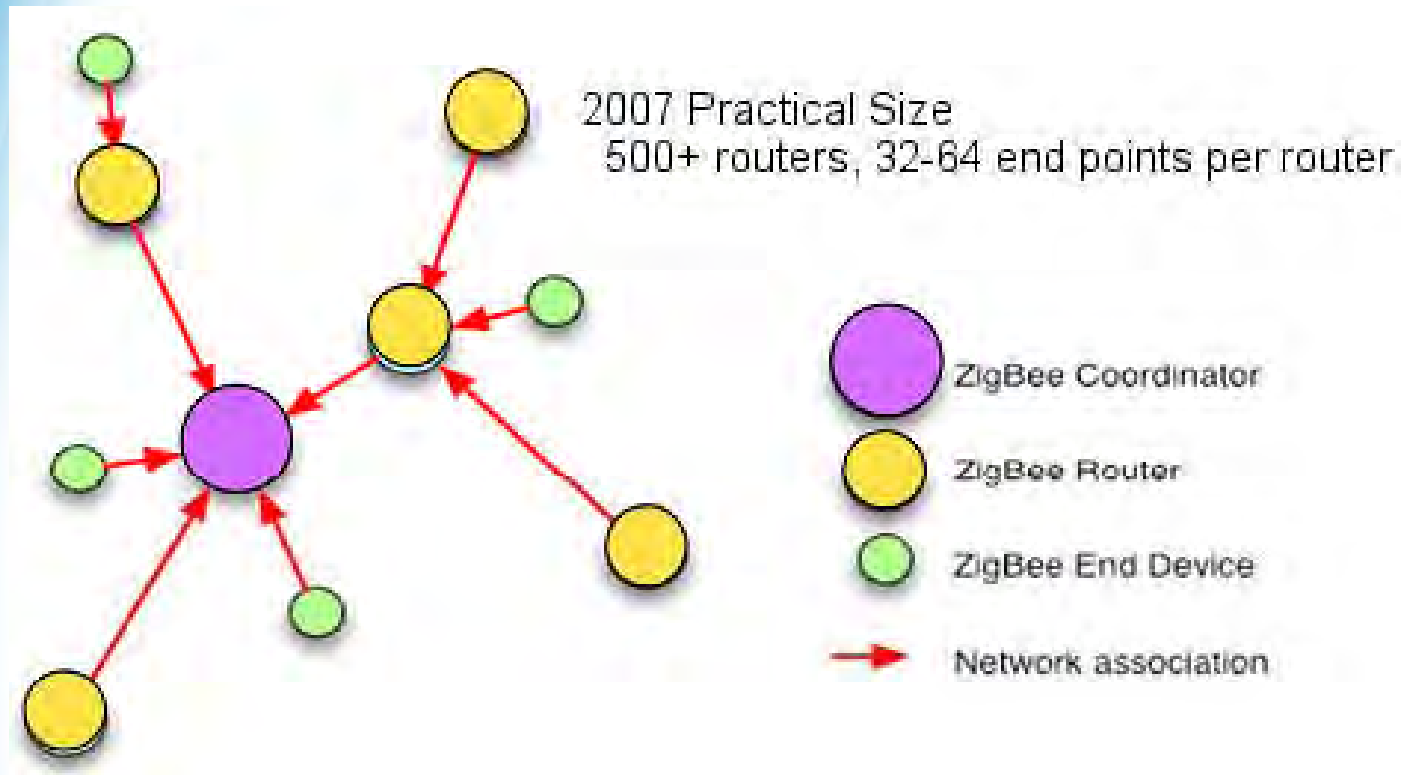
WSN using Satellite Communications



(From J.K. Young, Digi International, 2010)

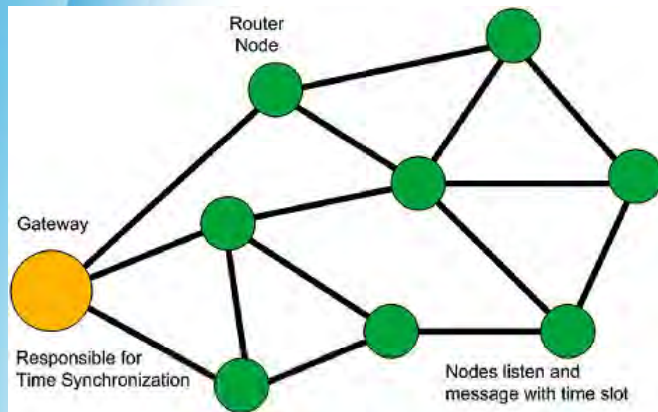
Available Technologies

❑ ZigBee PRO (ZigBee 2007)

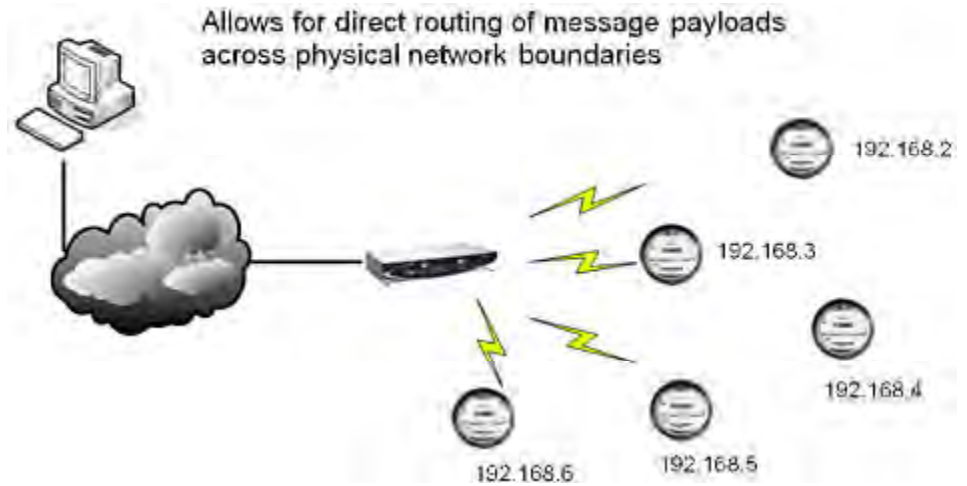


Available Technologies

❑ Wireless HART

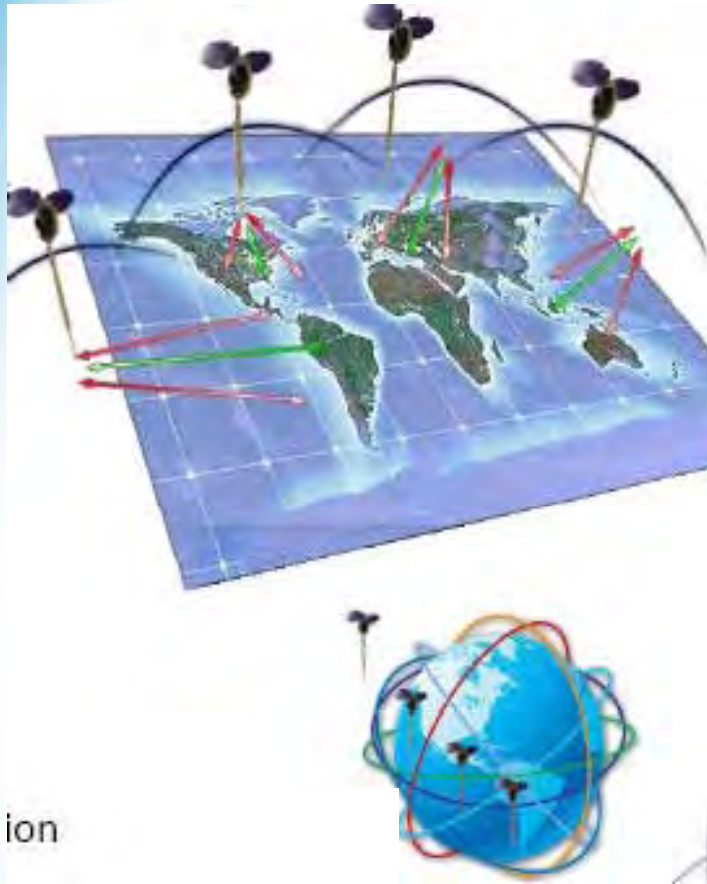


❑ 6LoWPAN ("IPv6 over low power wireless personal area networks")



(Young, 2008; Sensors Magazine)

WSN using Satellite Communications



- ❑ Orbcomm low-Earth orbiting satellites (29)

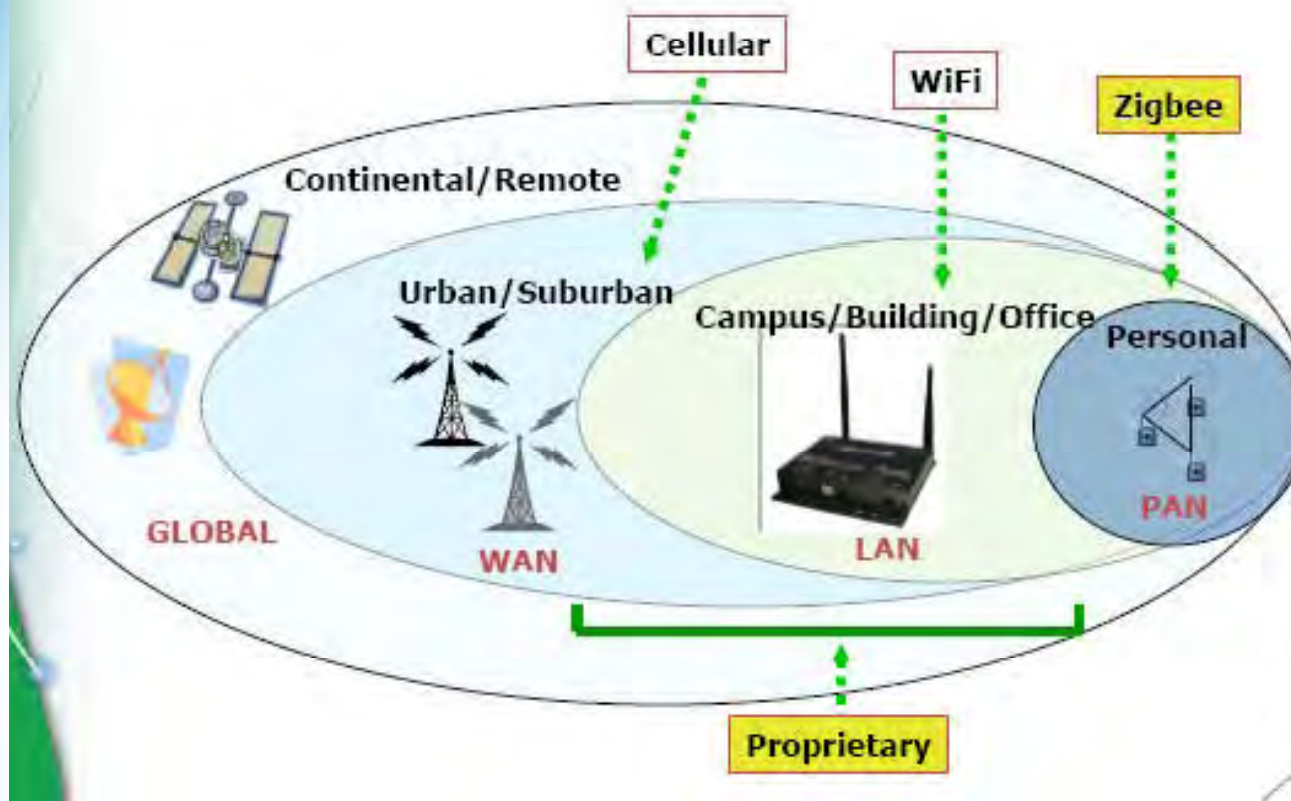
- ❑ Two-way data communication

- ❑ Focused on Machine-to-machine (M2M) applications

- ❑ Over 500,000 existing subscribers

(From J.K. Young, Digi International, 2010)

WSN using Satellite Communications

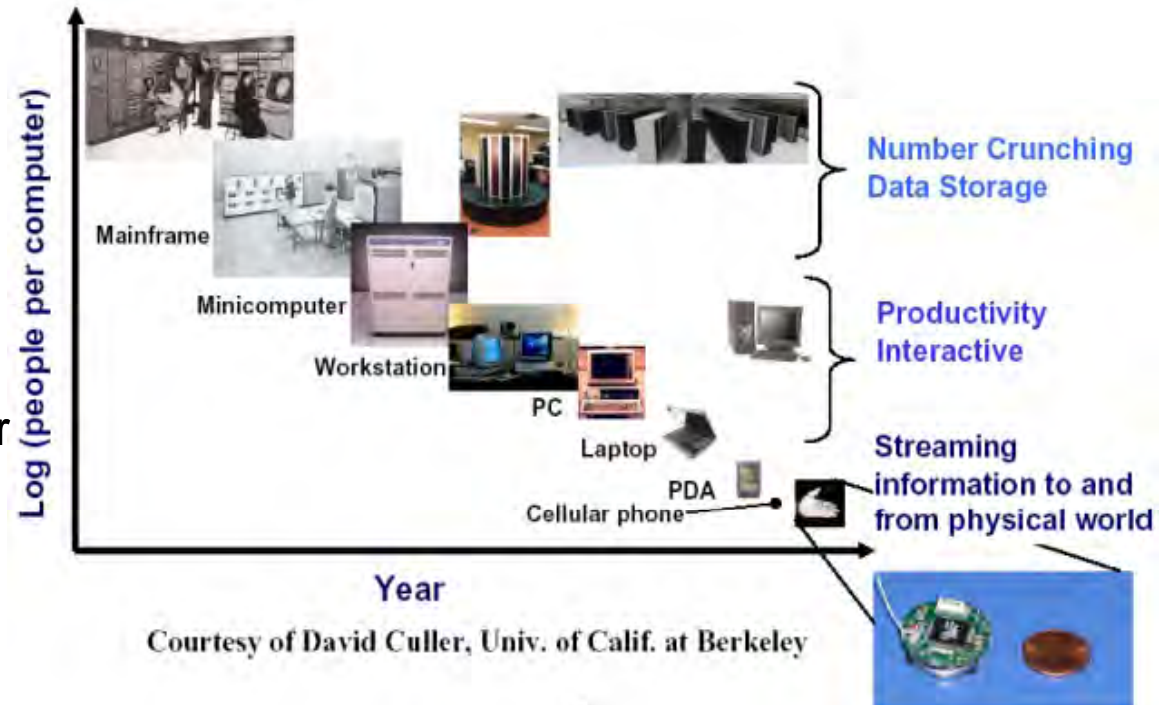


(From J.K. Young, Digi International, 2010)

Internet of Things (IOT)

Three waves of computing

- ❑ Mainframe (1940-1980): One computer shared by many people
- ❑ Personal computer (1980-2000): One computer used by one person
- ❑ “Ubiquitous computing” (2000-): Many computers serve one person



Technology recedes into the background of our lives to free our minds from a large amount of “intelligent” work, so that we can concentrate on the main challenges.

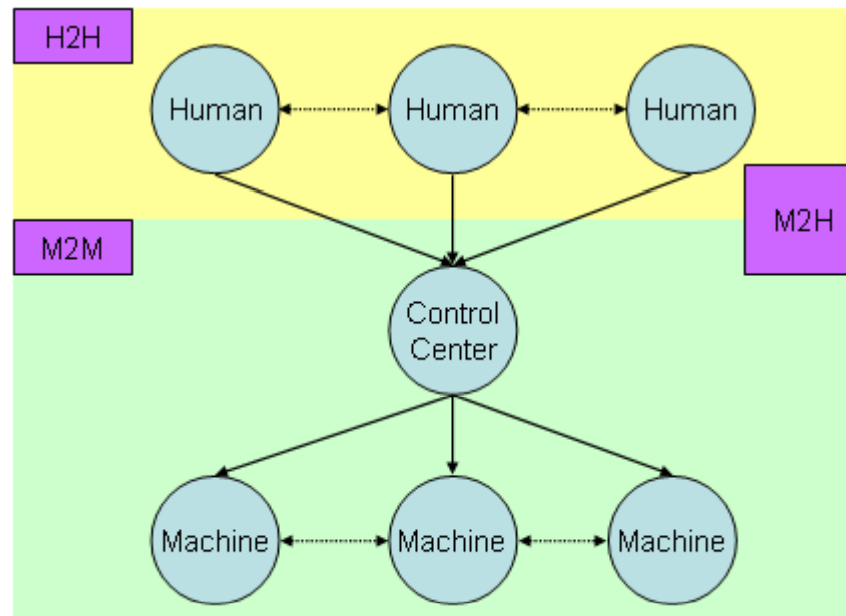
M2M

- ❑ Machine-to-Machine (M2M): technologies that allow both **wireless** and **wired** systems to communicate with other devices of the same ability.
- ❑ M2M uses **sensing** devices to capture an 'event' (temperature, inventory level, etc.), which is relayed through a **network** (wireless, wired or hybrid) to an **application** (software program), that translates the captured event into meaningful information

“M2M”: Machine-to-machine, machine-to-mobile, mobile-to-machine

M2M

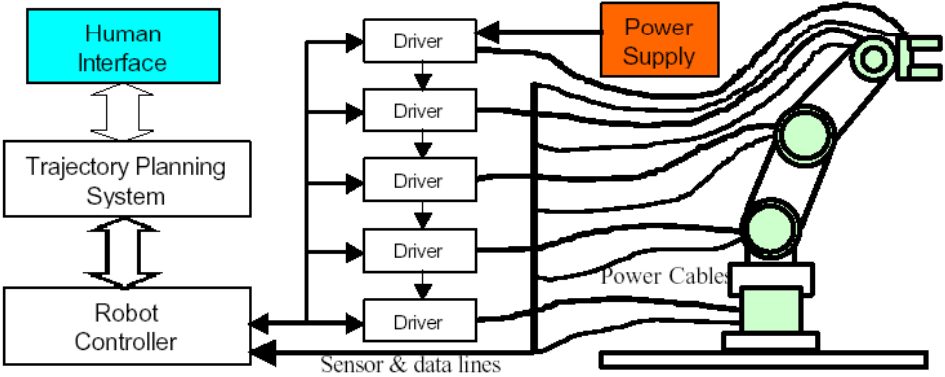
M2M系統運作架構



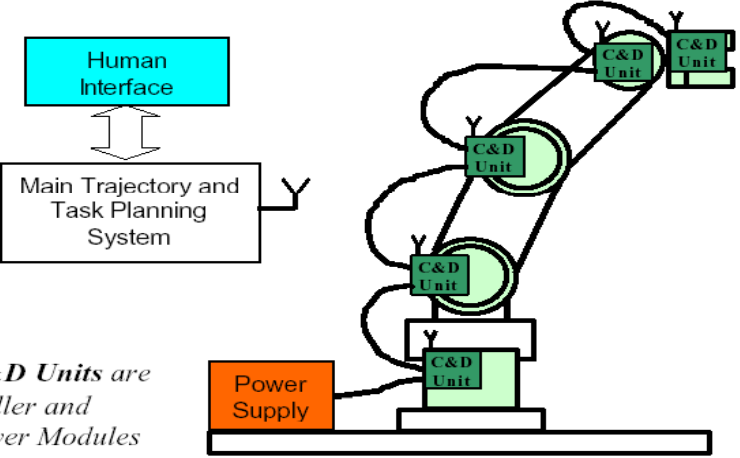
Source: 科技政策研究與資訊中心-科技產業資訊室, 2008/04。

Robot Control

Wired control



Wireless control

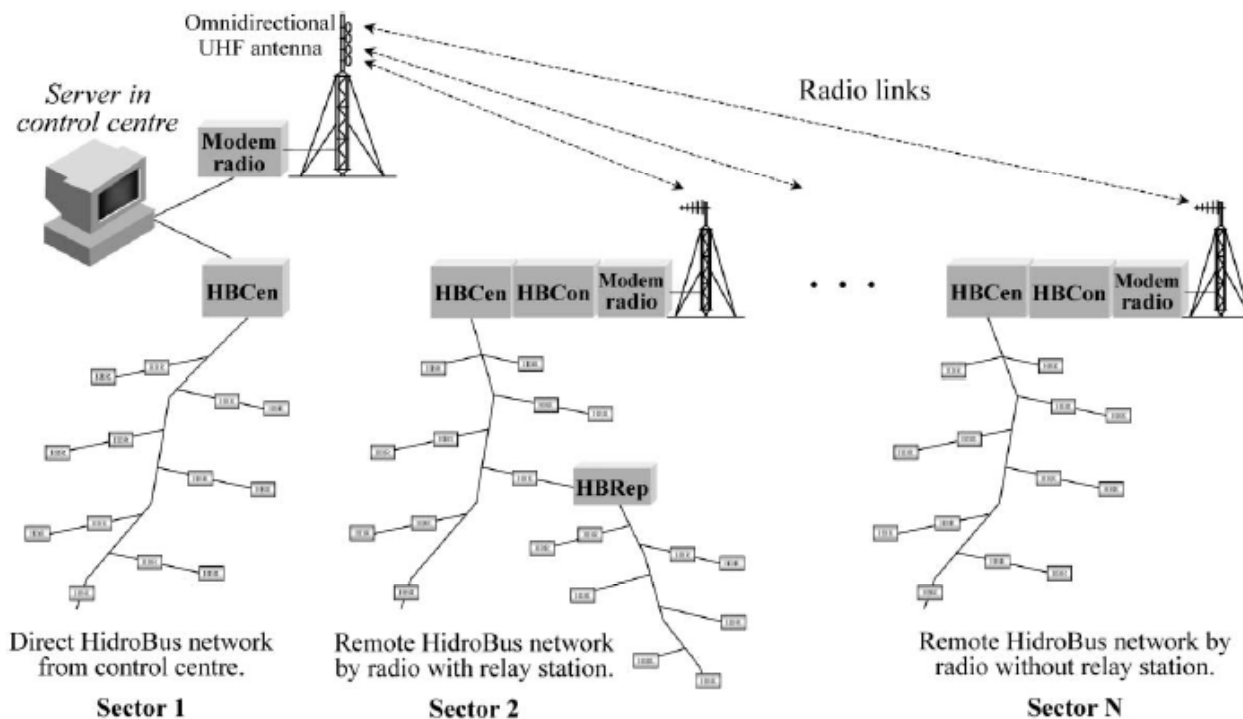


Where: C&D Units are the Controller and Power Driver Modules

Irrigation Control

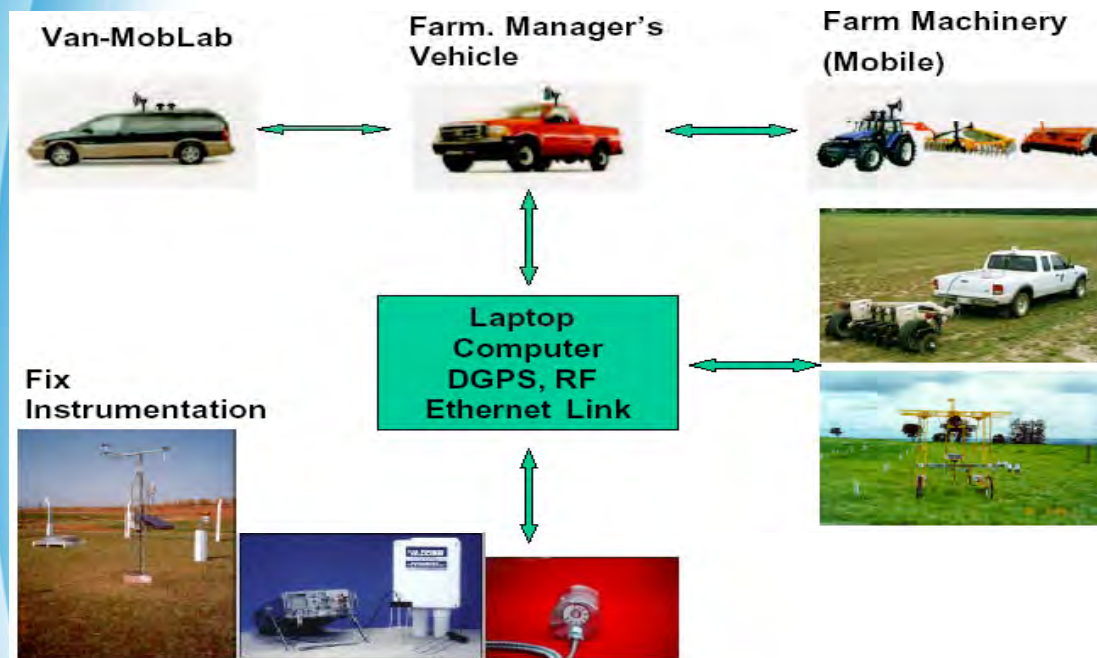
Centralized remote control and supervision of a large area of irrigation land (Spain):

- Controls 1,500 ha irrigation area
- Seven sub-regions, each monitored and controlled by a control sector
- Control sectors communicate via WLAN



Mobile Monitoring and Management

Mobile laboratory network for data monitoring and management using Wireless LAN (Brazil)



Measurement:

- Soil water content
- Soil compaction
- Soil fertility
- Biomass
- Leaf area index
- Local weather
- Insect infestation
- Disease infestation
- Weed Infestation
- Yield

Fleet Operation Monitoring and Management

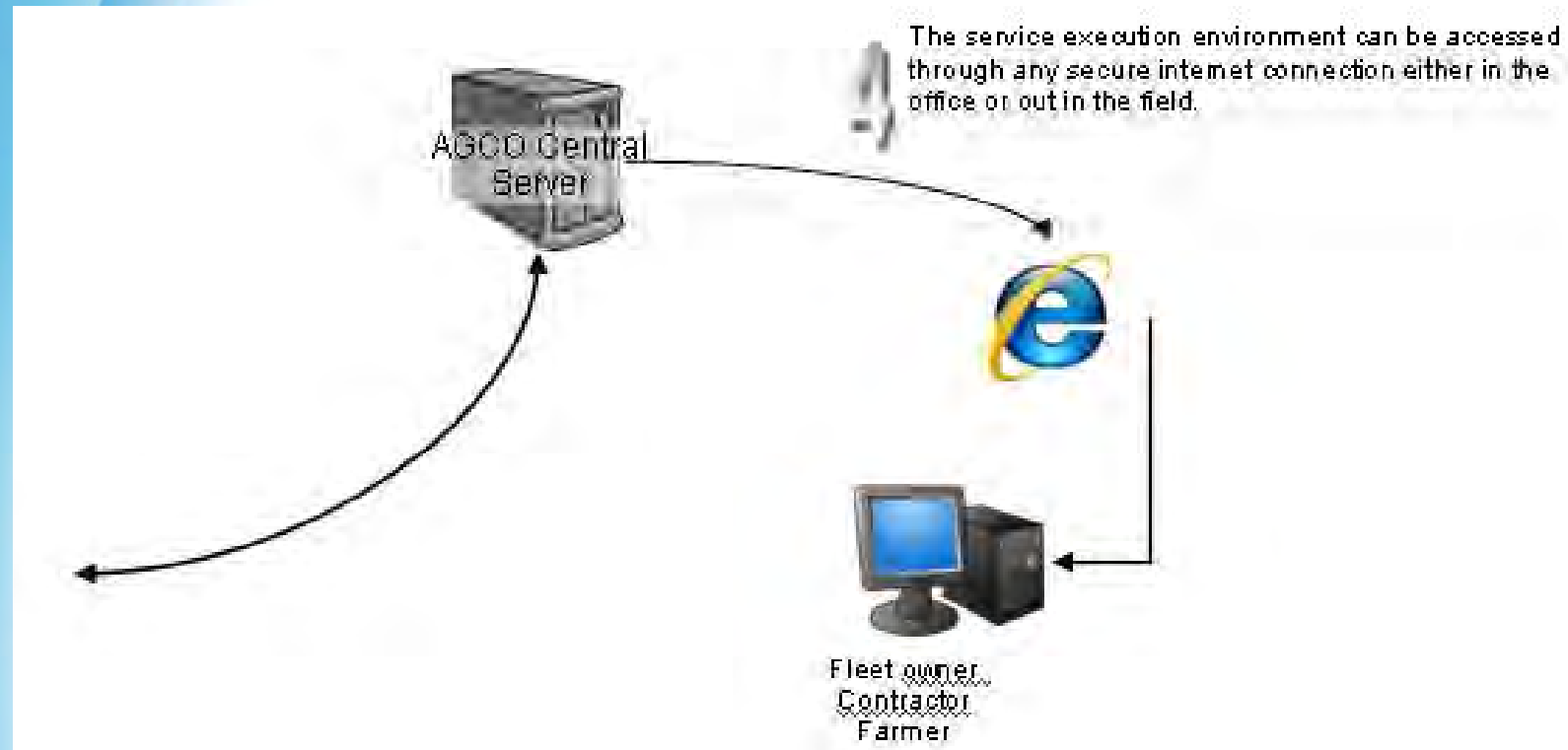
- Remote monitoring of fleet operation
- Homogenize incompatible data from diverse legacy vehicles
- Improve fleet operation efficiency through fleet management in near real-time

Fleet Management



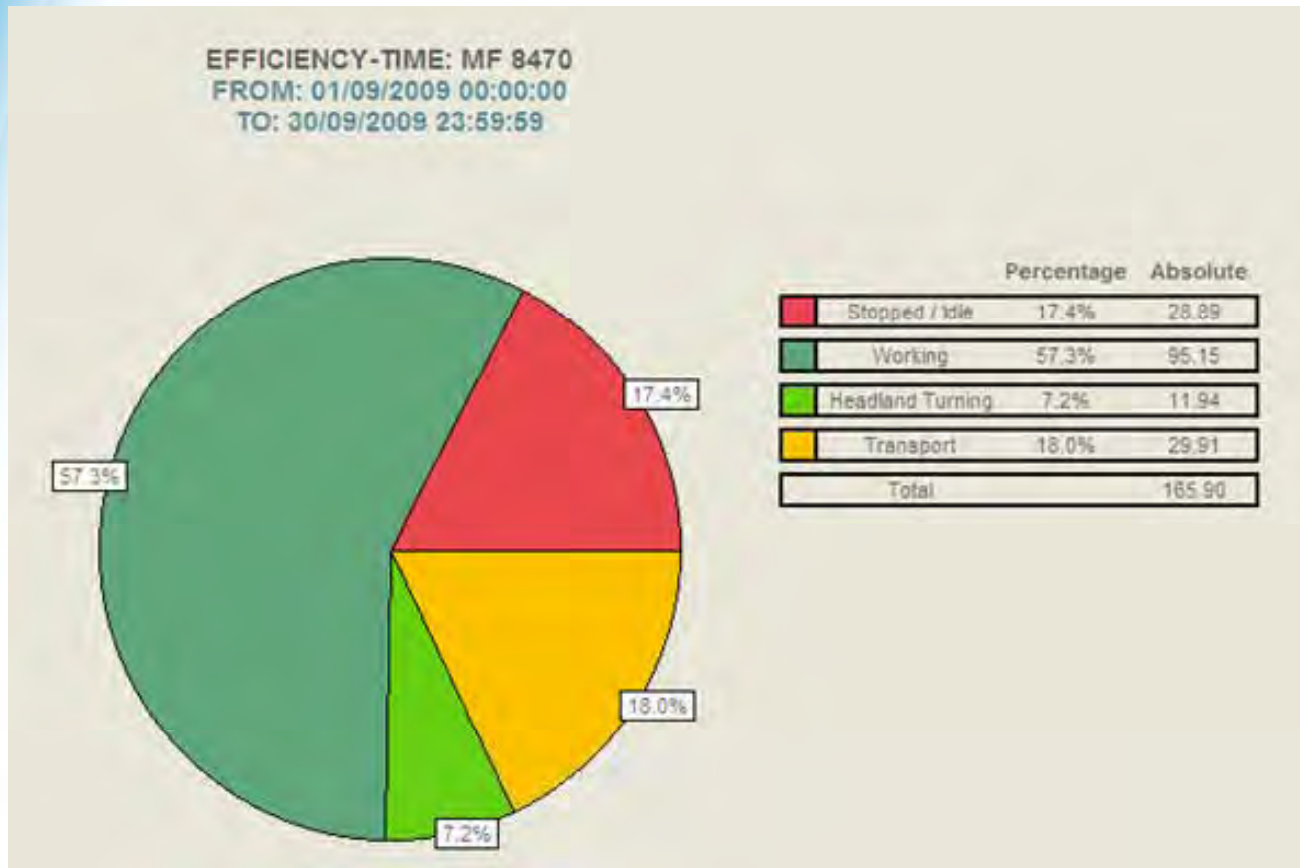
(From C. O'Neil, AGCO, 2010)

Fleet Management



(From C. O'Neil, AGCO, 2010)

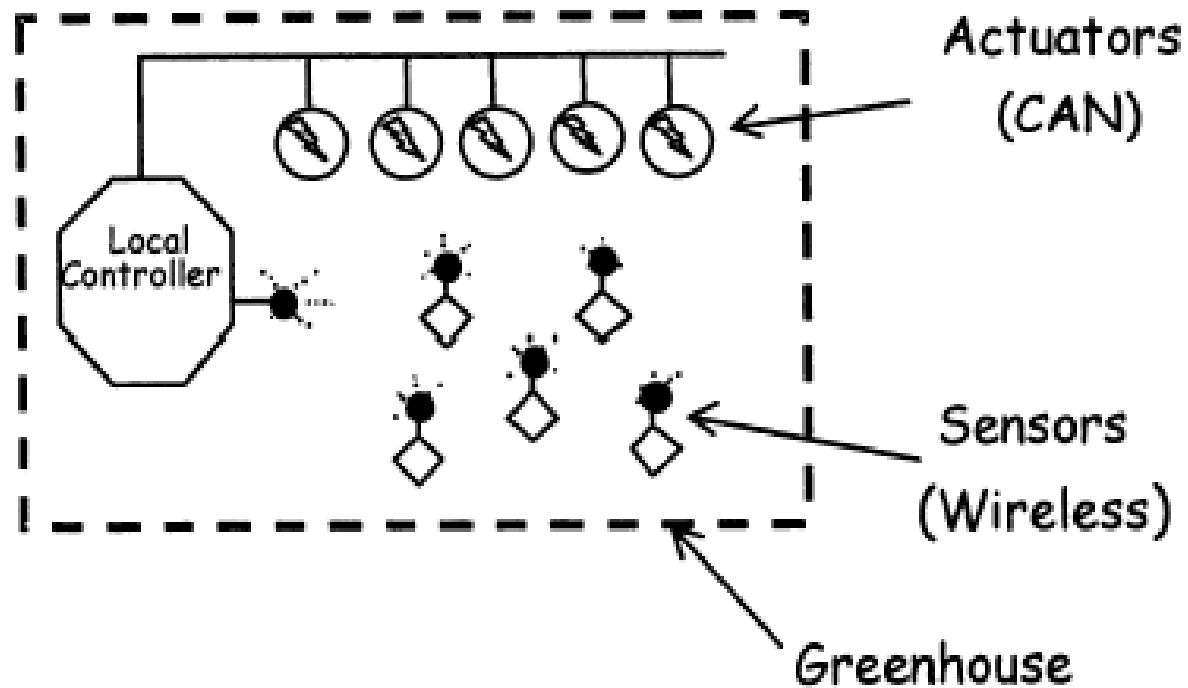
Efficiency Measurement



(From C. O'Neil, AGCO, 2010)

Green House Management

Greenhouse Management (Portugal):

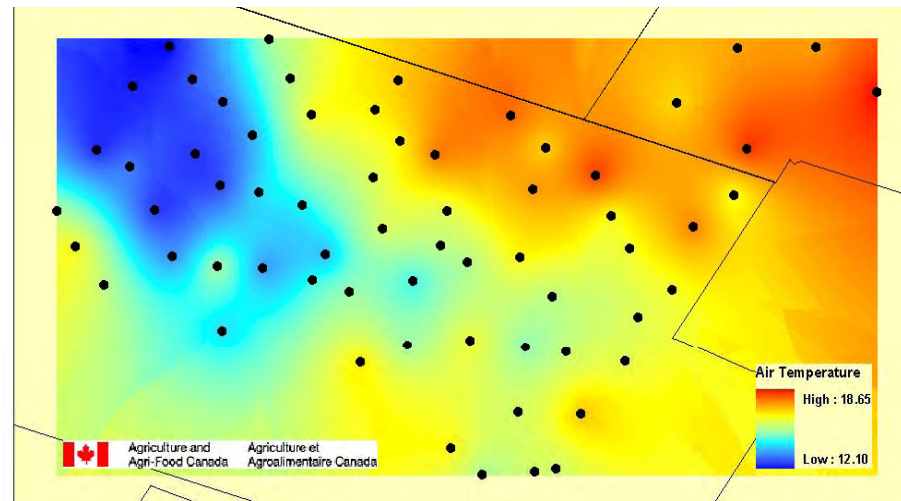
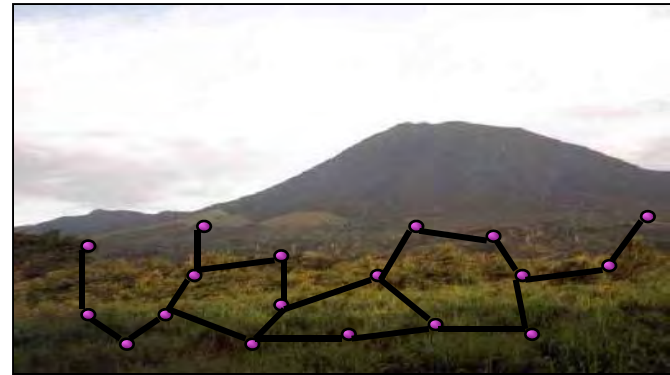


Wireless network + CAN

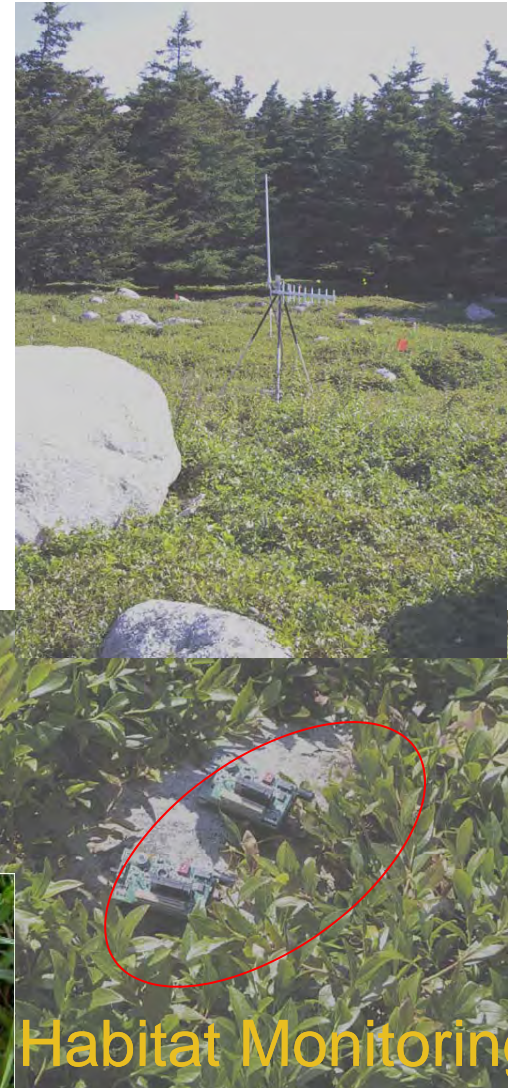
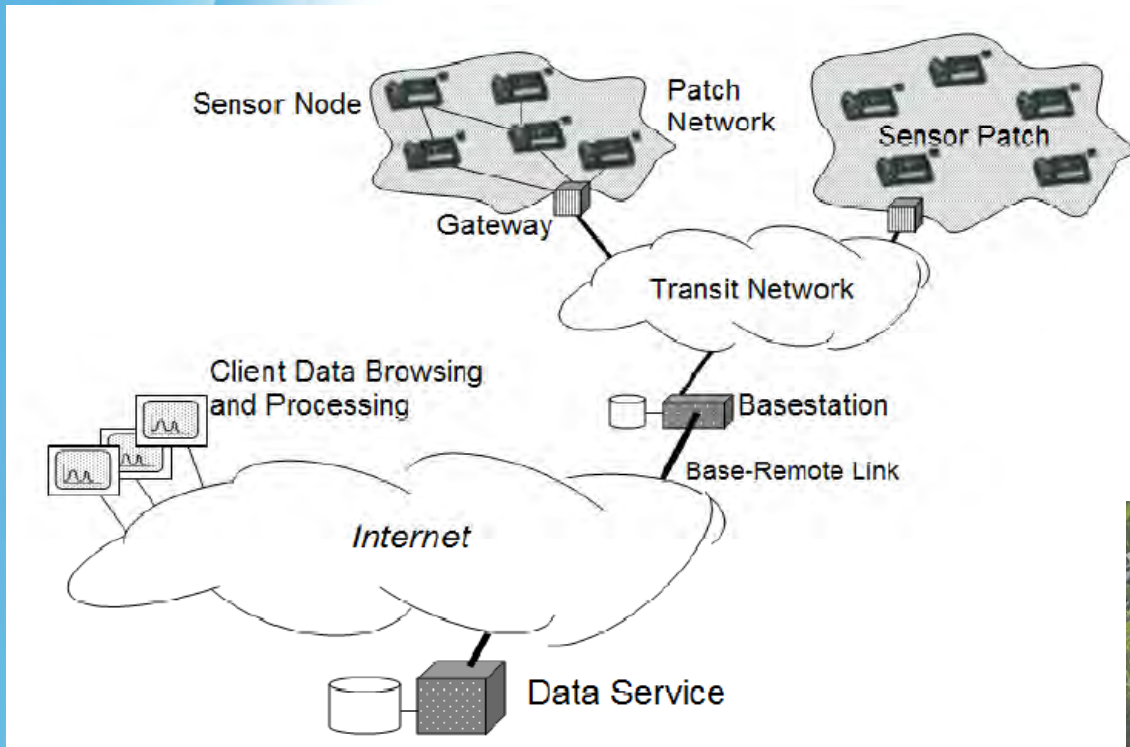
Vineyard Environmental Monitoring

Vineyard Environment monitoring:

- 65 Nodes in 1 acre
- Sensors
 - temperature
 - moisture
 - sun-light
- Applications
 - avoid frog damage
 - manage irrigation
 - determine fertilizer application
 - arrange harvest schedule



Habitat Monitoring



Habitat Monitoring



Livestock Monitoring



A sensor network for sow monitoring

- Tracking in large pens
- Heat period alert
 - Motion detectors
 - Correlation between movement of sows and their heat period

Traceability System

- Traceability systems (RFID)
 - Animal identification and health monitoring
 - Food packaging
 - Transportation
 - Asset tracking
 - Food inspection

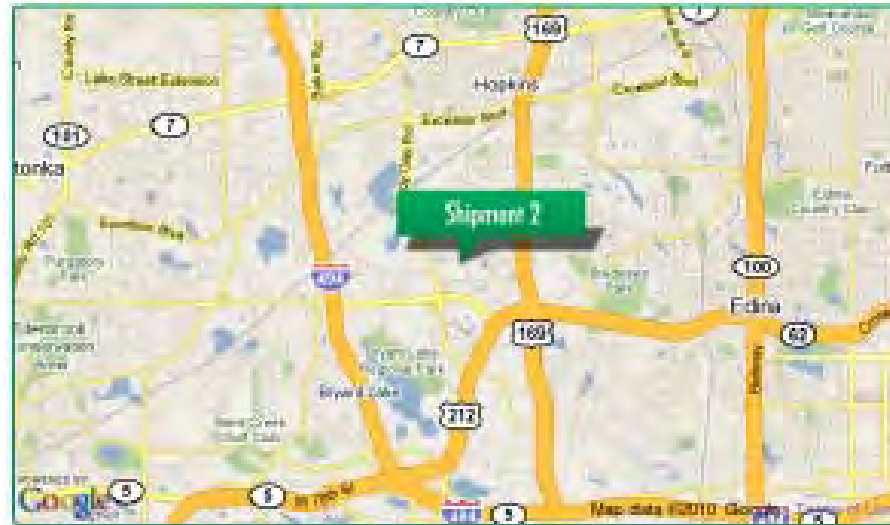
RFID

I can't believe I ate the whole thing!



<http://www.smartspaces.csiro.au/applic/smart-lands.htm>

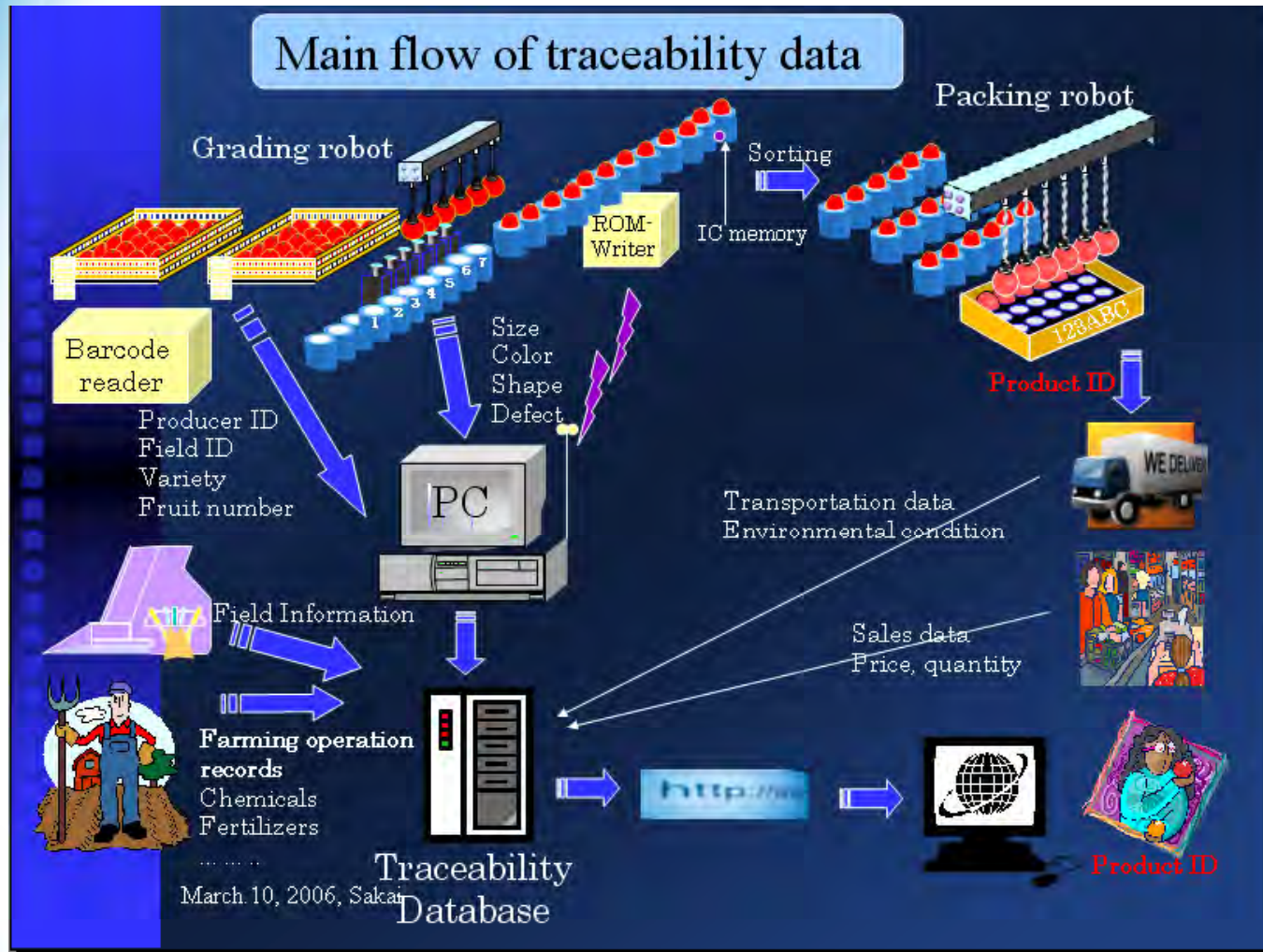
Asset Tracking



HOW IT WORKS



Traceability



Issues

- ❑ Signal coverage
- ❑ Path loss
- ❑ Energy harvesting
- ❑ Data handling
- ❑ Distributed, open infrastructure - IOT

Cellular Coverage - Three-tier WSN

- ❖ **Local sensor network**

 - ZigBee – 100 m

- ❖ **Mid-range radio network**

 - (in areas with no cellular coverage)

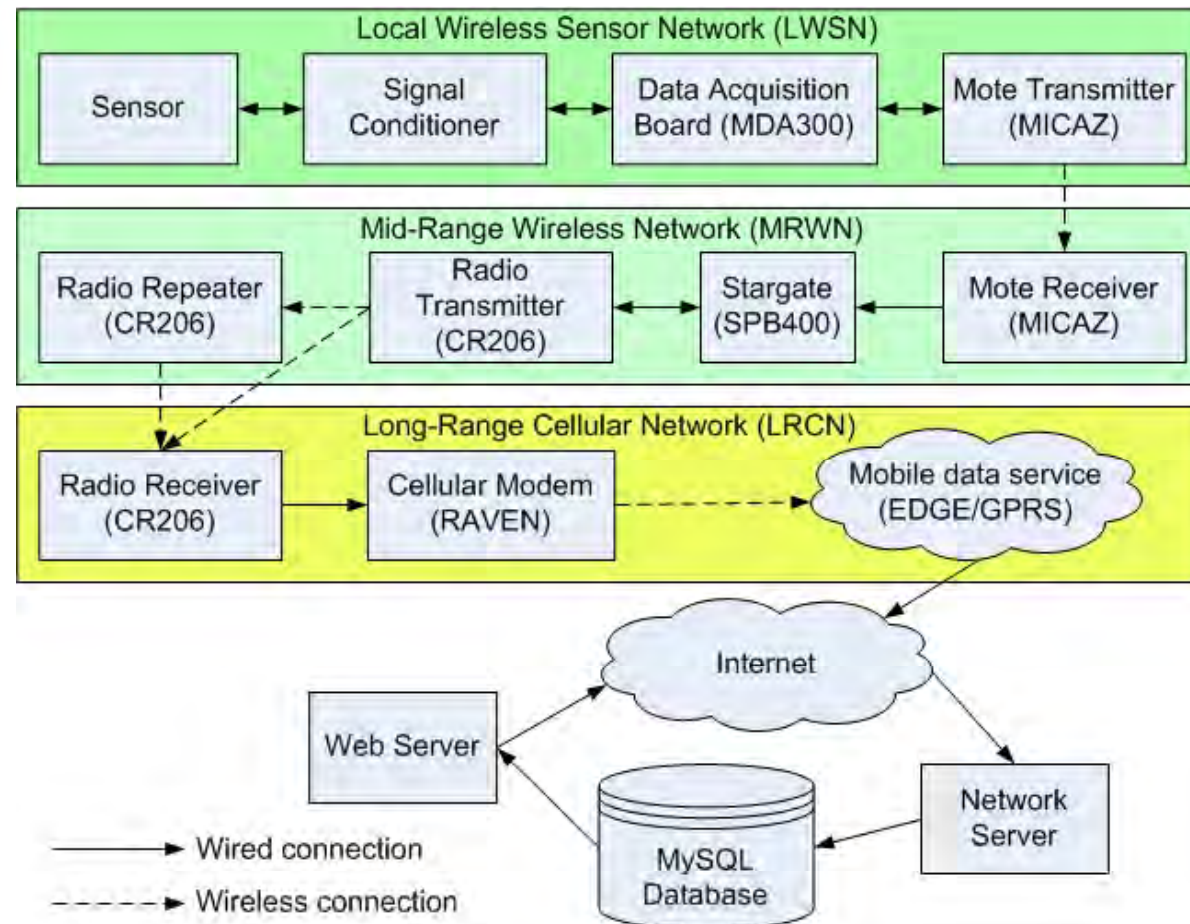
 - 915 MHz spread spectrum radio – 10 km

- ❖ **Cellular network**

 - ❖ GSM

 - ❖ CDMA

Three-tier Wireless Sensor Network

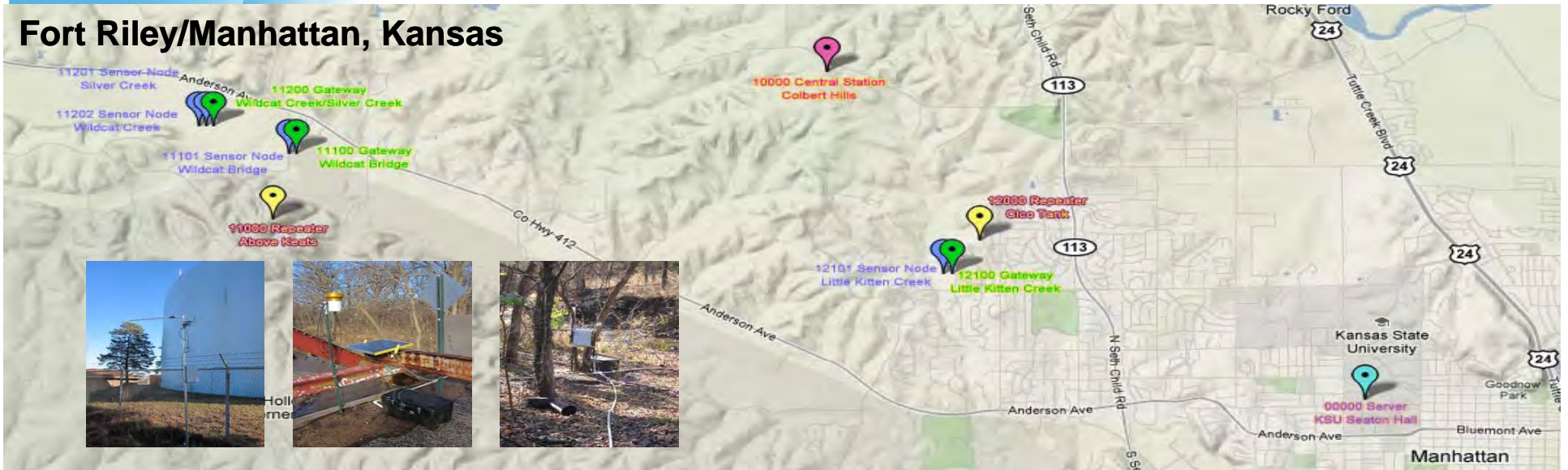


Three-tier WSN



Deployment

Fort Riley/Manhattan, Kansas



Aberdeen Proving Ground, Maryland

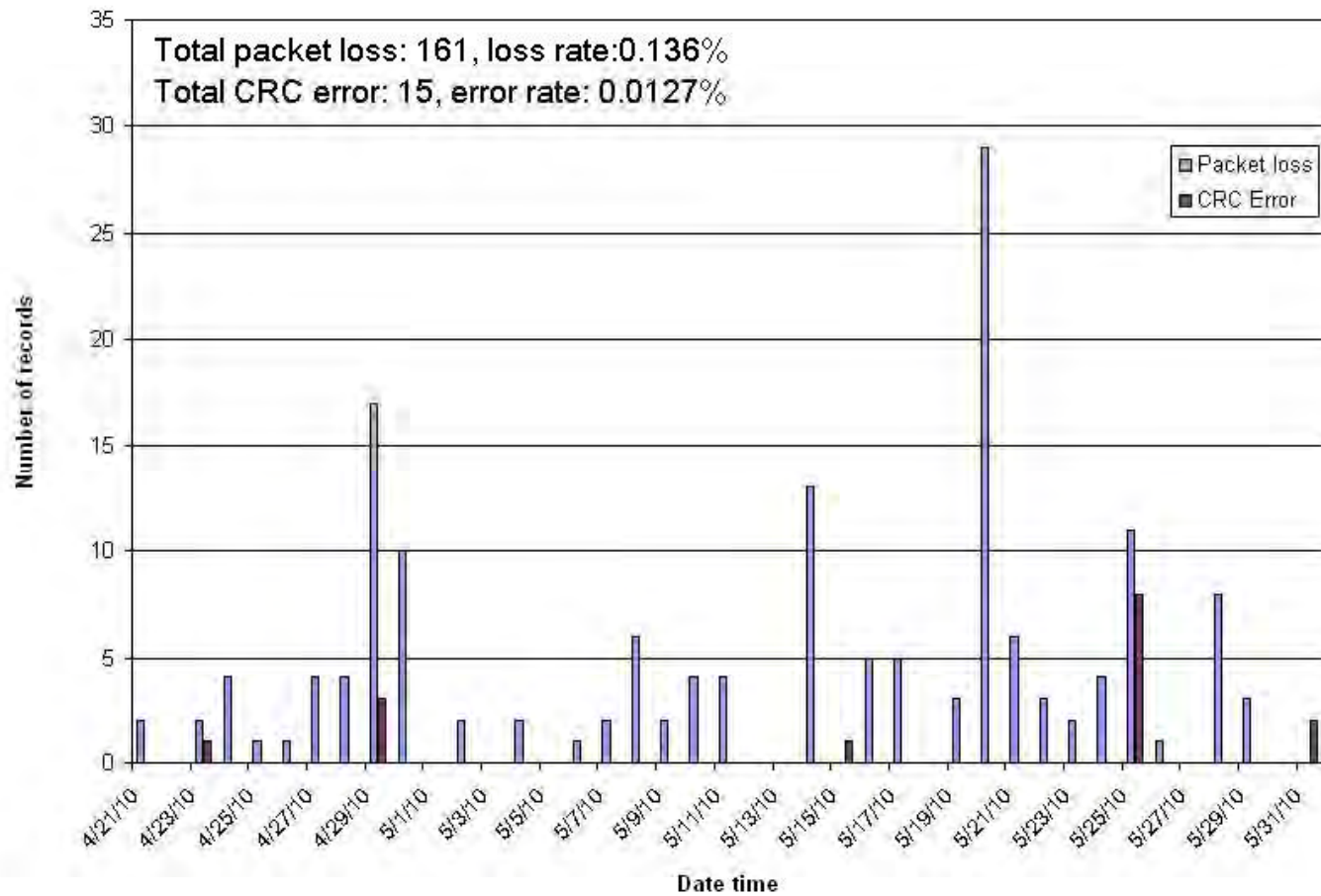


Deployment



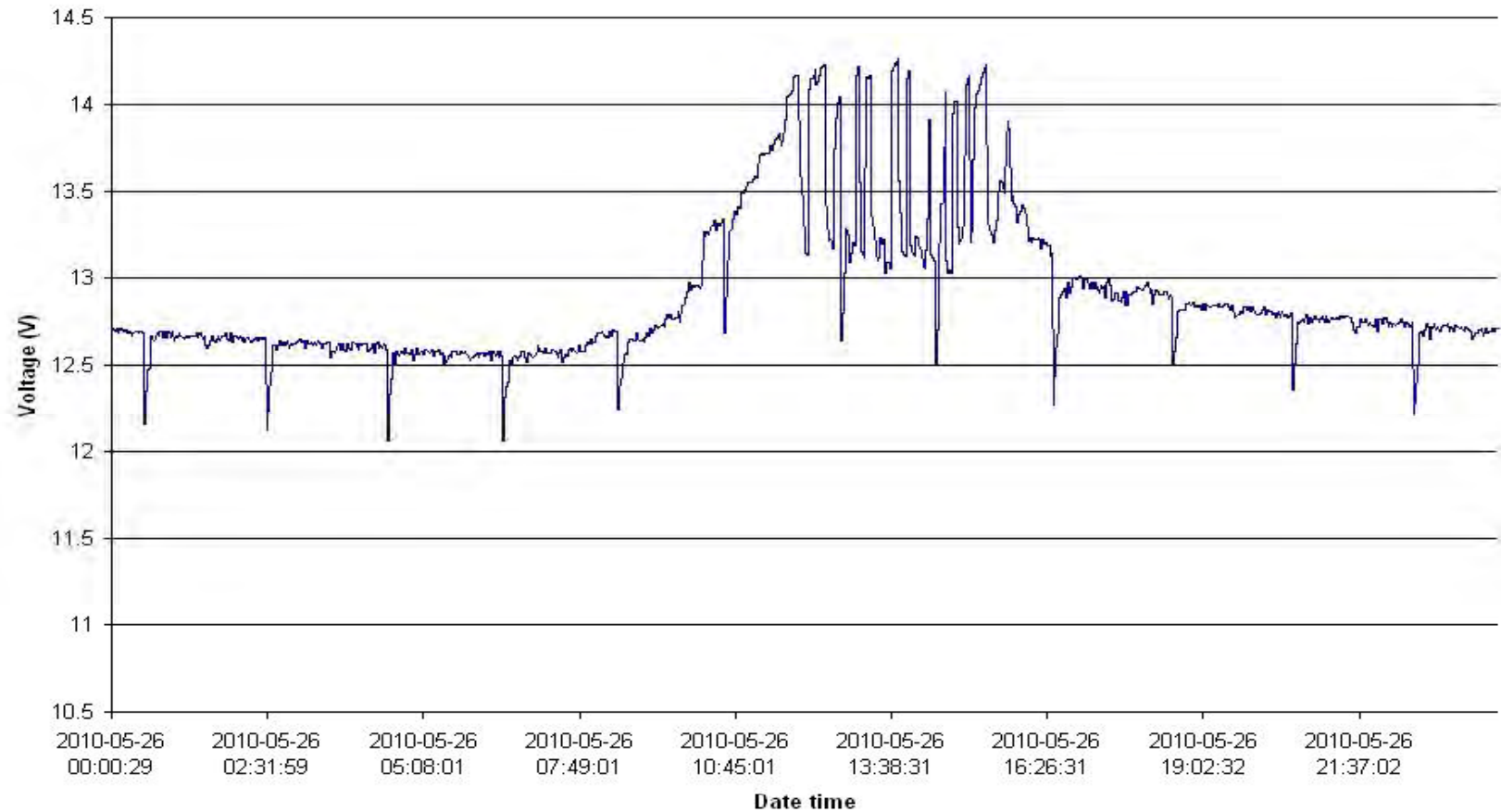
Packet Loss

Packet loss and CRC Error at Upatoi south, Ft. Benning, GA



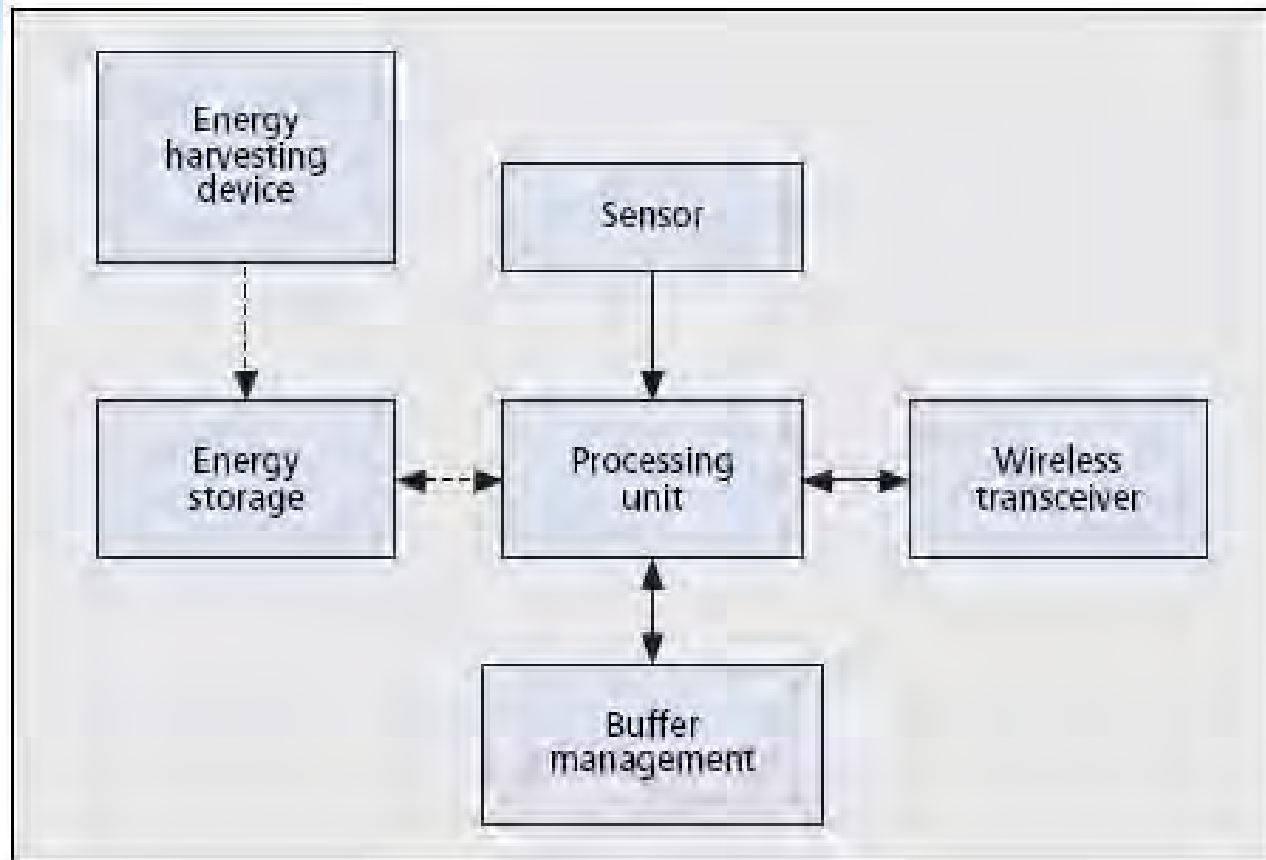
Energy Harvesting

Air-blast effect reflected on the gateway power supply at Little Kitten Creek, Manhattan, KS



Energy Harvesting

A WSN sensor node



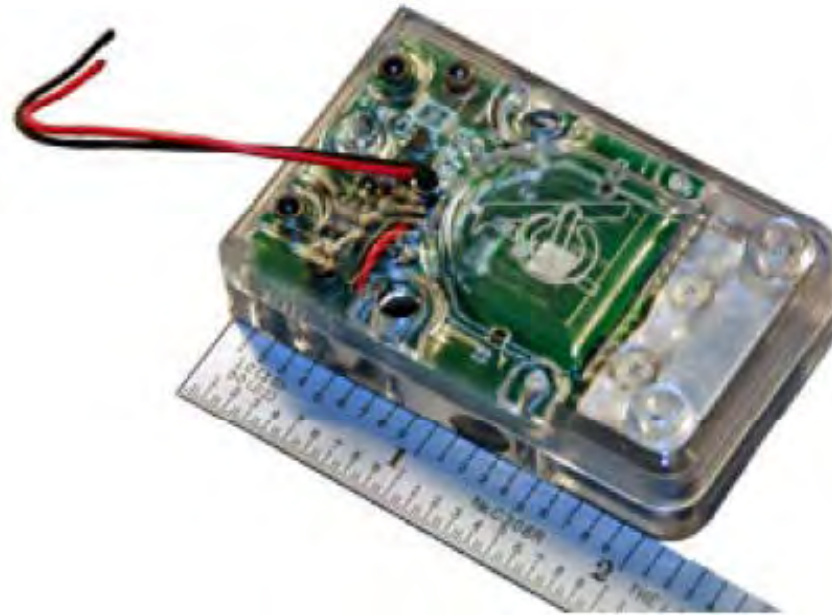
The most common energy storage devices are batteries and supercapacitors (Niyato, 2008; IEEE)

Energy Harvesting

- Solar cell
- Vibration-based
 - Miniature AC generator
 - Piezoelectric effect
- Thermoelectric
- Air/fluid dynamic
- Electromagnetic waves

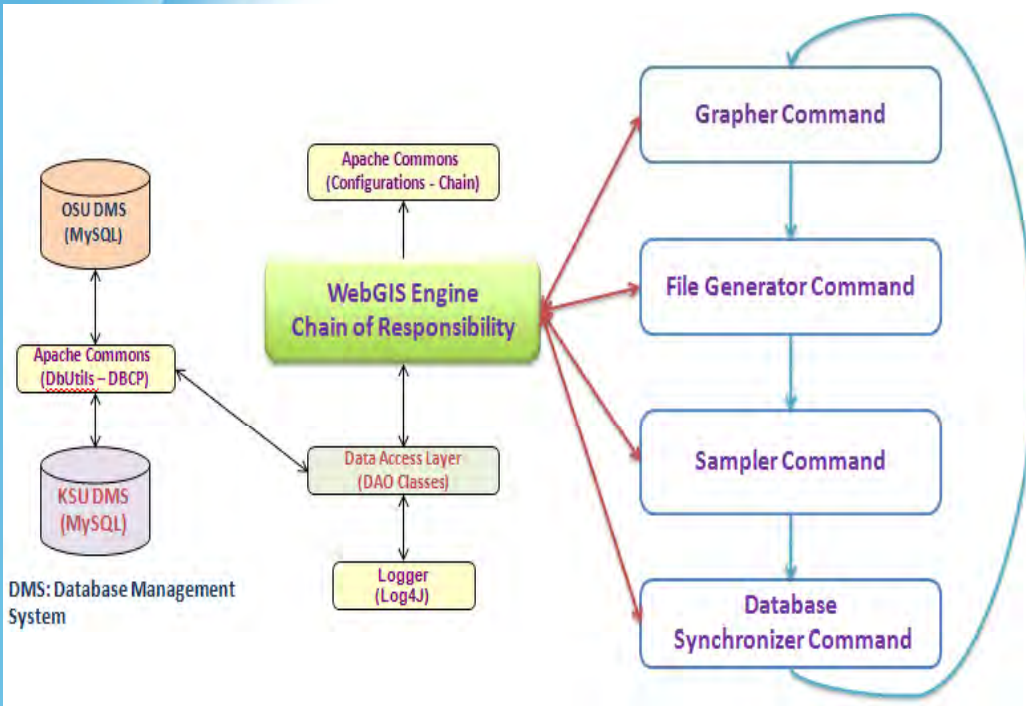
Energy Harvesting

Energy-harvesting devices



A piezoelectric energy harvester (Tanner, 2008; Sensors Magazine))

Data Handling – Web GIS



Continuous Segment Contamination Monitoring System
Approved by: 445127

Click on the address to browse data:

- Control Station - Colbert Hills
- FTP Web Server - KSU System Hall
- Pleasant - East Kelly
- Glennway 2 - Walnut Creek
- Glennway 2 - Silver Creek
- Glennway 2 - Lost Kinn Creek
- Sevier Fork - Silver Creek
- Shelby sensor node on north bank
- Shelby sensor node on west bank
- Shelby sensor node on south
- Shelby sensor node on north
- Control Station - Ft. Bennett
- Pleasant - Ft. Bennett

Copyright © 2008-2009 Oklahoma State University, Kansas State University, Aberdeen Test Center

View data for available for location:

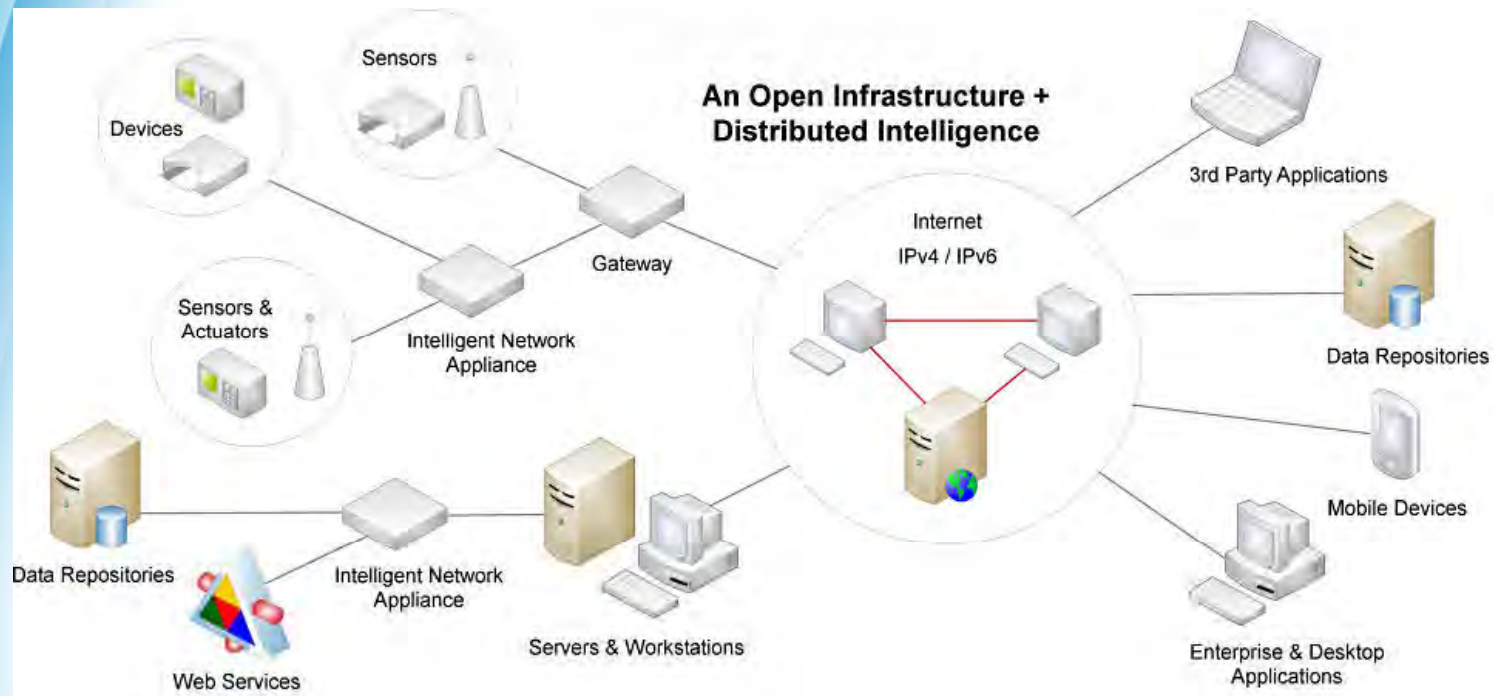
08W LED ON-1	Control Area	Low	High
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08W LED ON-3	Control Area	Low	High
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08W LED OFF-80	Control Area	Low	High
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08W LED OFF-81	Control Area	Low	High
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08W LED ON-88	Control Area	Low	High
08W LED OFF-88	Control Area	Low	High
08W LED ON-89	Control Area	Low	High
08W LED OFF-89	Control Area	Low	High
08W LED ON-90	Control Area	Low	High
08W LED OFF-90	Control Area	Low	High
08W LED ON-91	Control Area	Low	High
08W LED OFF-91	Control Area	Low	High
08W LED ON-92	Control Area	Low	High
08W LED OFF-92	Control Area	Low	High
08W LED ON-93	Control Area	Low	High
08W LED OFF-93	Control Area	Low	High
08W LED ON-94	Control Area	Low	High
08W LED OFF-94	Control Area	Low	High
08W LED ON-95	Control Area	Low	High
08W LED OFF-95	Control Area	Low	High
08W LED ON-96	Control Area	Low	High
08W LED OFF-96	Control Area	Low	High
08W LED ON-97	Control Area	Low	High
08W LED OFF-97	Control Area	Low	High
08W LED ON-98	Control Area	Low	High
08W LED OFF-98	Control Area	Low	High
08W LED ON-99	Control Area	Low	High
08W LED OFF-99	Control Area	Low	High
08W LED ON-100	Control Area	Low	High
08W LED OFF-100	Control Area	Low	High

Data Handling - Web GIS

Functions:

- Data display – graphical and tabular
- Map display – Google Earth
- Data downloading
- Query and simple statistics
- Remote disaster alert – signal abnormality and power failure
- Daily report via email
- Report generating using the Jasper reporting system

Distributed, Open Infrastructure - IOT



A next-generation network, with applications that support an **open infrastructure** deployed on servers, workstations, and intelligent network appliances
(Esposito, 2008; Sensors Magazine)

