Wireless Sensor Networks at IGCAR

On behalf of WSN Team

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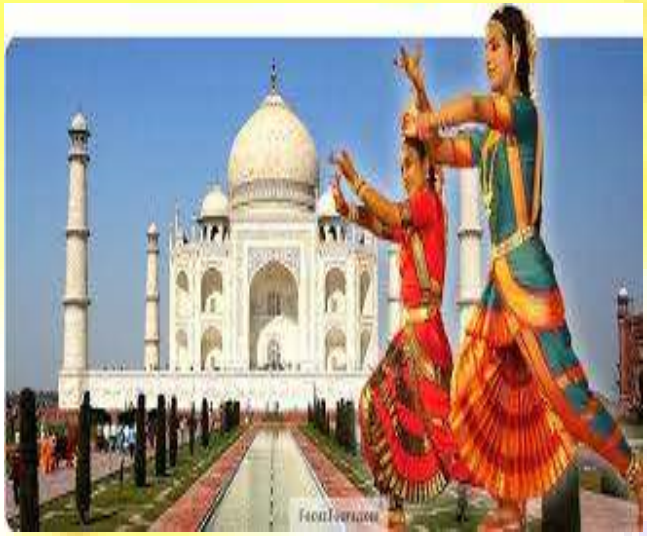


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- **Design & Developments**
- **Qualification Tests**
- **Deployments**
- **Software Used**
- **Ongoing Activity**

Design and Development of WSN Node

- The wireless sensor nodes used to monitor the plant parameters in the nuclear facilities should be rugged enough to withstand the harsh environmental conditions like high temperature, radiation, water proof, etc.
- As the commercially available WSN nodes are mostly suitable for lab testing purpose, the WSN sensor nodes and routing nodes have been designed and developed in house.
- It operates at 2.4 GHz ISM band. The microcontroller used is based on ARM architecture which offers high performance for very low power consumption.
- The node gets power from the mains and the battery backup is also provided.
- The radios used were either XBee or XBee-PRO RF Modules. It was engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks.
- Modulation scheme used is O-QPSK and Spreading method is DSSS.

Characteristics of the in house developed WSN node

Max. CPU speed		60 MHz	
Flash		512 kB	
SRAM		32 kB	
Interfaces		2x UARTs, I2C, ISP support, 5 GPIO	
Peripherals		10 bit 8 channel ADC, 10 bit DAC, 2x 32-bit Timers, 12bit External ADC, SHT15 sensor, external memory	
Radio used		**XBee**	**XBee-PRO**
Tx current drawn		45mA	295mA
Rx current drawn		40mA	45mA
Sleep current drawn		10nA	10nA
Radio range	outdoor	90m	1600m
	indoor	30m	90m
Datarate		250Kbps	250Kbps
Tx power		1mw/0dBm	63mw/18dBm
Rx power		$1x10^{-9}$mw/ -91dBm	$1x10^{-10}$mw / -100dBm

Design and Development of WSN Router Node

- Each sensor nodes comprises of microcontroller, power supply unit, memory unit, radio transceiver unit and signal conditioning circuit unit for interfacing variety of sensors as per application.
- According to the magnitude of the network and the coverage area, the multihopped network needs multiple routes for forwarding the data to base station.
- As the routing node does not require any general purpose ports, sensing unit and ADC, it has been designed and developed only with transceiver unit.
- The WSN router node consists of XBee PRO transceiver, 7.4V/3Ahr rated rechargeable Li-ion battery, Battery charging circuit, relay, 230V AC/ 12V DC converter, Line filter, Metal Oxide Varistor (MOV), fuse and regulator ICs, LED indicators for Associate, RSSI, power ON and Battery ON, Reset button.

Design and Development of Gateway Nodes

Wi-Fi Gateway

This extender board has been designed to include Wi-Fi interface to the sensor node. Along with this extender board, the sensor node can be used to act as a gateway between 802.15.4 and 802.11 networks.

RF gateway

RF gateways are meant to interface the different frequency radios. This extender board has been designed to include 868/915 MHz based IEEE 802.15.4 radio interface to sensor node. Along with this extender board, the sensor node can be used to act as a gateway between 2.4 GHz and 868/915 MHz networks

Ethernet Gateway

Instead of collecting the data using basestation node, to increase the flexibility, the Ethernet gateways have been designed. They serve as a connecting link between a heterogeneous network formed by wired and wireless links.

Development of Network Analyzer Tools

the sniffing tools were developed in-house to analyze the network operation during different phases of development and deployment.

EMI/EMC Qualification of WSN Sensor & Router nodes

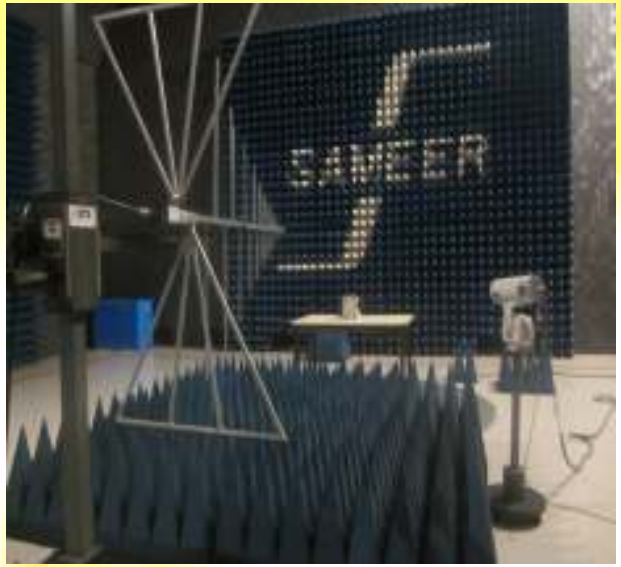
The Industrial Grade WSN sensor as well as router node was subjected to Electro-Magnetic Interference/ Electro-Magnetic Compatibility (EMI/EMC) tests which include both emission and susceptibility tests because it is used in industrial environments where EMI can happen and can cause damage to the node or the node can affect the environment.

The following tests were carried out as per the PFBR standards.

- Electrostatic discharge immunity test (IEC 61000-4-2)
- Radiated susceptibility test (IEC 61000-4-3)
- Electrical fast transient immunity test (IEC 61000-4-4)
- Surge immunity test (IEC 61000-4-5)

EMI/EMC Qualification of WSN Sensor & Router nodes Cont……..

- Conducted radio frequency immunity test (IEC 61000-4-6)
- Power frequency magnetic field test (IEC 61000-4-8)
- Pulse magnetic field immunity test (IEC 61000-4-9)
- Damped oscillatory wave test (IEC 61000-4-12)
- Ring wave immunity test (IEC 61000-4-12)
- Harmonics, inter harmonics & low frequency immunity test (IEC 61000-4-12)
- Conducted emission test (CISPR 11)
- Radiated emission test (CISPR 11)
- Harmonic current emission test (IEC 61000-3-2)



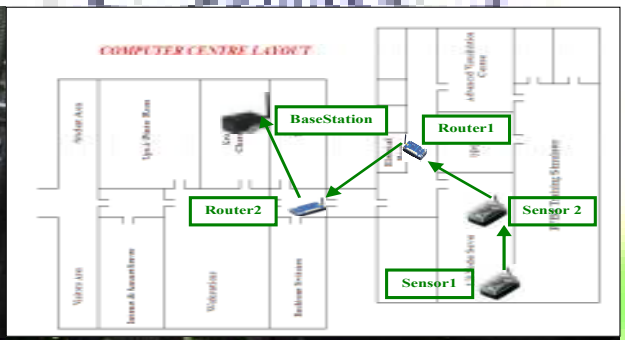
WSN Deployments in Nuclear facilities

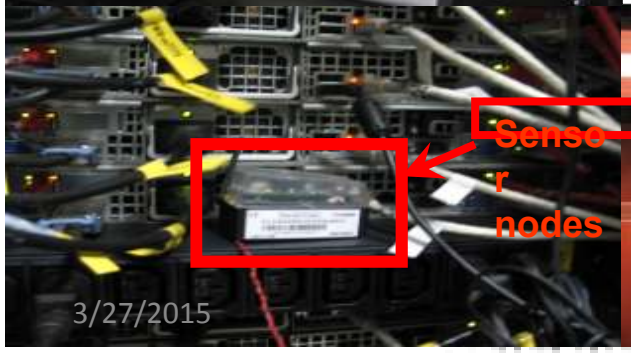
- Temperature and Humidity monitoring at Computer Centre, CD
- Temperature and Humidity monitoring at SADHANA, FRTG
- Temperature, Vibration and Flow measurements at FBTR
- Sodium Leak Detection at INSOT, FRTG
- Electrochemical Cell potential and Actinide drawdown Process

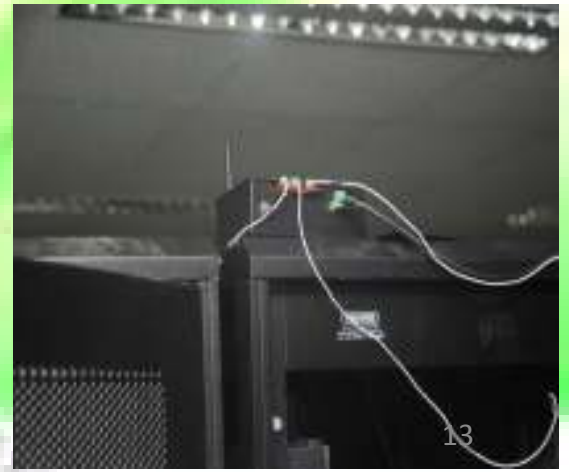
Temperature Monitoring at Pyro Lab, RCL

WSN DEPLOYMENT AT CC

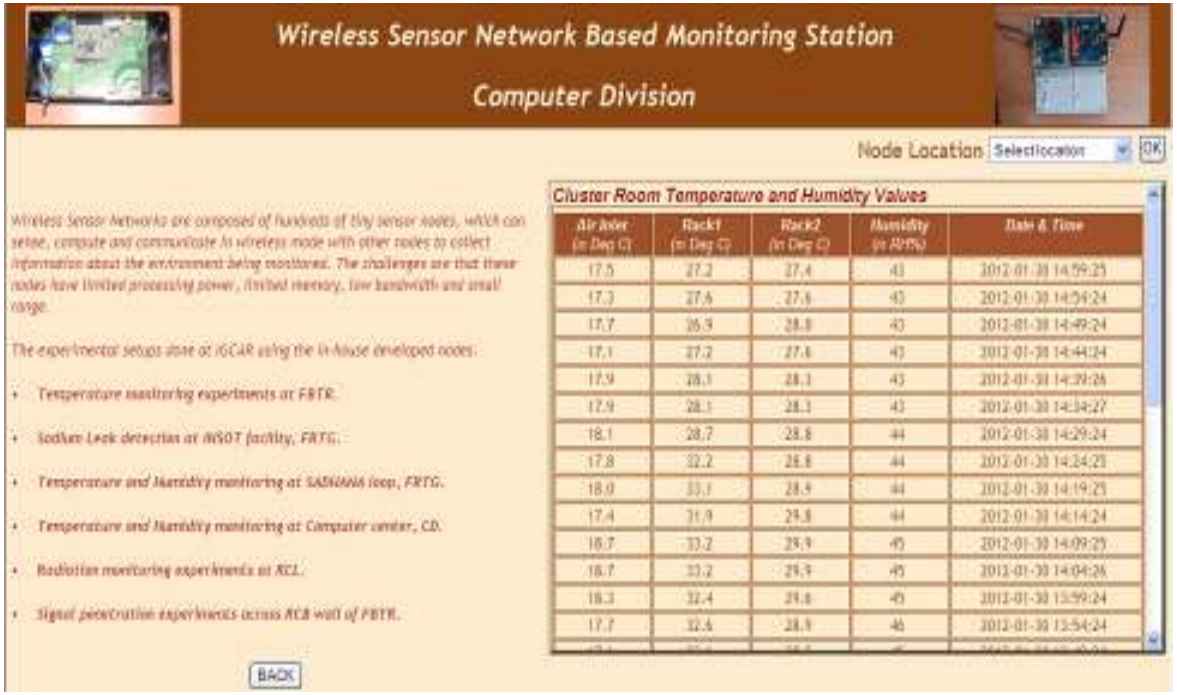
- The temperature and humidity at the 128 node High Performance Computing Cluster has to be maintained in 16° C and 50 %RH respectively for its smooth functioning. If the cooling is not proper and temperature raises beyond 22° C, the HPC cluster will auto shutdown due to overheating.
- The wireless sensor node senses and transmits the current value of temperature and humidity to the base station.
- The data collected at base station is made available to the administrators of HPC for necessary action.








WSN based Temperature Monitoring.vi
Cluster
Rack1 Temperature 31.9 Deg C
Rack2 Temperature 28.5 Deg C
Air Inlet Temperature 18.1 Deg C
Room Humidity 44 RH %
Rack1
Rack2
Temp
Hum
Amplitude
Time 2012-01-30 12:22:00
Server
Room Temperature 23 Deg C
Room Humidity 48 RH %
Temp
Hum
Time 2012-01-30 12:22:00
Simulator
Room Temperature 23 Deg C
Room Humidity 58 RH %
Datarate 5
COM1
Temp
Hum
Time 2012-01-30 12:22:00
Campus Backbone
Room Temperature 19 Deg C
Room Humidity 50 RH %
Datarate 5
Temp
Hum
Time 2012-01-30 12:22:00
- Developed By WSN Lab/CD

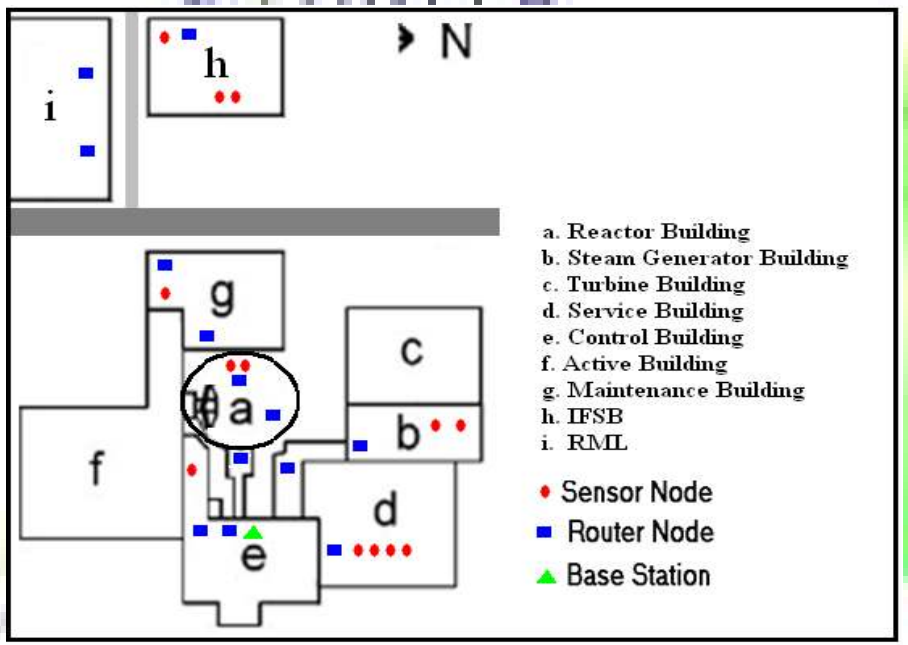

Wireless Sensor Network Based Monitoring Station
Computer Division
Node Location
Selectlocation
OK
Wireless Sensor Networks are composed of hundreds of tiny sensor nodes, which can sense, compute and communicate in wireless mode with other nodes to collect information about the environment being monitored. The challenges are that these nodes have limited processing power, limited memory, low bandwidth and small range.
The experimental setups done at IGCAR using the in-house developed nodes:
Temperature monitoring experiments at FBTR.
Sodium Leak detection at IWSOT facility, FRTG.
Temperature and Humidity monitoring at SADHANA loop, FRTG.
Temperature and Humidity monitoring at Computer center, CD.
Radiation monitoring experiments at KCL.
Signal penetration experiments across RCB wall of FBTR.
BACK
Cluster Room Temperature and Humidity Values
Air Inlet (in Deg C)
Rack1 (in Deg C)
Rack2 (in Deg C)
Humidity (in RH%)
Date & Time
17.5 27.2 27.4 43 2012-01-30 14:59:25
17.3 27.6 27.6 43 2012-01-30 14:54:24
17.7 26.9 28.8 43 2012-01-30 14:49:24
17.1 27.2 27.6 43 2012-01-30 14:44:24
17.9 28.1 28.1 43 2012-01-30 14:39:26
17.9 28.1 28.1 43 2012-01-30 14:34:27
18.1 28.7 28.8 44 2012-01-30 14:29:24
17.8 32.2 28.8 44 2012-01-30 14:24:25
18.0 33.1 28.9 44 2012-01-30 14:19:25
17.4 31.9 29.8 44 2012-01-30 14:14:24
16.7 33.2 29.9 45 2012-01-30 14:09:25
16.7 33.2 29.9 45 2012-01-30 14:04:26
16.3 32.4 29.8 45 2012-01-30 13:59:24
17.7 32.6 28.9 46 2012-01-30 13:54:24

WSN DEPLOYMENT AT SADHANA

- A Natural Convection Sodium loop named SADHANA (SAfety grade Decay Heat removAl loop in Natrium) has been constructed at Engineering Hall-III.
- It has simulated models of decay heat exchanger (DHX) and air heat exchanger (AHX) to study the performance of Safety Grade Decay Heat Removal (SGDHR) system of PFBR.
- The 20m high Chimney develops the air flow required to transfer the heat from secondary sodium to the atmosphere through the AHX.
- When the loop is in operation, it is necessary to continuously monitor the temperature and humidity at chimney outlet (11th floor) and chimney inlet (5th floor) from the control room (2nd floor).
- Laying cables for long distance is cumbersome task in already established plant. Hence the wireless sensor network has been set up for covering the area vertically. Link is established for continuous data monitoring in the interval of 1 minute at 2.4GHz.
- K type thermocouple has been used for measuring the Chimney Air outlet temperature.

WSN DEPLOYMENT AT FBTR

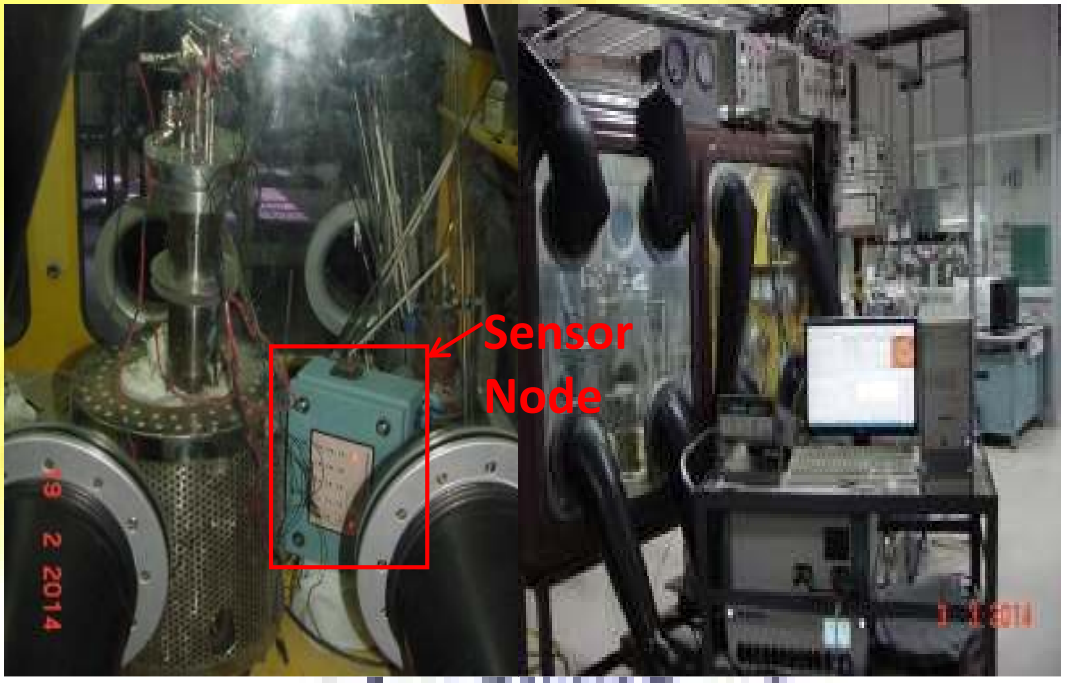
- Wireless Sensor Network with 27 nodes was deployed to measure Temperature, Vibration and Flow parameters at FBTR
- 21 numbers of non nuclear safety signals (12-Temperature, 2- Flow and 7-Vibration) have been connected to 13 sensor nodes.
- 13 numbers of router nodes were placed, to forward the sensor data to basestation
- Wireless Network Management Station (WNMS) is running in PC connected to basestation, placed in control room.



WSN DEPLOYMENT AT RCL

•Reprocessing of the irradiated U-Zr alloy fuel is carried out by molten salt electrorefining, a pyrochemical reprocessing method used at Pyro lab, RCL. Before introducing the irradiated fuel for reprocessing in the hot cell, the basic as well as the engineering level work is carried out in the glove boxes, containment boxes etc., The process parameters like temperature, voltages, currents, camera signals, etc., are measured by running the radiation resistant cables from inside the glove box to the measuring instruments kept outside by using electrical feedthroughs, connectors etc., as an experimental setup, two WSN nodes have been deployed inside the two argon atmosphere glove boxes to eliminate the electrical feedthroughs and the connectors.

- WSN measures continuously the electrochemical cell potential & actinide drawdown process temperatures.
- It continuously monitors the signal at the interval of two seconds


Sensor
Node

Design and Development of Signal conditioning Boards

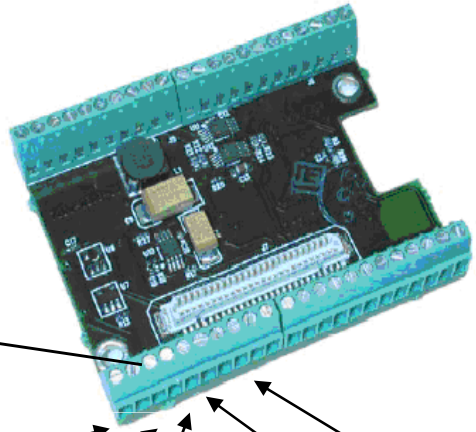
According to the application, the signal to be monitored by WSN varies. Interfacing the signal to our WSN sensor node is been done by the design and development of signal conditioning boards. These signal conditioning boards are interfaced via 40 pin expansion connector.

Following are signaling conditioning boards developed at WSN Lab

- Temperature sensor board for K type thermocouple
- Temperature sensor board for RTD
- Humidity sensor
- Level sensor board
- Electro chemical cell potential measurement board
- Actinide drawdown process temperature measurement board
- Flow rate measurement board
- General purpose 4-20mA board

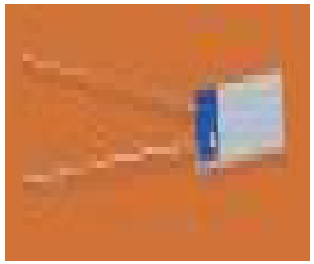
Signal Conditioning

IRIS2110 Wireless sensor node

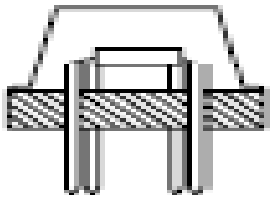


Interface Board

UV Level Sensor



PT1000 Temperature Sensor

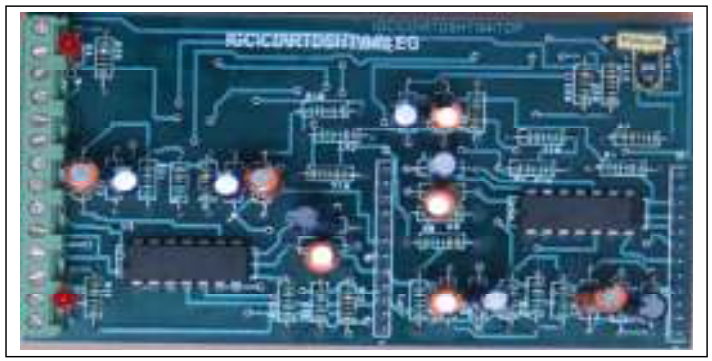


MQ2 Smoke Sensor

AC102-1A Vibration Sensor

Minisense_100 Vibration sensor

→Designed for→



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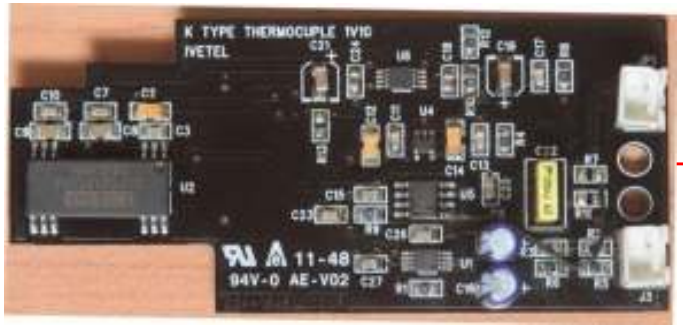
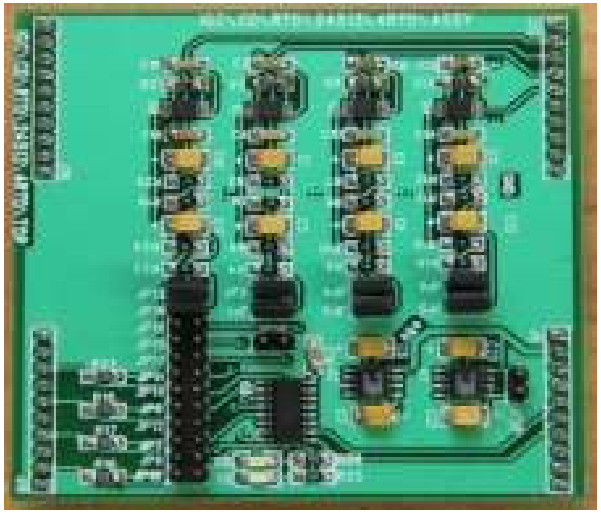


→Designed for→

Designed for



Designed for

Keil Programming

- Keil is a cross compiler which supports C language code. The µVision IDE from Keil combines project management, make facilities, source code editing,program debugging, and complete simulation in one powerful environment.
- The µVision development platform is easy-to-use and helping you quickly create embedded programs that work.
- The code to implement the WSN based monitoring system has been developed.
- The coding involves average technique for accuracy.

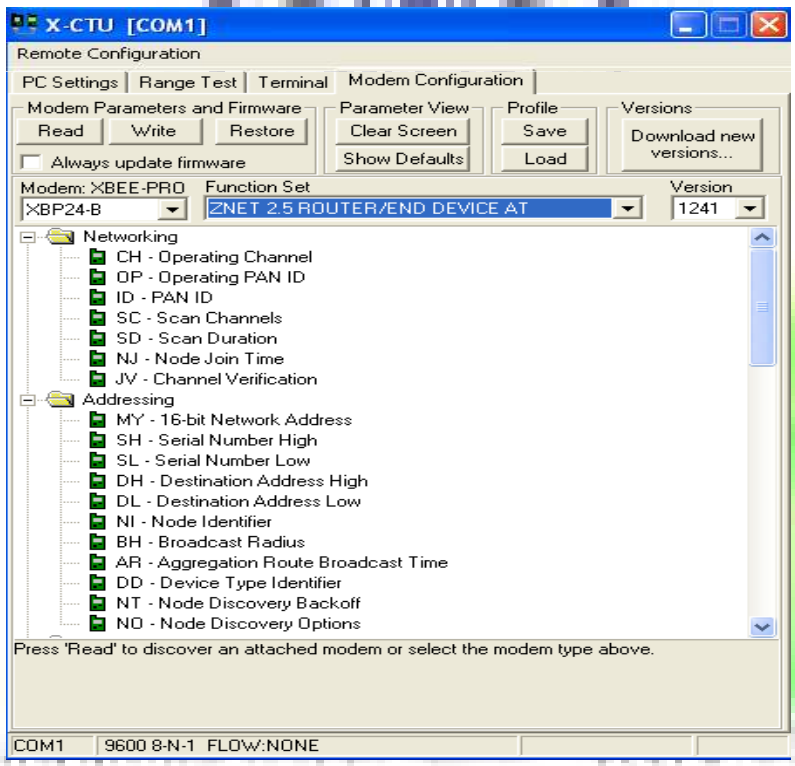
User Interface and Application Tools

- GUI has been developed using Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) to be display the parameters measured by the sensors at the PC connected to BS.
- It is a programming language with Graphical Language developed by National Instruments. It is built for the design, simulation, modification, and compilation of digital instrumentation systems.
- The GUI displays the sensor tag number with location of the sensor.
- The graphical view is also provided in the GUI.

X-CTU-Configuration & Test Utility Software

It is a MaxStream windows-based application used to interface with and configure Max-Stream RF Modules. It provides a simple-to-use graphical user interface to them.

- The software application is organized into four tabs, such as
- PC Settings tab – used to setup PC serial ports for interfacing with an RF module
- Range Test tab – for testing the RF module's range and monitor packets sent and received,
- Terminal tab – To set and read RF module parameters using AT Commands
- Modem Configuration tab – used to set and read RF module parameters.



On going Activities

Energy harvesting technique

- For the radiation monitoring application in our complex, the nodes needs to be placed outdoors.
- The WSN nodes are normally battery or mains powered.
- For outdoor deployment of the nodes, they face the difficulty of unavailability of AC power mains as well as replacement of the batteries since the lifetime as well as capacity of the batteries is limited.
- The energy requirements of both the nodes have been practically calculated by conducting different experiment
- The size of solar cells and rechargeable battery for both the nodes has been calculated considering their energy requirements.
- A test network was established with solar powered WSN nodes and the same is being analyzed. The data will be analyzed in all the weather conditions and results from this testing will be used in future design improvements.

Solar Powered Extension to WSN Sensor node and Router nodes

- The energy requirements of WSN nodes identified.
- Size of solar cells and batteries calculated
- Efficient charging circuit, switching circuit, protection circuit designed


köszönöm
תודה!
děkuji
mahalo
고맙습니다
thank you
merci
谢谢
danke
Ευχαριστώ
شكرا
どうもありがとう
gracias