Compact Internet-capable Environmental Monitor

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Agenda

Part A

- Describe smart environmental monitoring sensors

Part B

- Describe networking with the IEEE 1451 transducer standard

Part C

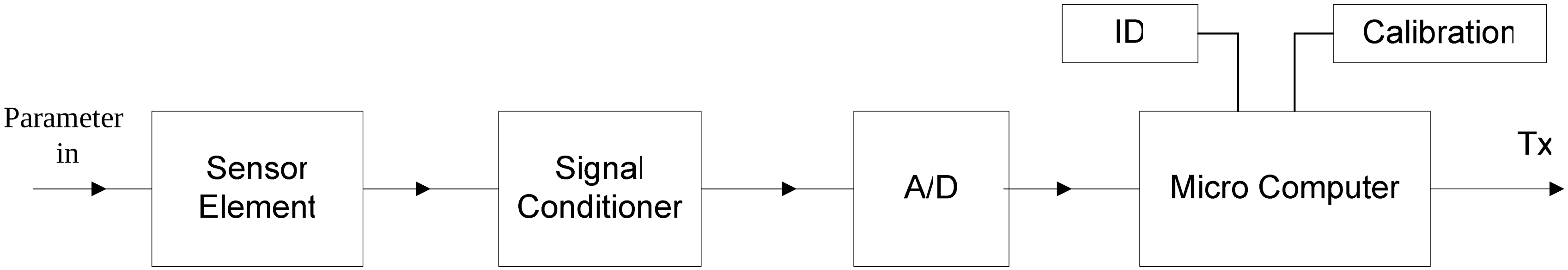
- Discuss applications of networked environmental monitors.

Environmental Monitor (EVM) Sensors Suite (six function option)

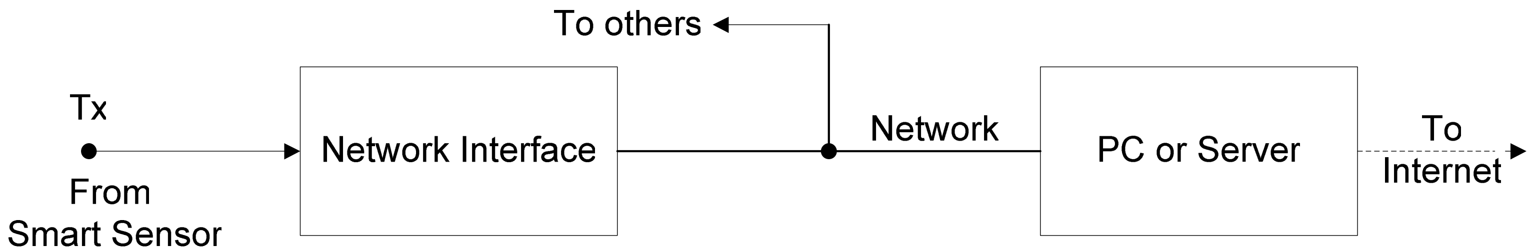
- Temperature
- Humidity
- Illumination
- Carbon Dioxide (CO_2)
- CO/VOC (Carbon monoxide and Volatile Organic Compounds)
- Atmospheric Pressure

Part A

Smart Sensor Block Diagram



SMART SENSOR

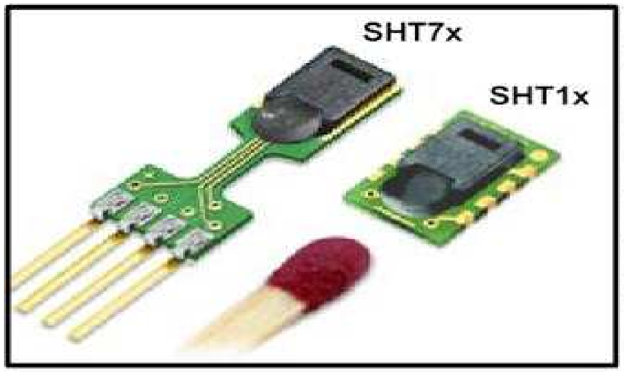


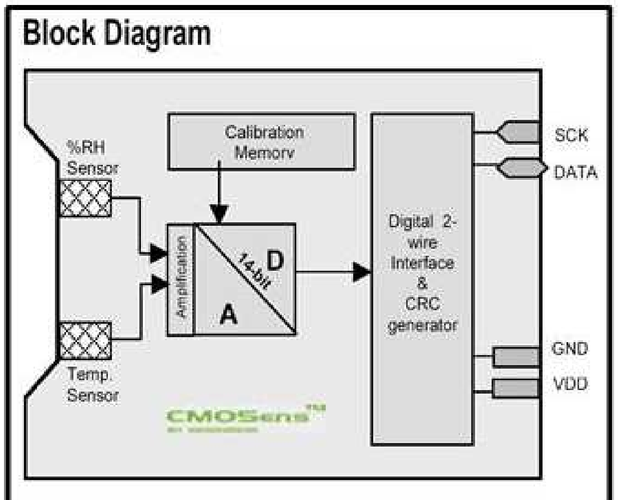
NETWORKED SMART SENSOR

Humidity/Temperature Sensor

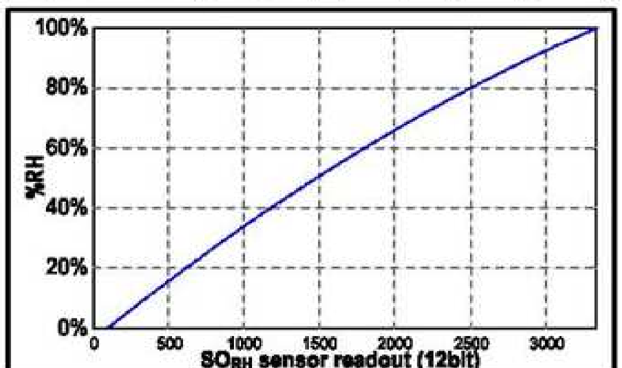
with digital output

SHT1x / SHT7x
Humidity & Temperature Sensor





Parameter	Conditions	Min.	Typ.	Max.	Units
Humidity					
Resolution (2)		0.5	0.03	0.03	%RH
		8	12	12	bit
Repeatability			±0.1		%RH
Nonlinearity	raw data		±3		%RH
	linearized		<<1		%RH
Range		0		100	%RH
Response time	1/e (63%) slowly moving air		4		s
Hysteresis			±1		%RH
Long term stability	typical		< 1		%RH/yr
Temperature					
Resolution (2)		0.04	0.01	0.01	°C
		0.07	0.02	0.02	°F
		12	14	14	bit
Repeatability			±0.1		°C
			±0.2		°F
Range		-40		123.8	°C
		-40		254.9	°F
Response Time	1/e (63%)	5		30	s

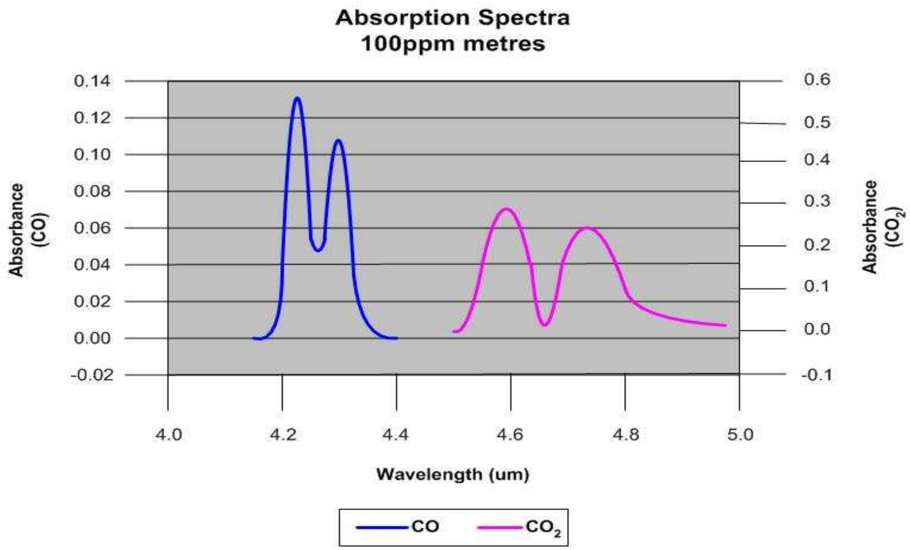


Carbon Dioxide (IR) Sensor

- Infra-red (NIR) technology selected because of long-term reliability
- Alternative Technologies
  - Solid Electrolytic
  - Amperometric

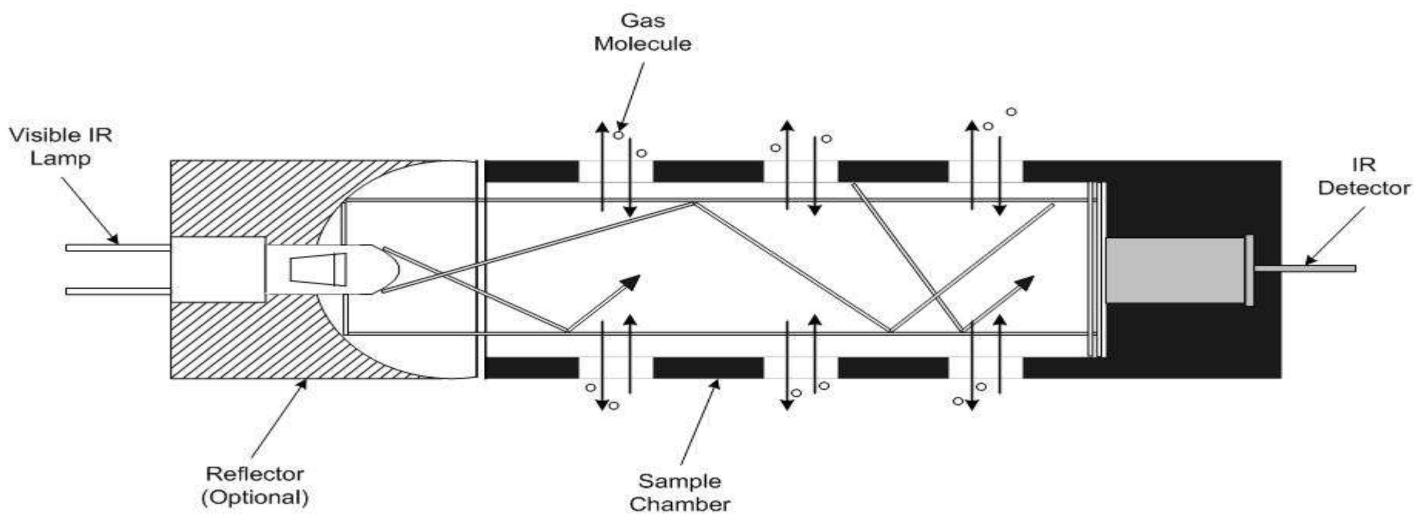
Infra-red Sensing Principle

- Some gases absorb light at particular IR wavelengths (CO_2 at 3 um)
- $I/Io = e^{-Ax}$ where I/Io is light absorbed during transmission, x is path length and A is absorption coef. at specific wavelength
- Transmission filters select specific wavelength bands
- A is proportional to gas concentration
- IR sensors reproducible but not sensitive (need high conc or long paths)



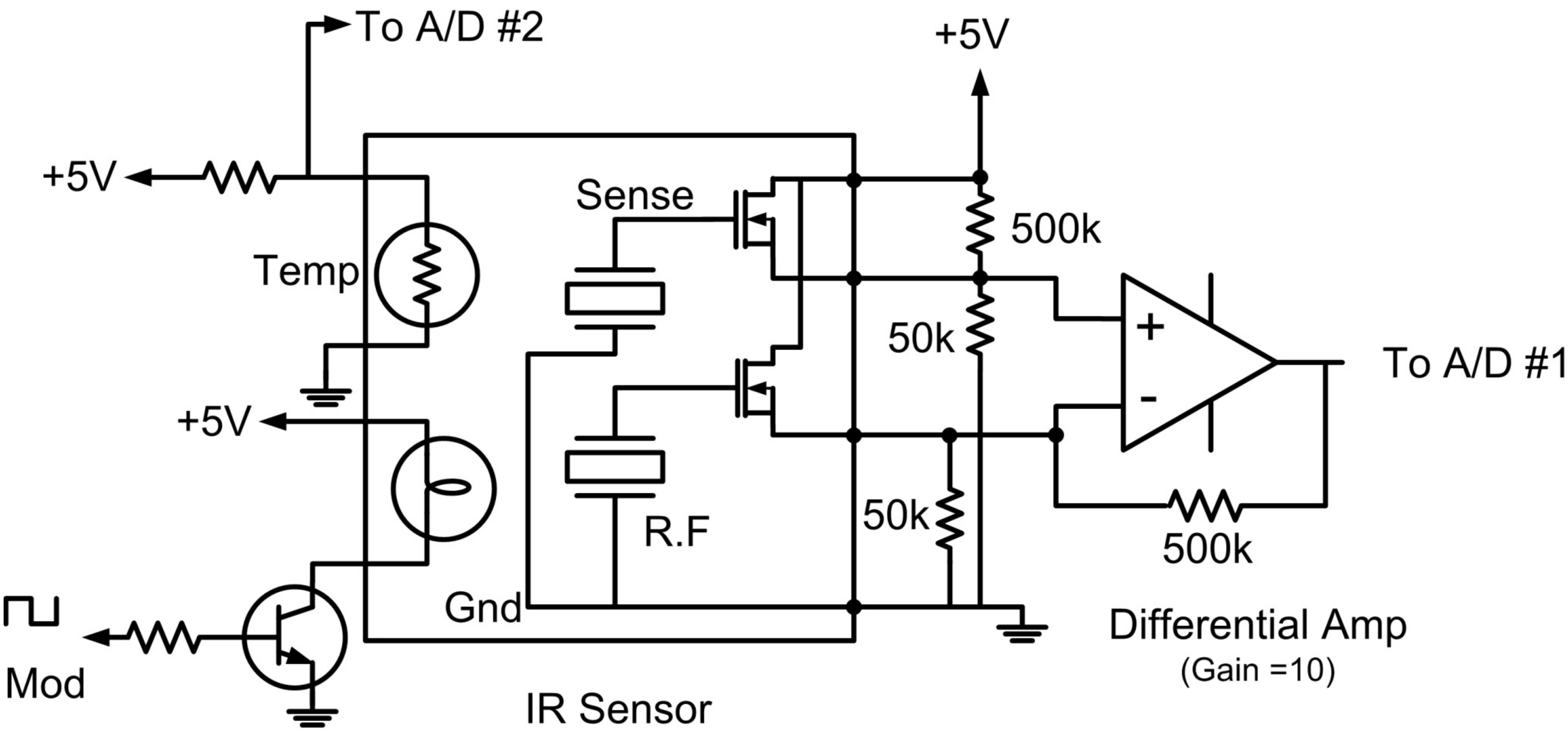
Infra-red Sensor Construction

NDIR Gas Sensor

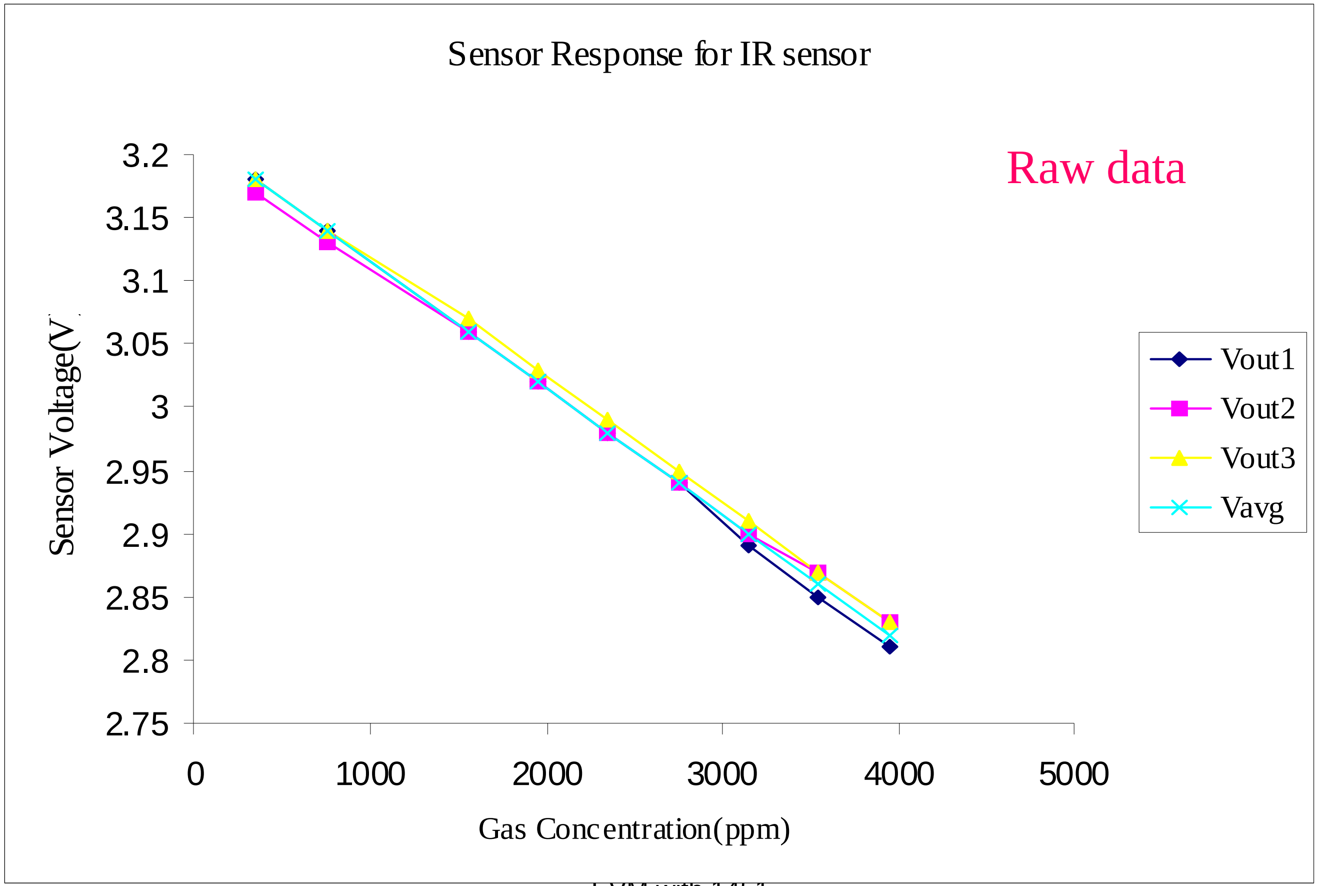


Acoustical detection an attractive option

IR Sensor and Signal Conditioner

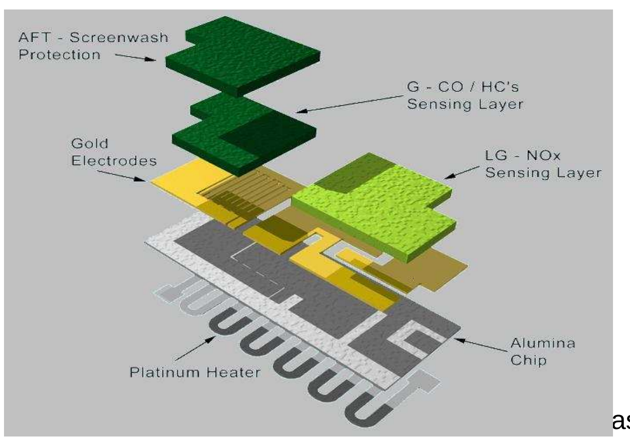


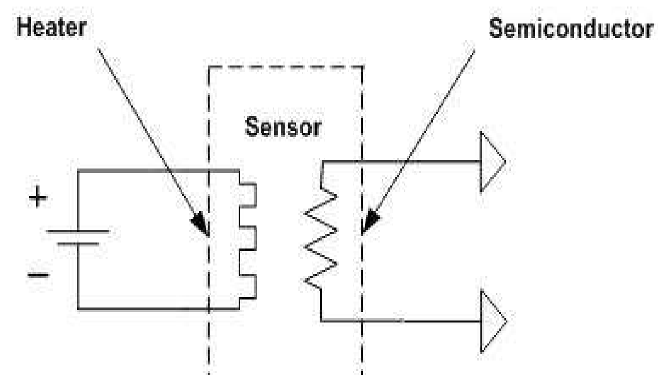
Response of IR sensor to Carbon Dioxide Gas



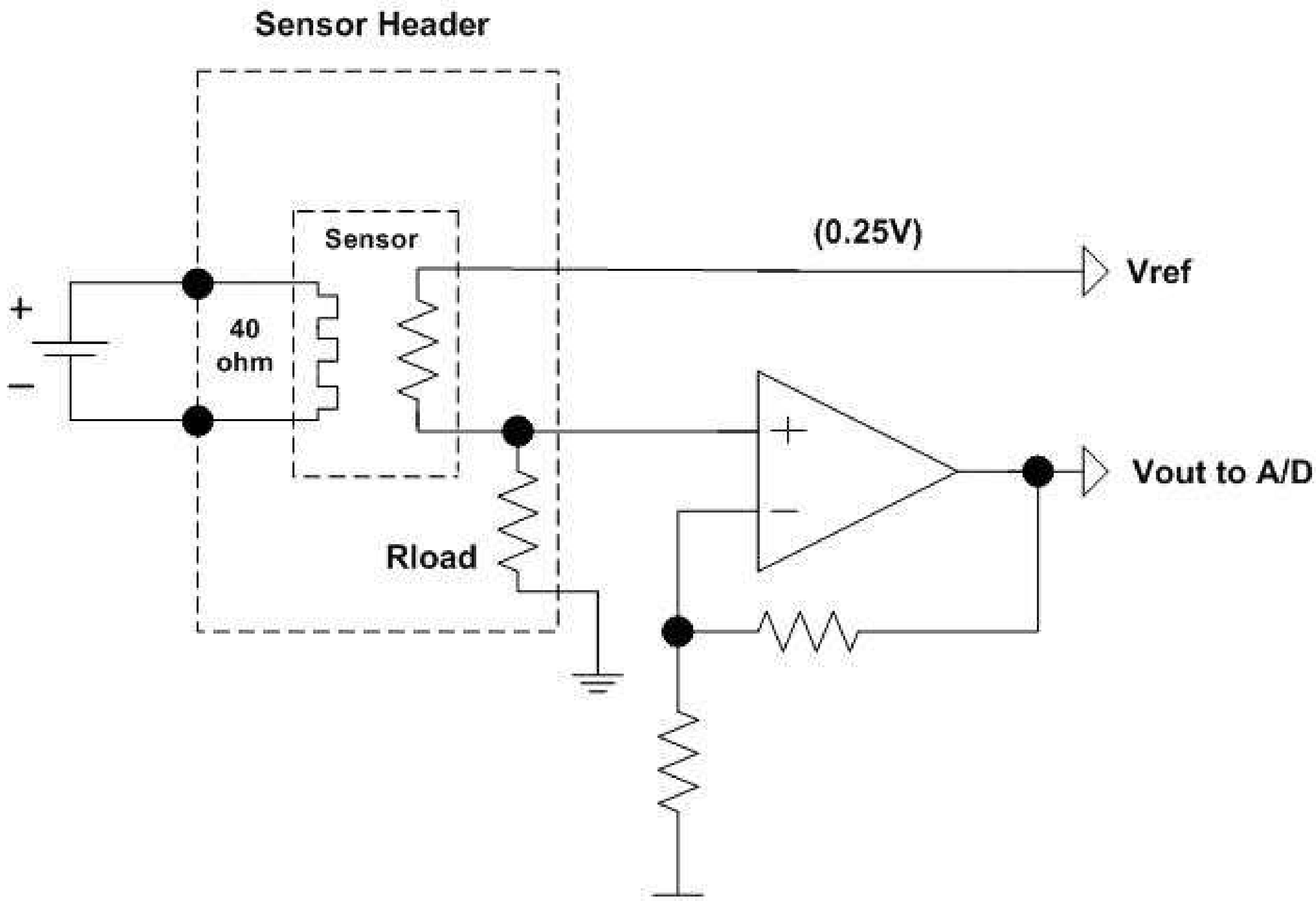
Volatile Organic Compound (VOC) Sensor

- Based on metal oxide semiconductors (SnO_2)
- Surface reaction with ambient gases when hot (350-500 ^{o}C)
- Heater (e.g. 4 v @ 100 mA) heats substrate
- Adsorbed gas reduces grain-boundary potential barrier and thus increases conductivity (decreases resistance)
- Delta-R is a function (approx. log or square root) of gas conc. (ppm)

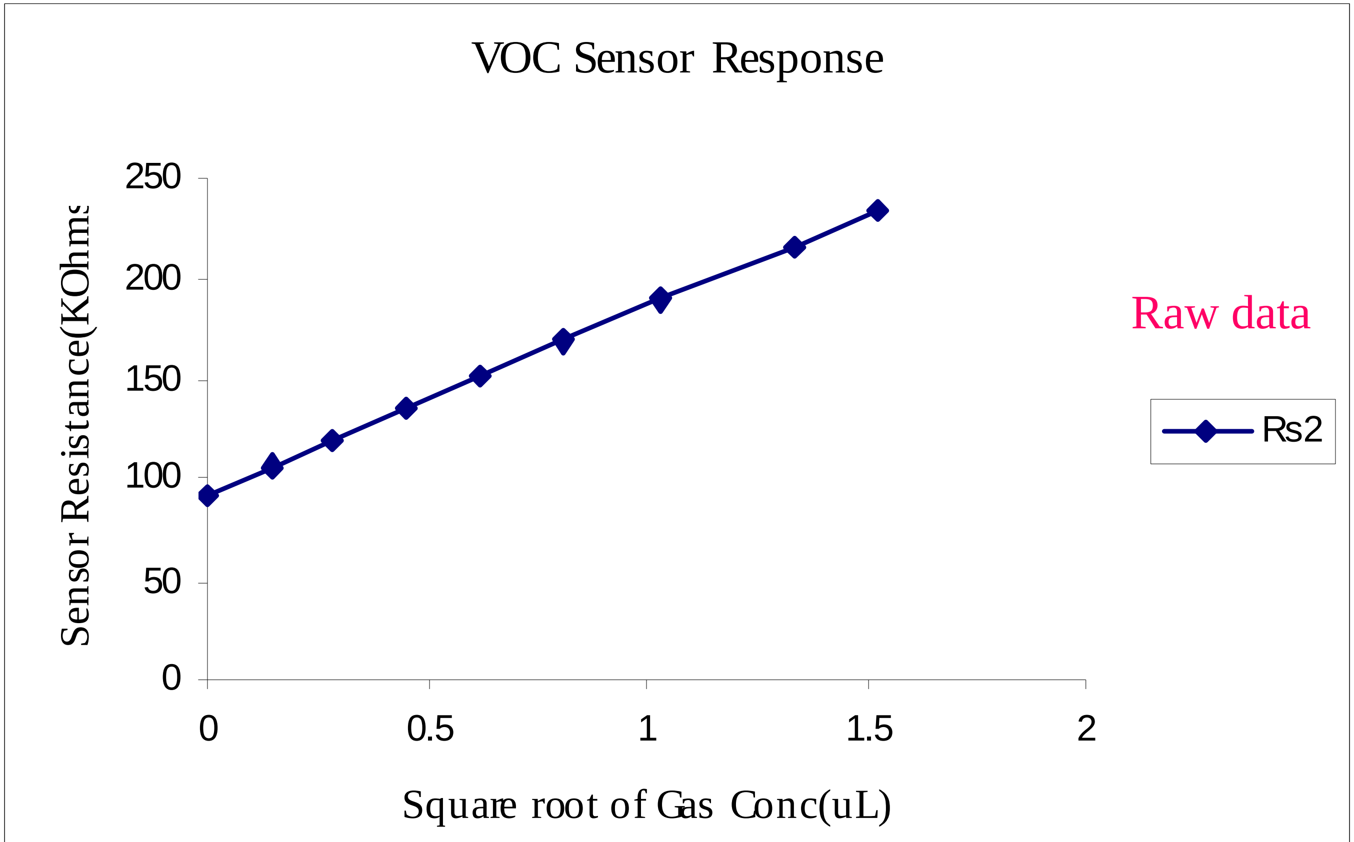




VOC Sensor Signal Conditioner



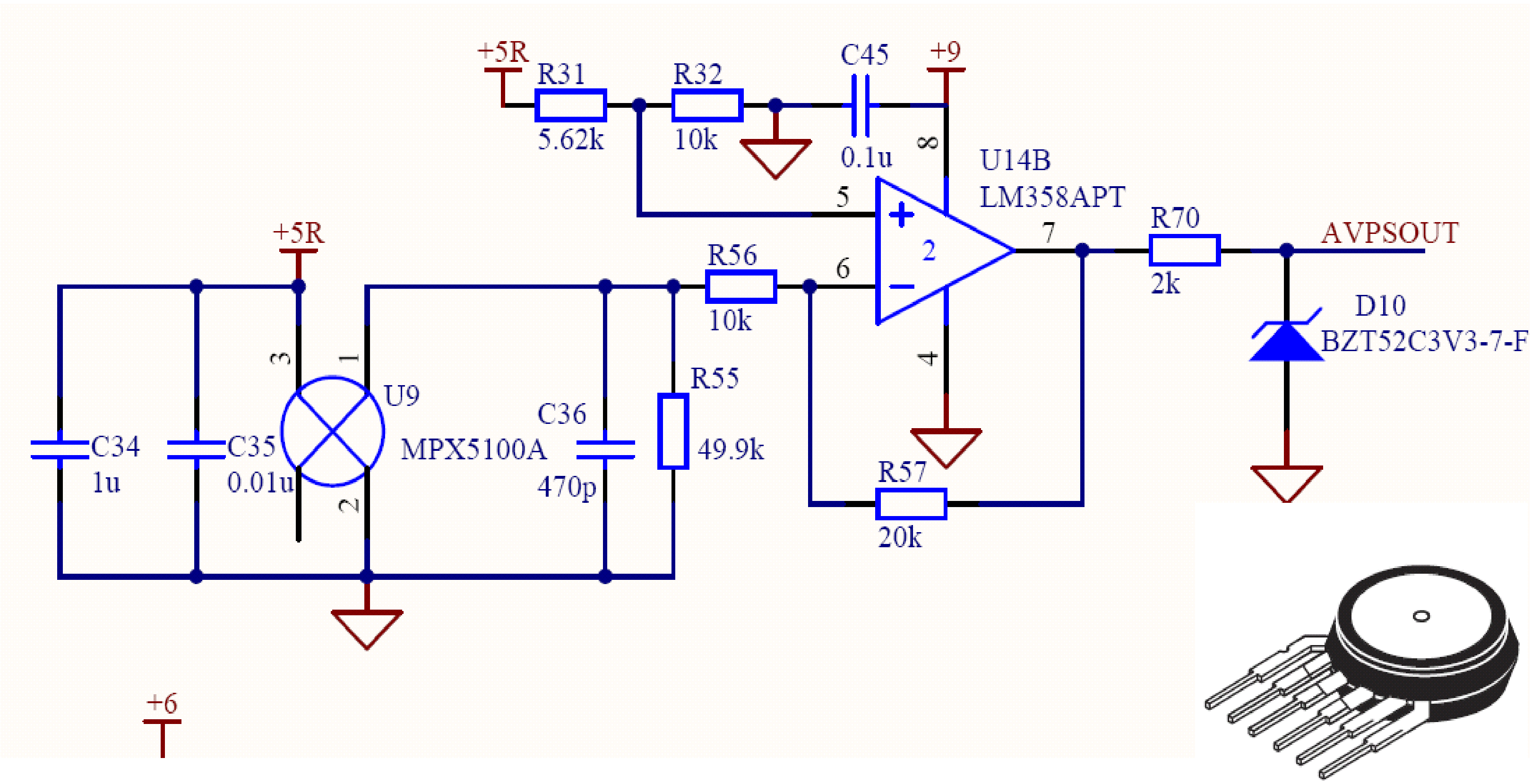
Response of VOC sensor (MOS) to Acetone Vapor



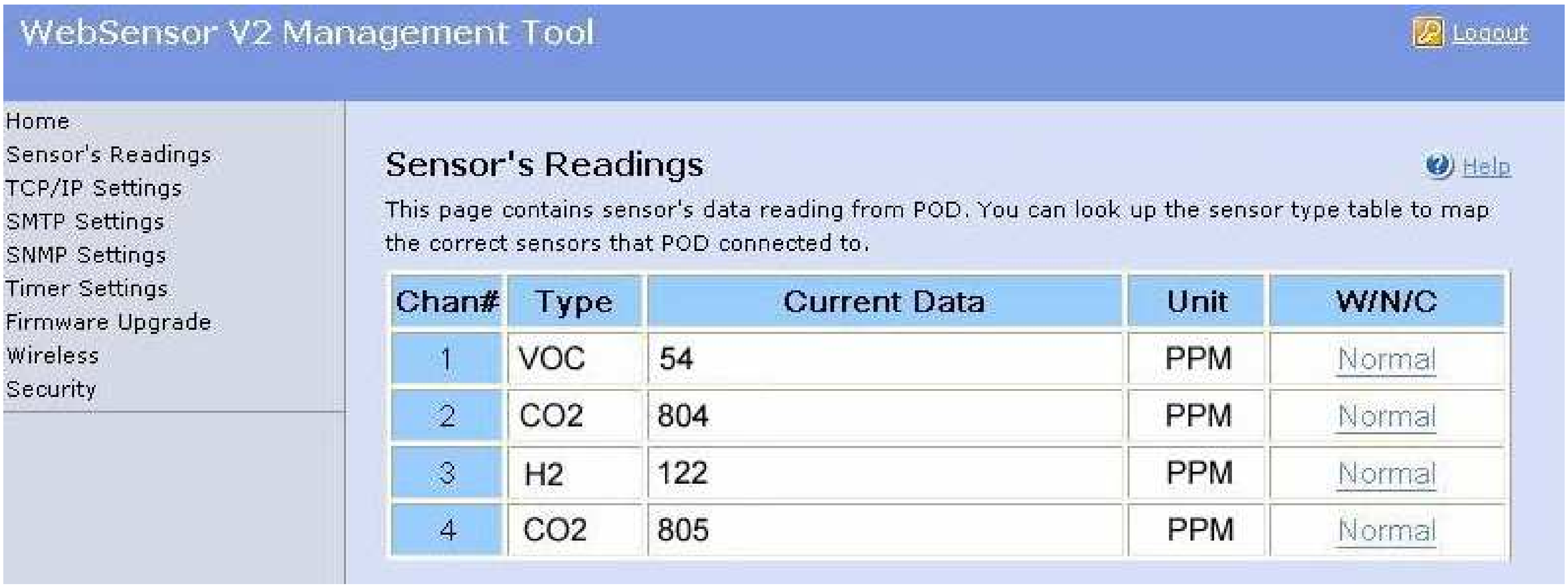
Measured at analog test point

Pressure Sensor

- Absolute type (1 atmosphere or 760 Torr full scale)



Response in Engineering Units
(converted from raw sensor units)



WebSensor V2 Management Tool

Logout

Home
Sensor's Readings
TCP/IP Settings
SMTP Settings
SNMP Settings
Timer Settings
Firmware Upgrade
Wireless
Security

Sensor's Readings

Help

This page contains sensor's data reading from POD. You can look up the sensor type table to map the correct sensors that POD connected to.

Chan#	Type	Current Data	Unit	W/N/C
1	VOC	54	PPM	Normal
2	CO2	804	PPM	Normal
3	H2	122	PPM	Normal
4	CO2	805	PPM	Normal

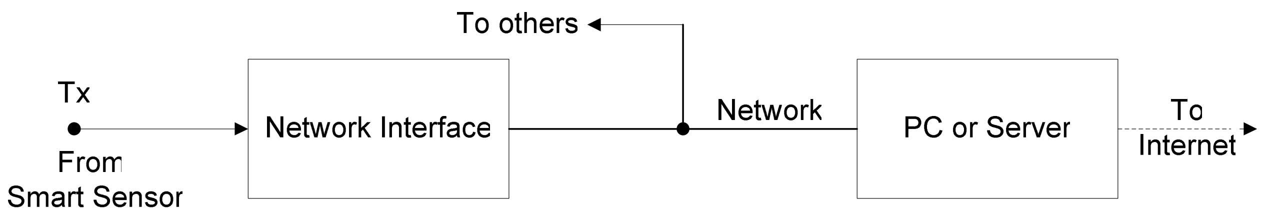
Part B -Networking
Features and Applications

Features

- Plug and play
- Multiple sensors on one network or bus

Applications

- Monitoring and Control
- Automatic testing
- Machine to Machine (M2M) sensor data communications
- Wide area (Nationwide) data collection



Sensor/Transducer Networks

- A network connects more than one addressed sensor (or actuator) to a digital wired or wireless network
- Both network and sensor digital data protocols are needed
- Standard data networks can be used but are far from optimum
- Numerous (>100) incompatible sensor networks are currently in use – each speaking a different language

The Tower of Babel

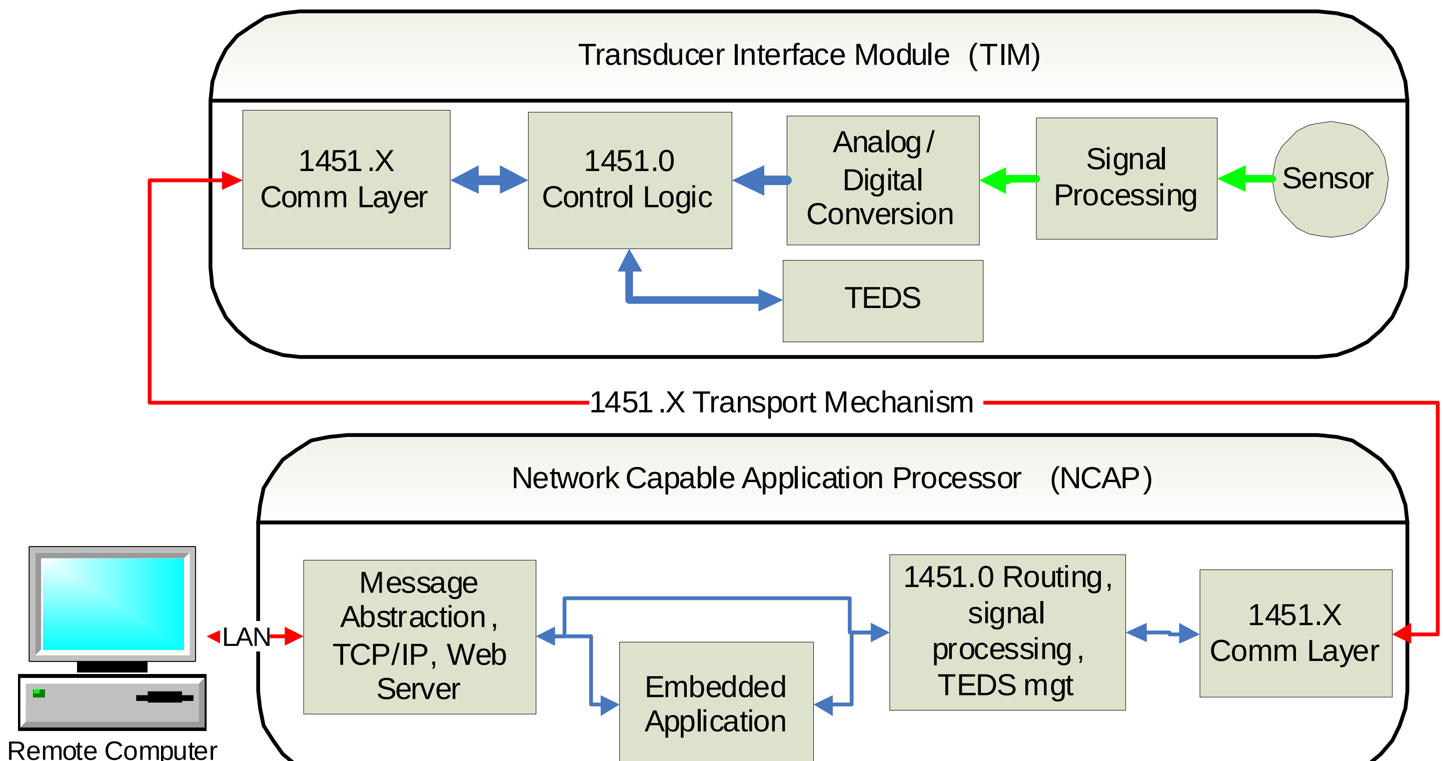
IEEE 1451 – the Universal Transducer Language

- Problem: too many network protocols in common use
- Narrow solutions and borrowed protocols have not worked
- Sensor engineers in the fragmented sensor industry need a simple method of implementation

- *How can it be done*?
- We need something like USB, except for sensors
- Solution: the IEEE 1451 Smart Transducer Protocol open standard is the best universal solution
- Supported by NIST, IEEE and many Federal agencies

A review of the

IEEE 1451 Smart Transducer Concept

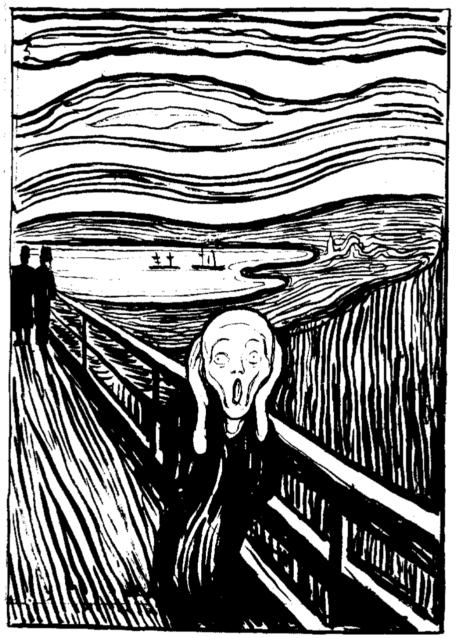


IEEE 1451 Advantages

- Comprehensive enough to cover nearly all sensors and actuators in use today (not 20/80% approach)
- Many operating modes
  (buffered, no-buffer, grouped sensors, timestamps, timed data, streaming …)
- Extensive units, linearization and calibration options
- Multiple timing and data block size constraints handled.
- Compatible with most wired and wireless sensor buses and networks (point-to-point, mesh, TIM-to-TIM, mixed networks).
- Efficient binary protocol (especially suitable for wireless)
- Standard is 400+ pages for basic part, over 1500 page total

But the Complexity!

- A comprehensive standard is necessarily complex
- There was little adoption of the original IEEE 1451.2 (TII) standard because of its perceived complexity
- Manual preparation of the TEDS is not practical -- A TEDS compiler is needed
- A compliance test procedure is also desirable to prove that a design is correct



Munch –The scream

Status of Various Parts of IEEE 1451

1451.0 – Basic data/TEDS format	**Done (2007)**
1451.1 – NCAP/Computer Interface	Done (1999)*
1451.2 – Serial (RS-232, etc)	Being revised (1997)
1451.3 – Wired Multi-drop	Done (2002)*
1451.4 – TEDS Only	Done (2005)
1451.5 – Wireless (WiFi, Zigbee, etc)	Done (2007)
1451.7 – RFID	Being ratified

* Needs revision

IEEE 1451.0 (Dot 0) TEDS Format

- Required TEDS [Memory block with defined format]
  - MetaTEDS
  - Channel TEDS
  - Calibration TEDS (unless SI units)
  - Xdr-name TEDS
  - Phy TEDS
  - Also optional TEDS
- Data Transmission [specific octet format]
  - TEDS/Status requests
  - Triggering and configuration
  - Sensor read commands and data return
  - Actuator write commands and data sending

TEDS Format

- General format for each TEDS section (except Dot 4):

Field	Description	Data Type	Number of Bytes
-------	TEDS Length	UInt32	4 bytes
1 to N	Data Block	Variable	Variable
-------	Checksum	Uint16	2 bytes

- Binary TEDS Tuple format for each data block:

  Type-Length-value (TLV)

  Example: 01 02 A3 04

  Field type is 1, Length is 2 bytes, field value is “A304” hex

- Field example: Meta-TEDS (TEDS # 1)

  13: Number of Implemented Transducer Channels (default=1)

Standard Transducer Units

(binary format)

SI Based Units

Base Quantity	Name	Unit Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Field	Description	Data Type	Number of octets
1	Physical units interpretation	UInt8	1
2	(2 * <exponent of radians>) + 128	UInt8	1
3	(2 * <exponent of steradians>) + 128	UInt8	1
4	(2 * <exponent of meters>) + 128	UInt8	1
5	(2 * <exponent of kilograms>) + 128	UInt8	1
6	(2 * <exponent of seconds>) + 128	UInt8	1
7	(2 * <exponent of amperes>) + 128	UInt8	1
8	(2 * <exponent of kelvins>) + 128	UInt8	1
9	(2 * <exponent of moles>) + 128	UInt8	1
10	(2 * <exponent of candelas>) + 128	UInt8	1

Dot 0 Command/Response Header

Byte Number	Description
1	Destination Transducer Channel Number (Most significant byte)
2	Destination Transducer Channel Number (Least significant byte)
3	Command Class
4	Command Function
5	Length (Most significant byte)
6	Length (Least significant byte)
7-N	Command dependent bytes

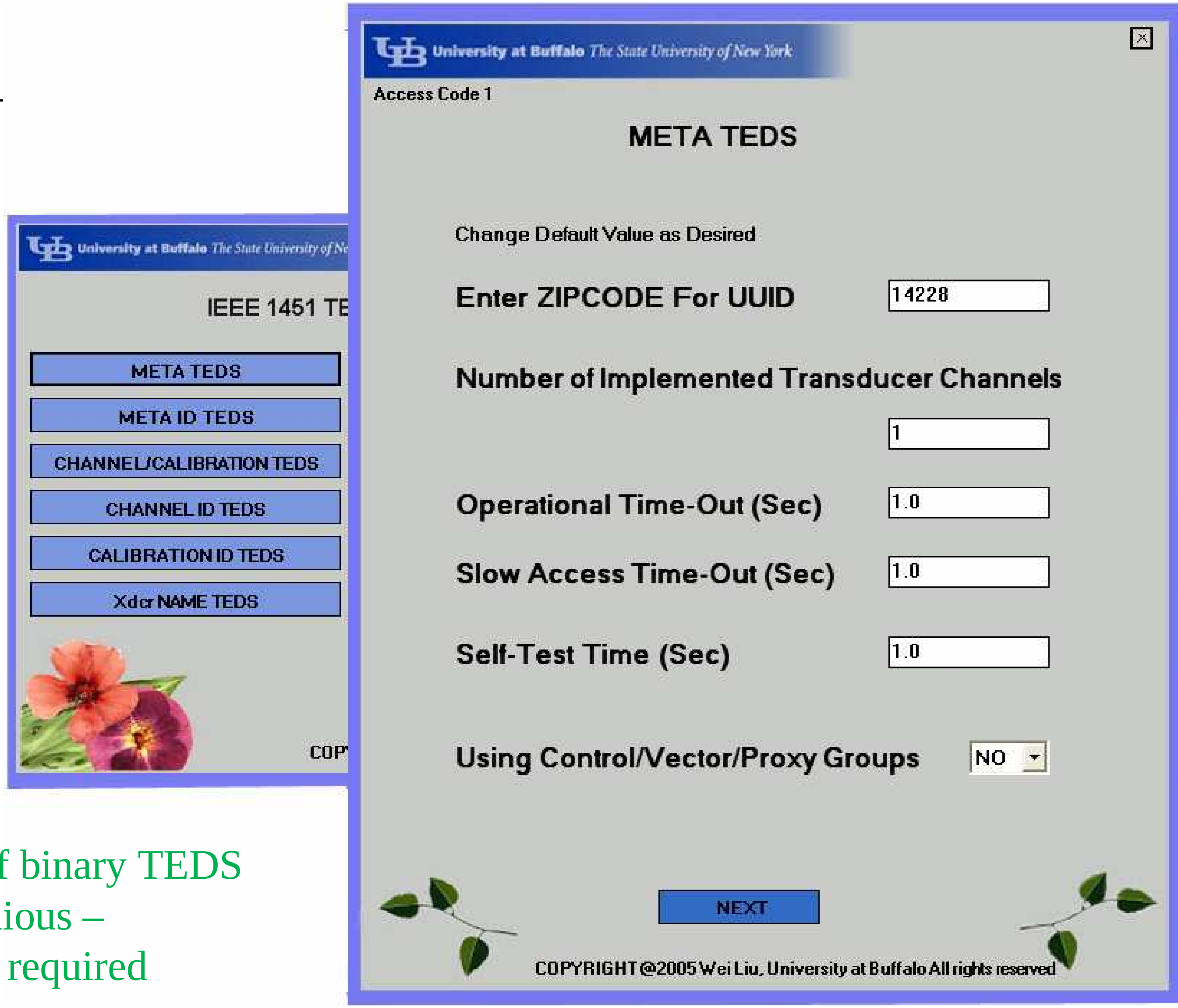
NCAP Command Message Structure

Byte Number	Description
1	Success/Fail Flag
2	Length (Most significant byte)
3	Length (Least significant byte)
4-N	Reply dependent bytes

TIM Reply Message Structure

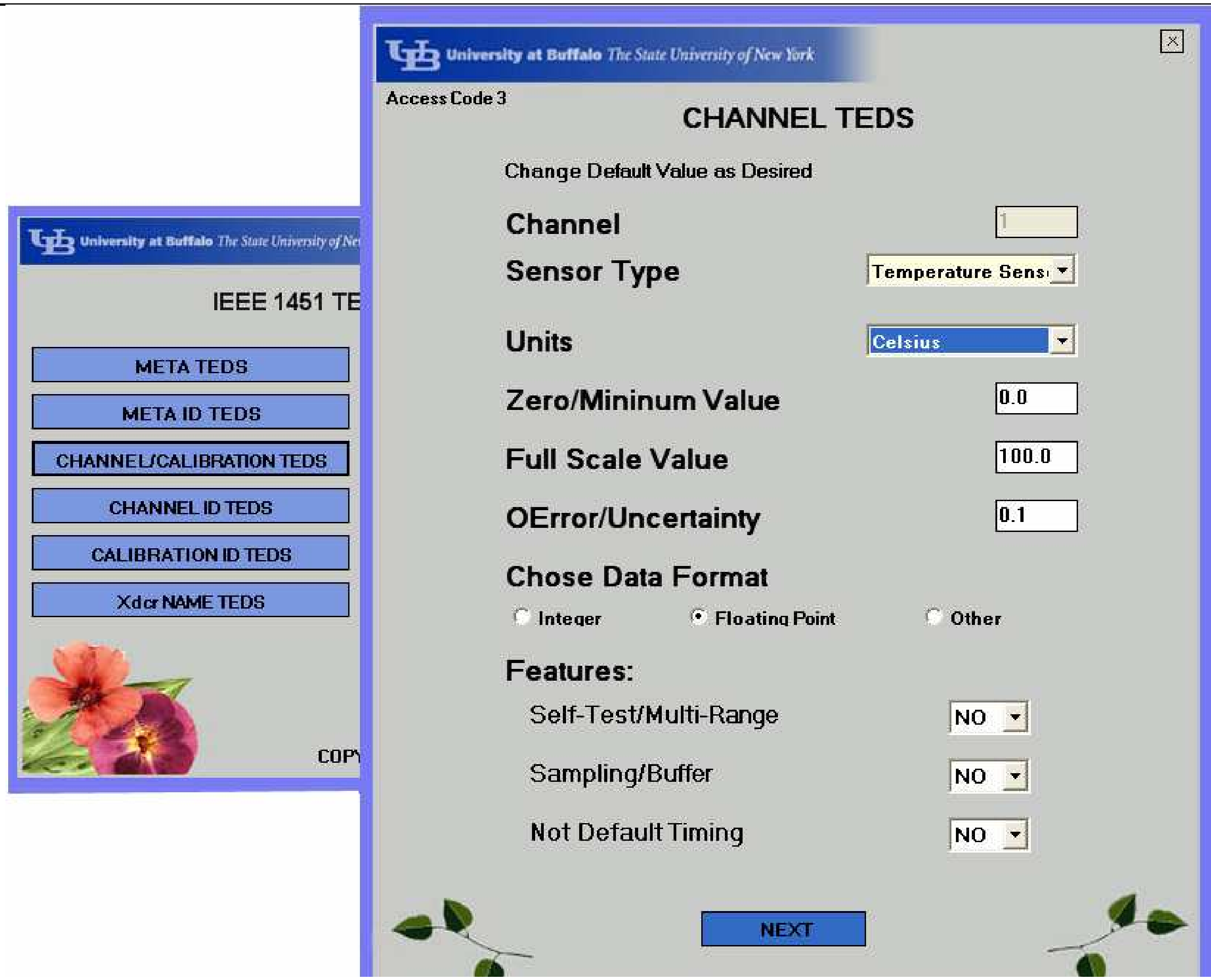
TEDS Compiler (Meta-TEDS section)

Part of Ph. D. thesis
Wai Liu
(Univ. at Buffalo)

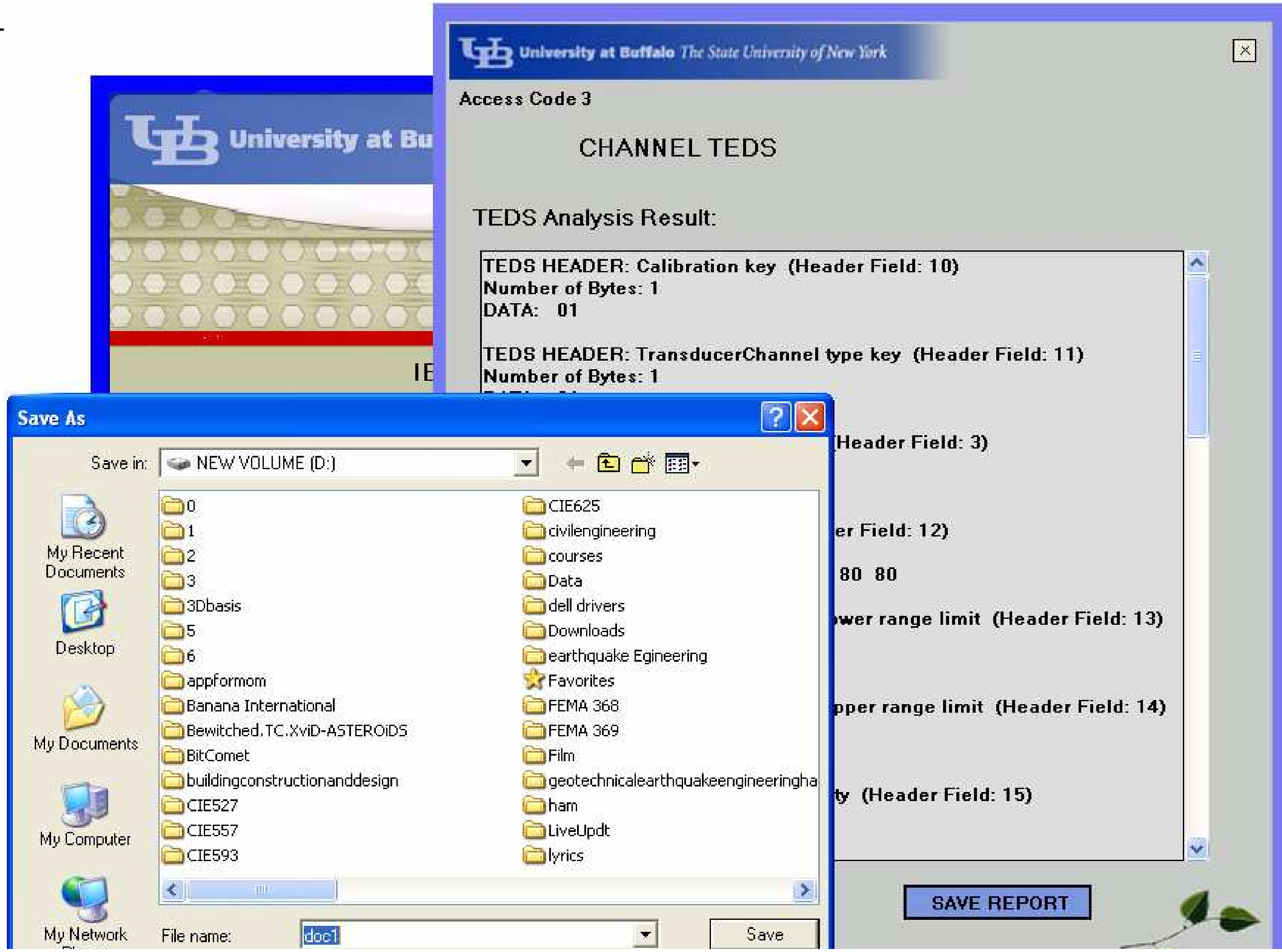


Preparation of binary TEDS
by hand is tedious –
A compiler is required

Channel/Calibration TEDS (for linear sensors)

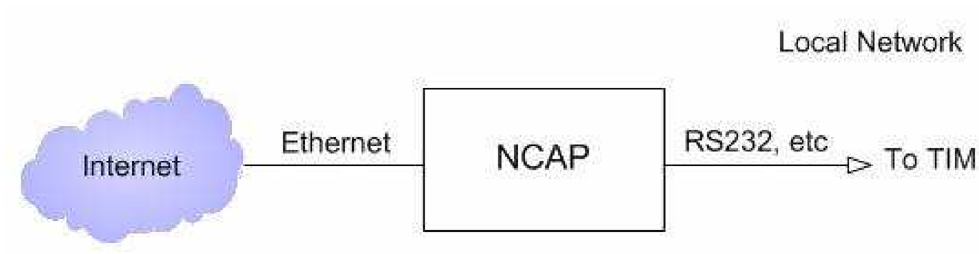


TEDS Reader

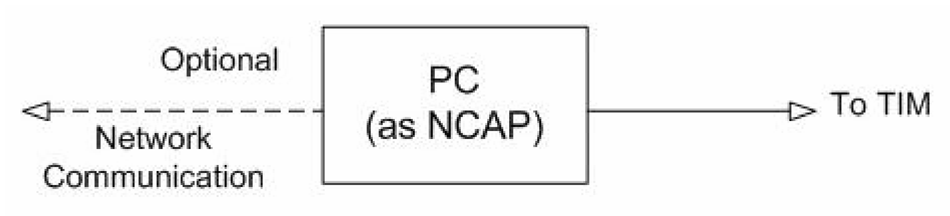

University at Buffalo The State University of New York
Access Code 3
CHANNEL TEDS
TEDS Analysis Result:
TEDS HEADER: Calibration key (Header Field: 10)
Number of Bytes: 1
DATA: 01
TEDS HEADER: TransducerChannel type key (Header Field: 11)
Number of Bytes: 1
(Header Field: 3)
er Field: 12)
80 80
wer range limit (Header Field: 13)
pper range limit (Header Field: 14)
ty (Header Field: 15)
SAVE REPORT
University at Bu
Save As
Save in:
NEW VOLUME (D:)
My Recent Documents
Desktop
My Documents
My Computer
My Network
0
1
2
3
3Dbasis
5
6
appformom
Banana International
Bewitched.TC.XviD-ASTEROiDS
BitComet
buildingconstructionanddesign
CIE527
CIE557
CIE593
CIE625
civilengineering
courses
Data
dell drivers
Downloads
earthquake Egineering
Favorites
FEMA 368
FEMA 369
Film
geotechnicalearthquakeengineeringha
ham
LiveUpdt
lyrics
File name:
doc1
Save

Network side (NCAP) options
(wired)

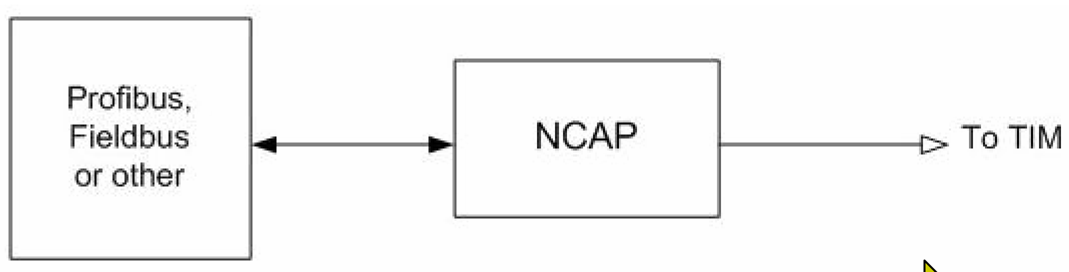
- <u>Internet/Ethernet</u>



- PC Readout



- Industrial network



All use Dot 0 protocol

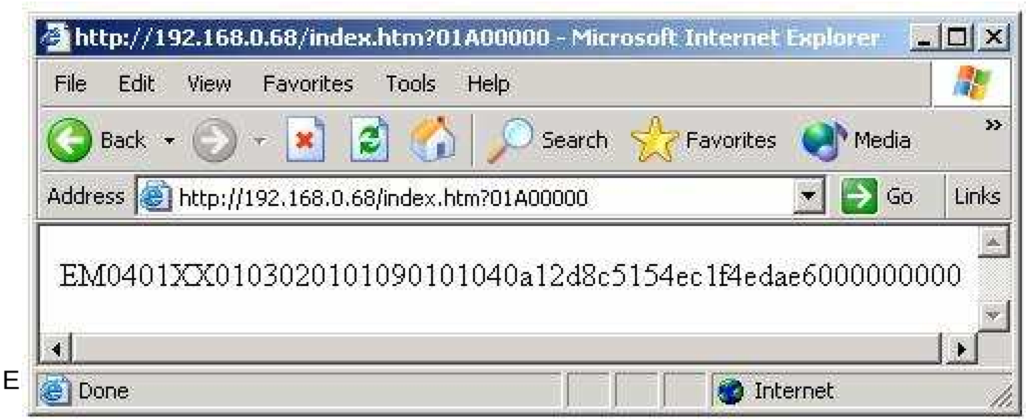
Data Readout Examples

(HTTP via Internet)

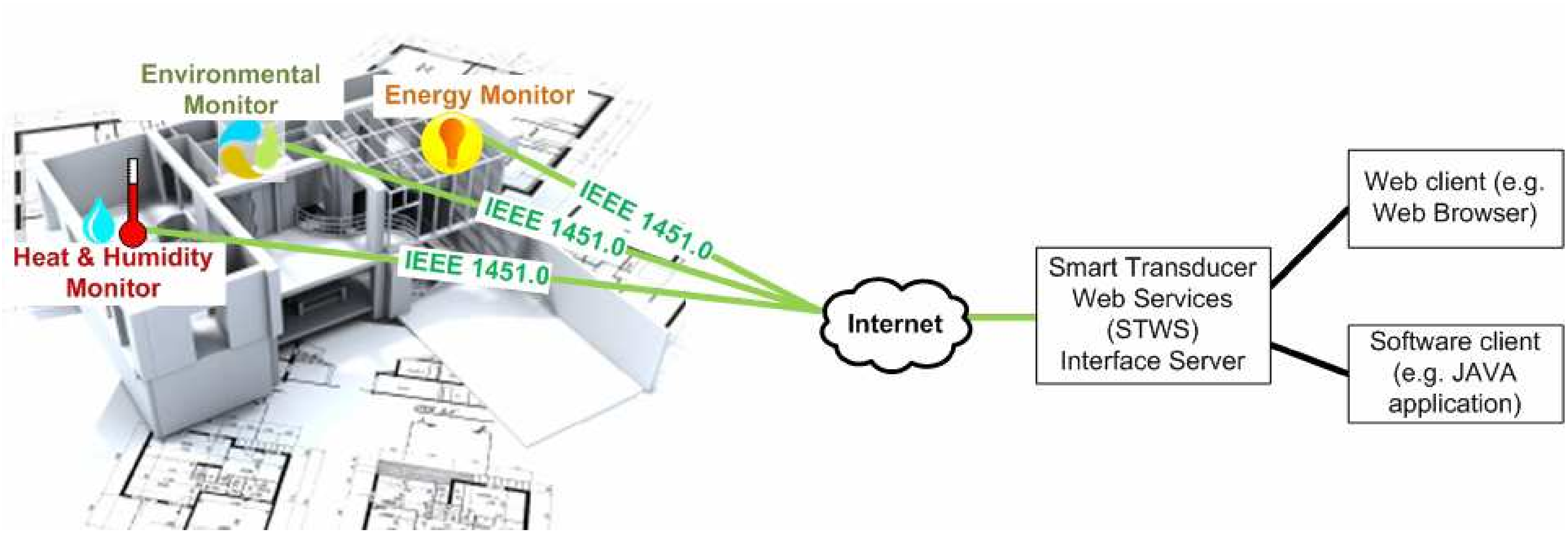
- Sensor data converted to ASCII for display

- TEDS data is displayed in hexadecimal form

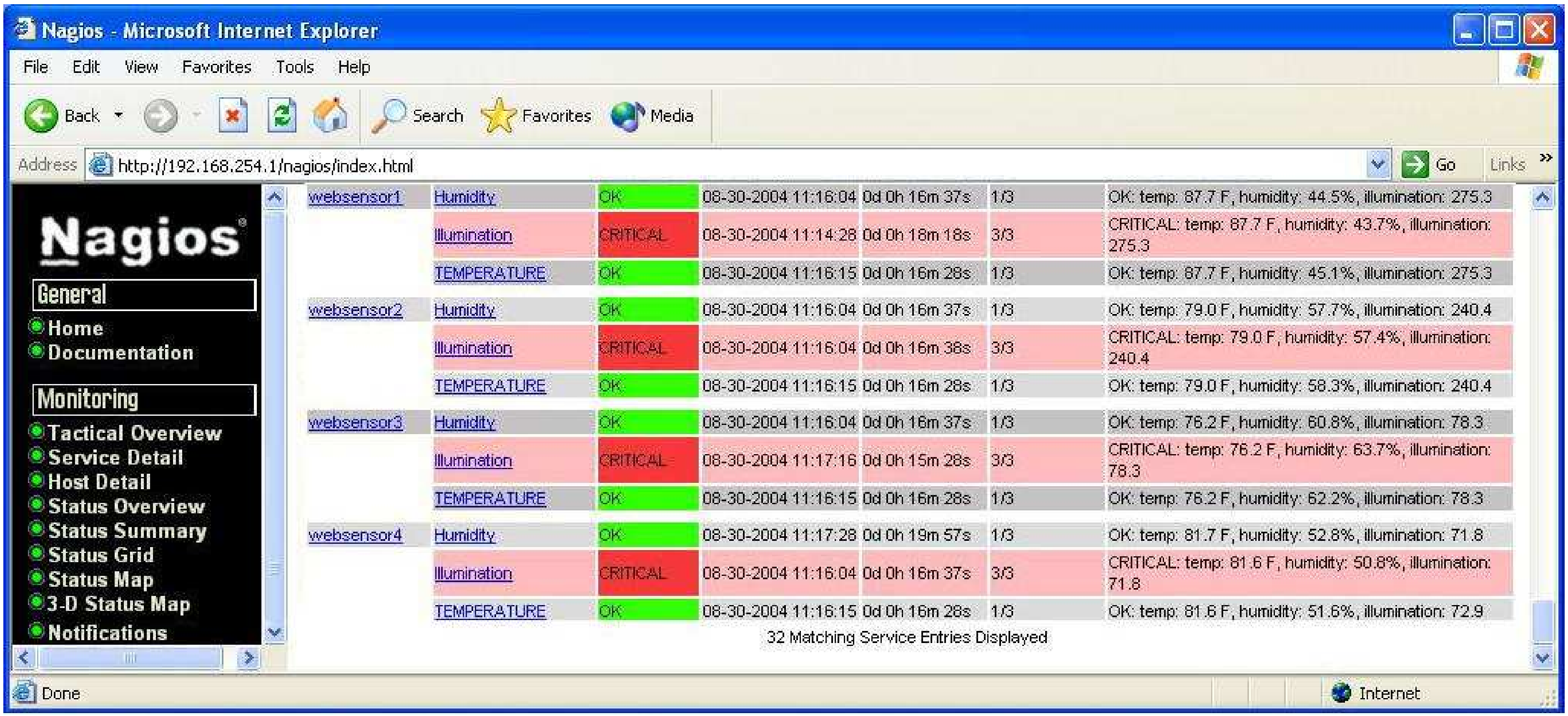
IE



Organization of
Environmental Monitor (EVM) Sensors



Data readout
(typical of digital sensor displays)



Uses standard web browser (HTTP)

Conversion to IEEE 1451.0 (Dot 0) Format

- Start with networked (Ethernet compatible) smart sensor -Combined TIM and NCAP
- Add TEDS
- Add HTTP Dot 0 commands interpretation
- Respond with data in Dot 0 format using HTTP
- Requires website which understands and displays Dot 0 format data
- Implement plug and play

TEDS (Dot 0) for EVM Smart Sensor

- Meta-TEDS (for ID and overall configuration)
- Chan 1 (time) TEDS -- optional, but recommended
- Chan 2 (temperature) TEDS (+ calib TEDS)
- Chan 3 (humidity) TEDS (+ calib TEDS)
- Chan 4-6 (CO_2, VOC, Press.)
- XdrcName TEDS – Name (e.g. furnace room) given by user
- GeoLoc (Location) TEDS -- optional

Dot 0 Commands for EVM Sensor -- TEDS Related

- Tim Discovery --to see what is available
- Transducer discovery – to see what is available
- Read TEDS (read individually)
- Read Name TEDS
- Read Location TEDS (if available)
- Read Data (each channel individually or as a group
- Other commands available but not implemented here

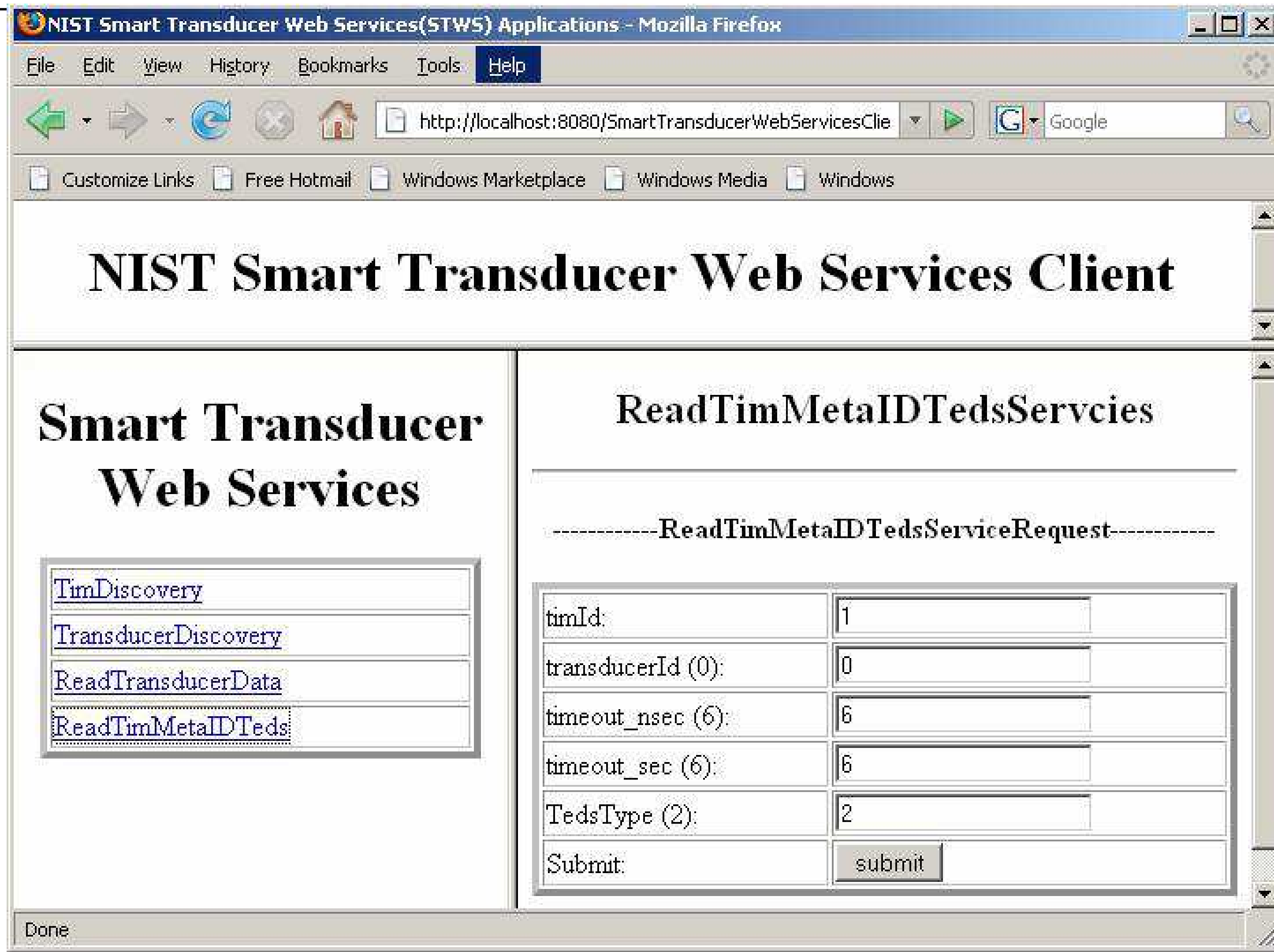
STWS vs HTTP direct

- Smart Transducer Web Services translates Dot 0 commands and data via HTTP into network friendly SOAP (Simple Object Access Protocol).

- STWS was developed at NIST (sponsor of 1451 protocol) – it is a version of the Dot 1 protocol which implements plug and play

- Other interfaces acceptable which are compatible with IEEE 1451.1 standard.

STWS Website



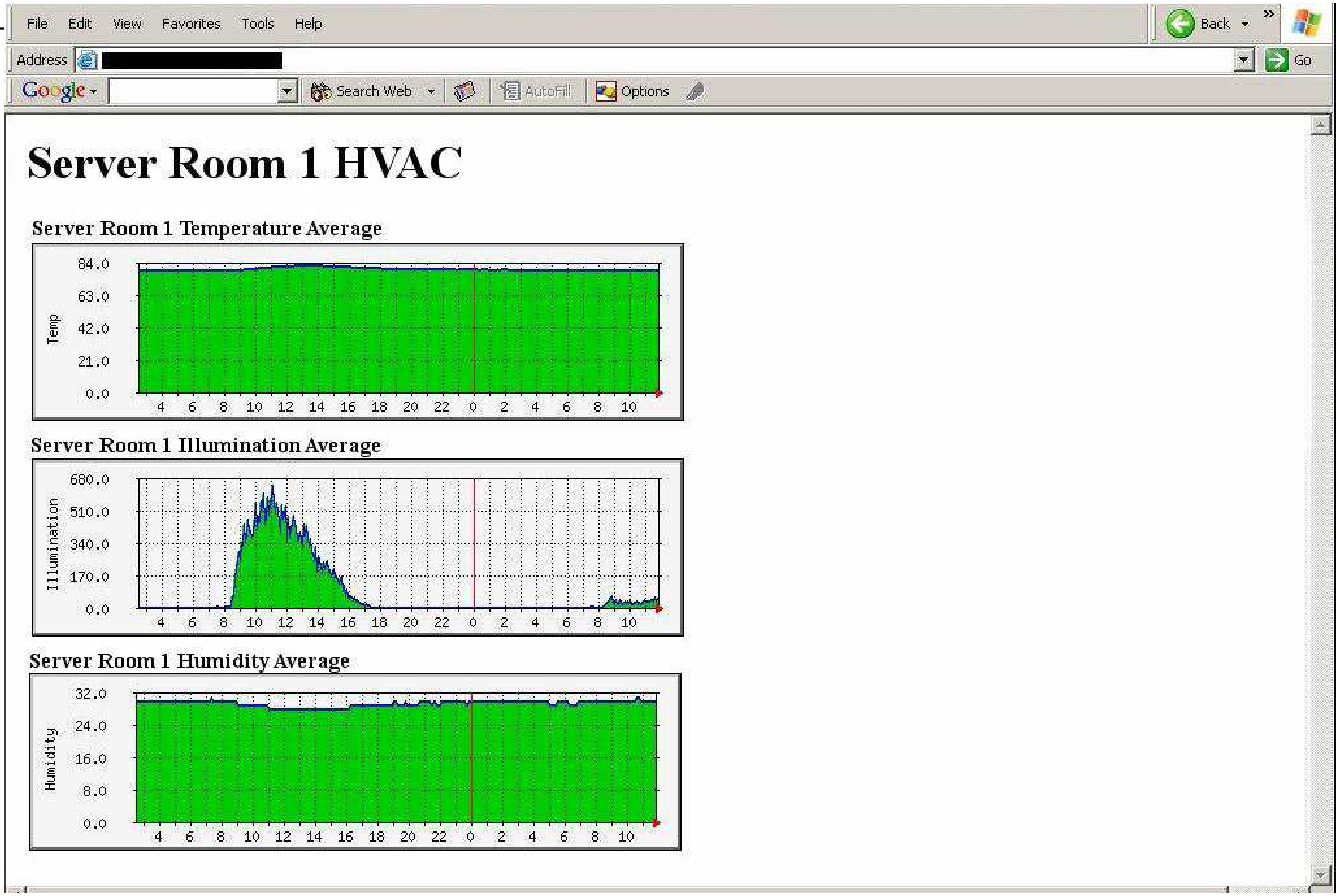
Dot 0 Commands for EVM Sensor -- TEDS Related

- TIM Discovery (to see which TIMs are available):
  http://192.168.254.99:80/1451/TIMDiscovery?responseFormat=text
  Response: 0,1
- TransducerDiscovery
  http://192.168.254.99:80/1451/TransducerDiscovery?timId=1&responseFormat=text
  Returns: 0,1,1,2,3,TEMP,HUM,ILLUM,CO2,VOC,PRESS
- Read TEDS (read individually)
- other

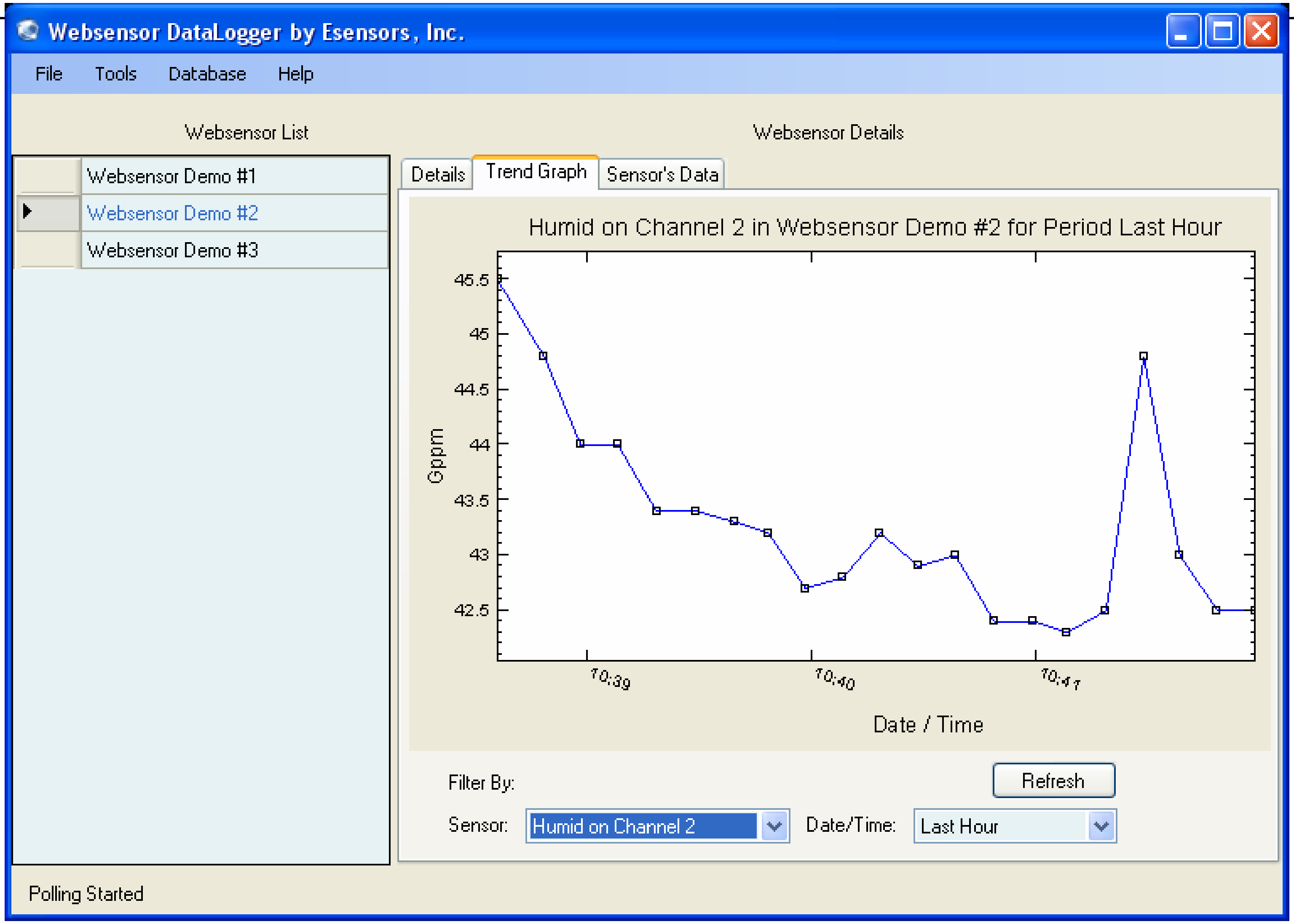
Readout of Dot 0 Data

- ReadTransducerData
  http://192.168.254.99:80/1451/ReadData?timId=1&channelId=1&sec=6&nsec=6&samplingMode=5&responseFormat=text
  Returns: 0,1,1,TEMP,25.99,C
- ReadMetaIDTEDS
  http://192.168.254.99:80/1451/ReadTeds?timId=1&channelId=0&sec=1&nsec=1&tedsType=2&responseFormat=text
  Returns: 0,1,0,2,24:75:32:10:FA:CC, Esensors Inc, Websensor

Graphical Readout of EVM Monitor
(3 function version)



Another Readout Example



Packaged Sensors

- Internet accessible via Ethernet
- Compact packaging
- IEEE 1451 Smart Transducer Standard Option

Temperature, humidity, illumination only [EM08]

EVM with 1451

Six function sensor suit (EVM) [EM09]

Part C

Environmental Monitoring Application Classes

- Building
  - Indoor air Quality
  - Energy usage (and control)
  - Lighting

- Industrial
  - *Above plus:*
  - Fire/smoke detection (fire alarms regulated)
  - Polluting gases (SO_2, NO_x)
  - Waste sites
  - Water quality

Building Monitoring
(indoor air quality)

- Occupant comfort
  - Temperature
  - Humidity
  - Illumination (lighting)
- Air quality (gases)
  - Carbon dioxide (CO_2)
  - Carbon monoxide (CO)*
  - Volatile Organic Compounds (VOC)*
- Storage
  - Refrigerated
  - Controlled environment (e.g. art)

*Safety

Building Monitoring for minimizing energy usage

- Monitor/meter
  - Electrical energy consumption
  - Illumination (varies with weather conditions)
  - Cost of energy (via Internet)
  - [control – reduce lighting and shed loads as needed]

- Monitor occupancy
  - Carbon dioxide level in occupied rooms
  - [control – decrease ventilation if CO_2 level is low]

Advantages of Internet-Capable Environmental Monitors

- Optimizes energy usage using information (e.g. current rates) from the Internet.
- Data from many buildings easily collected and complex analysis programs can be implemented
- Provides standard interfaces for monitors (sensors) and controls (actuators), thus facilitating transducer connection.
- Alerts to anywhere (email, cell phone) can be generated.
- Overall goals are to maximize efficiency and to minimize costs.

Summary

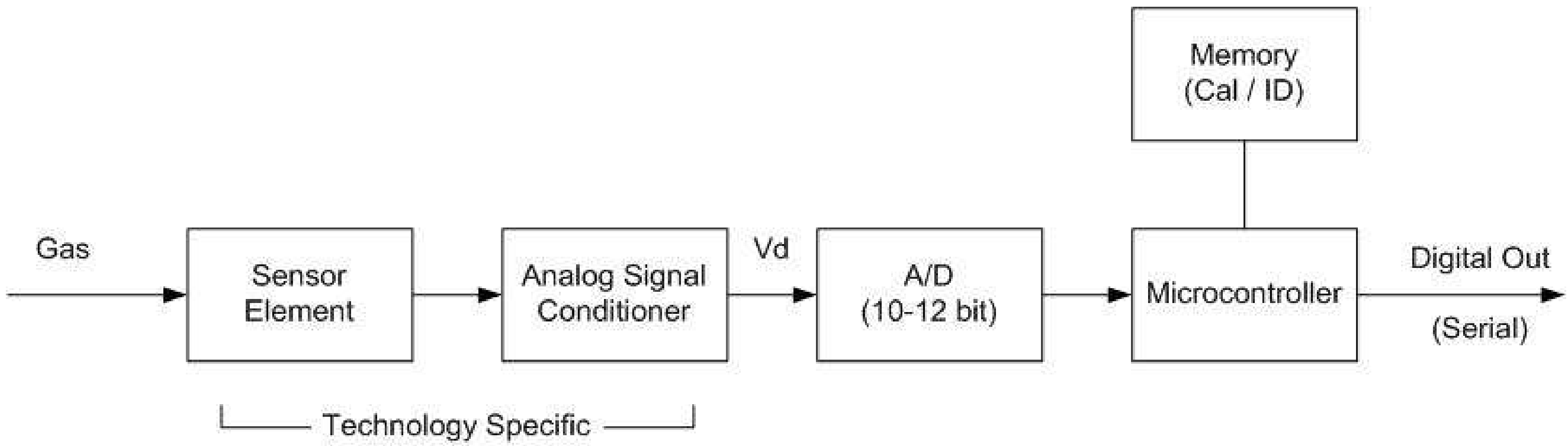
- Described smart environmental monitoring sensors (6 functions)
- Described networking with the IEEE 1451 transducer standard
- Discussed applications of networked environmental monitors.

www.eesensors.com

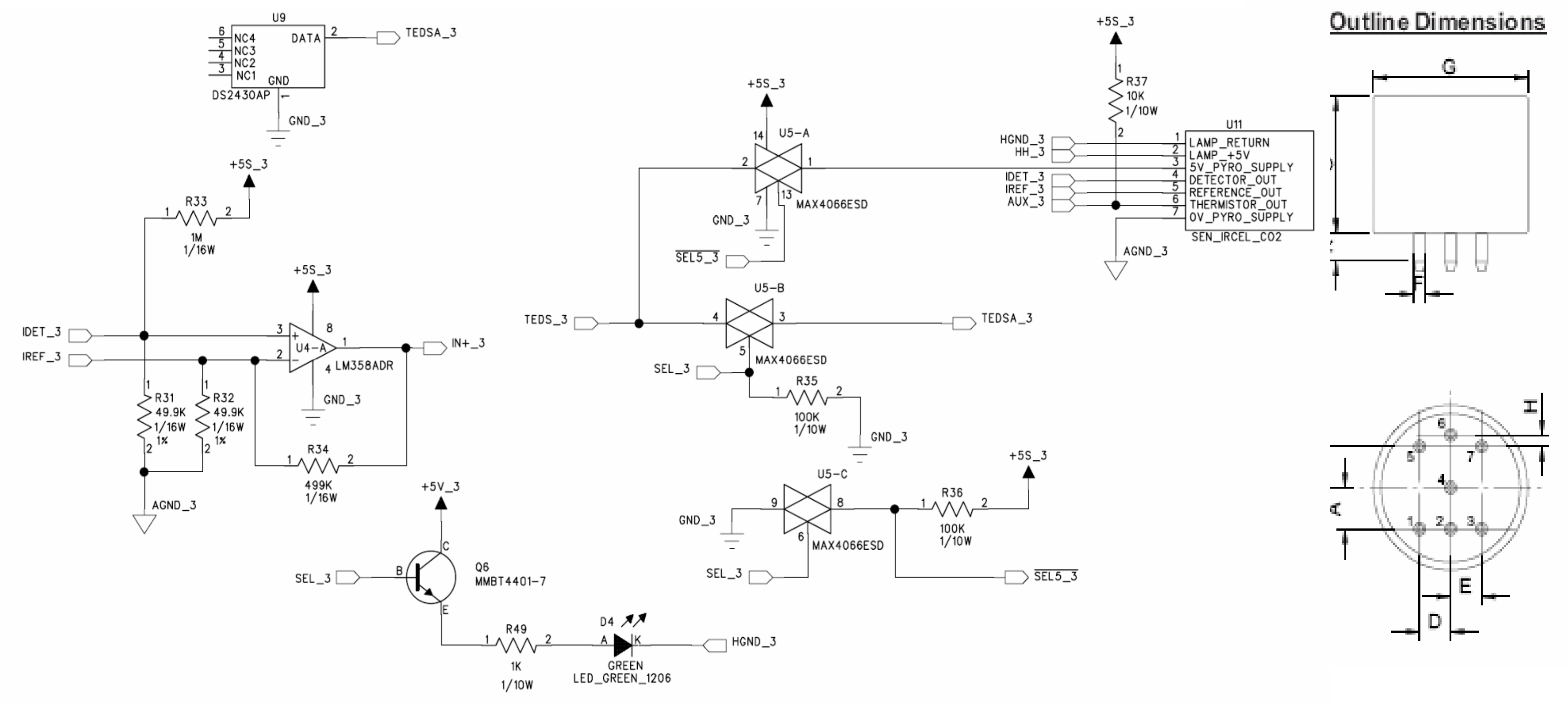
Backup Slides

Esensors Inc

Basic Digital Gas Sensor Block Diagram



Sensor Circuit Details



EMU (Environmental Monitoring Unit)

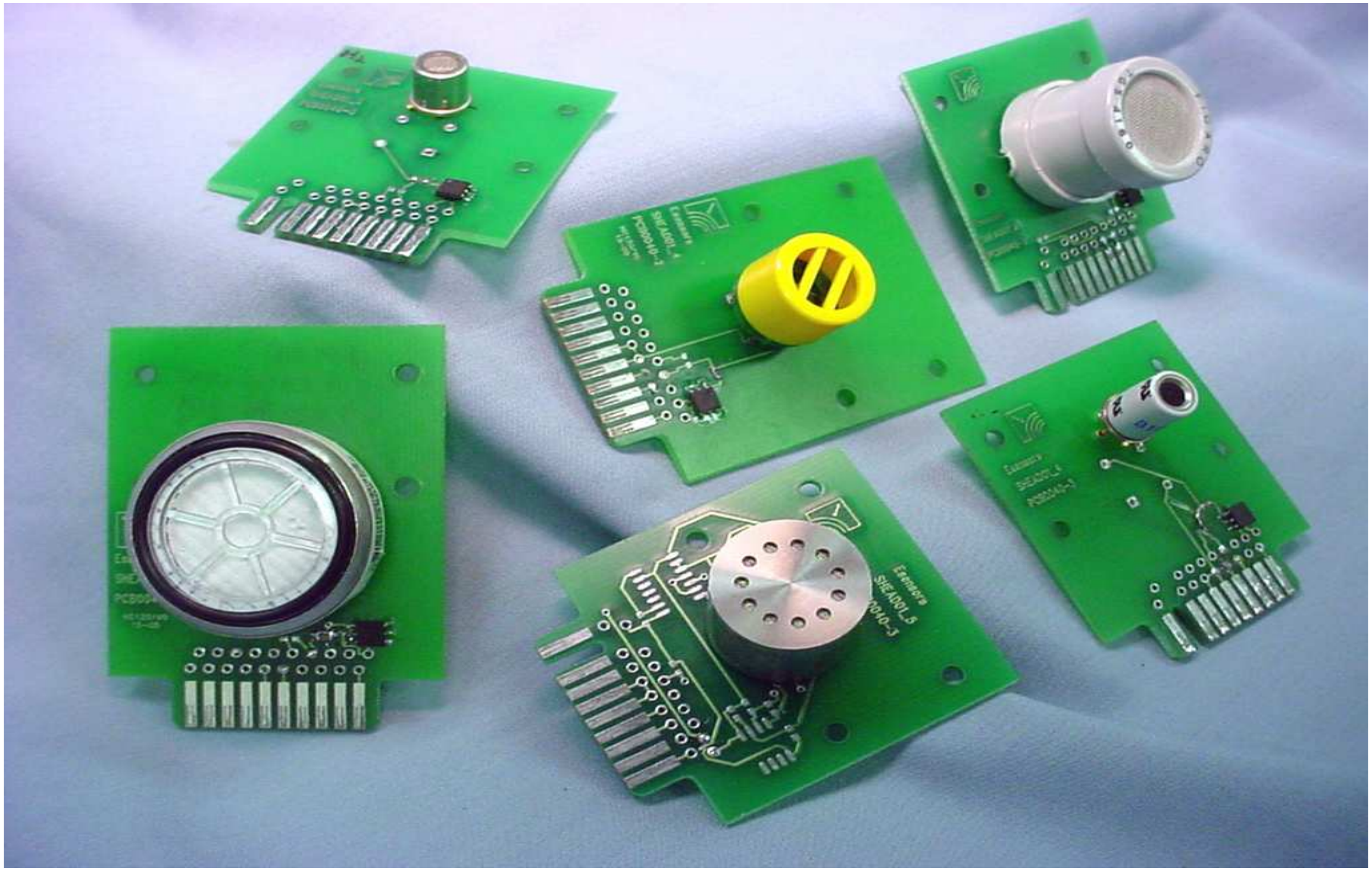
- Rapid Deployment
- Six Plug and Play Gas Sensor Slots
- Ethernet/Internet or wireless communication
- Uses IEEE 1451 Format (HTTP on network)

Demo version

Ruggedized version

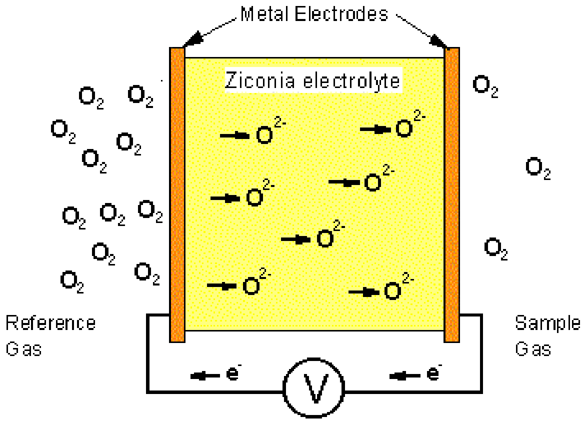
52

Photo of Sensor Pods

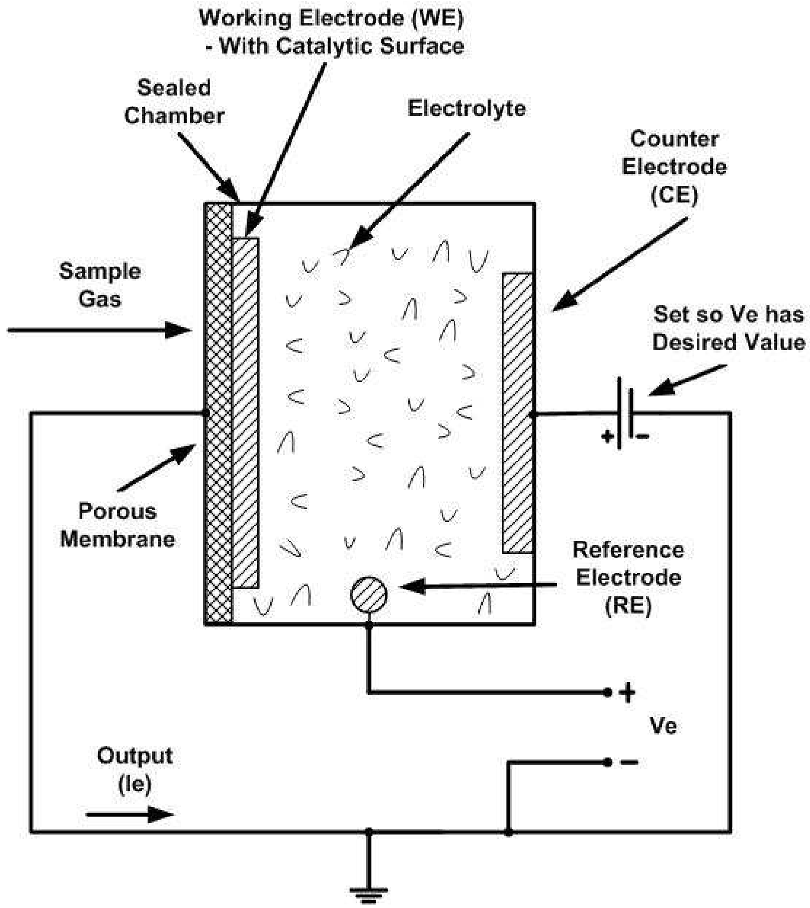


Solid Electrolyte Gas Sensor

- Similar to semiconductor gas sensor but has voltage output
- Heater (5v @ 11.5 ohms)
- Has thermistor for temperature control
- Vsen increases 50 mv per factor of 10 change in gas conc
  (220 to 490 mv at 350 ppm)
- Requires hi-Z amplifier
- Examples: Figaro TGS4160 (CO_2)
  or Oxygen (zerconia)
- Periodic re-zeroing desirable



Amperometric Sensor Construction



List of Gas Sensor Technologies

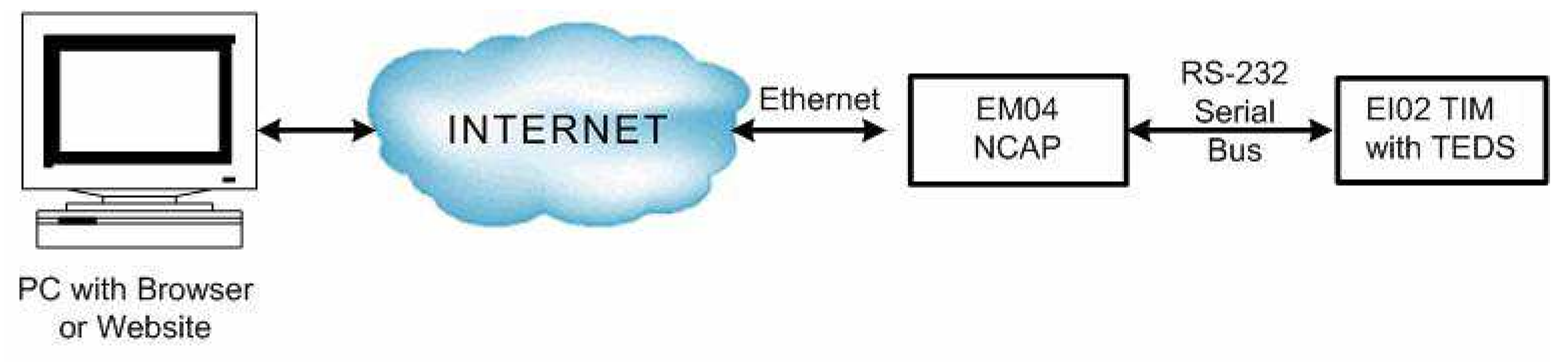
(different gases require different technologies)

- Semiconductor – resistive*
- Semiconductor – voltage*
- Amperometric*
- Catalytic*
- Infrared*
- Photo-ionization
- Fluorescent
- Surface acoustic wave (SAW) & vibrating beam
- Capacitive* and other

* Tested

Prototype TIM and NCAP

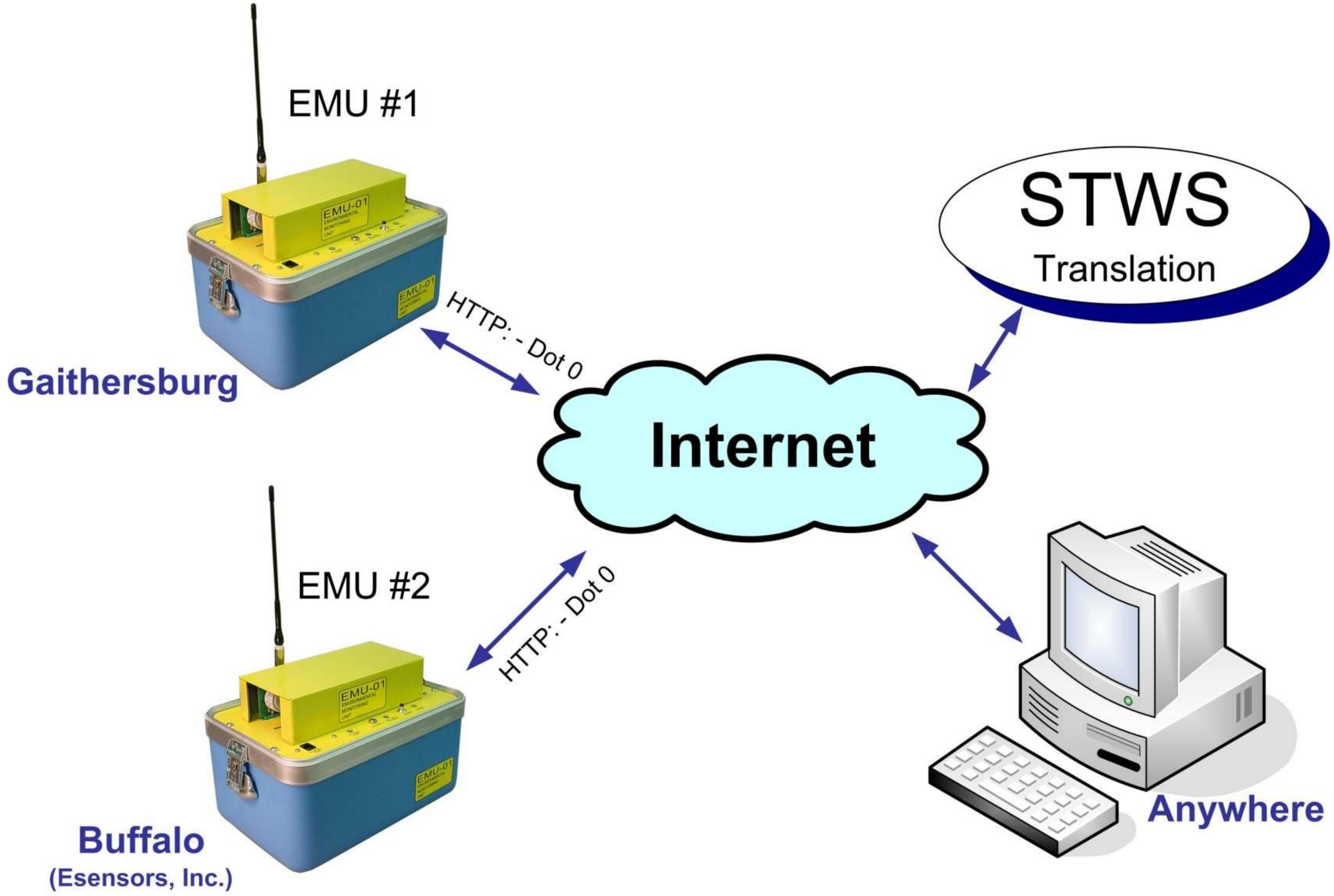
- NCAP interfaces to Internet via Ethernet



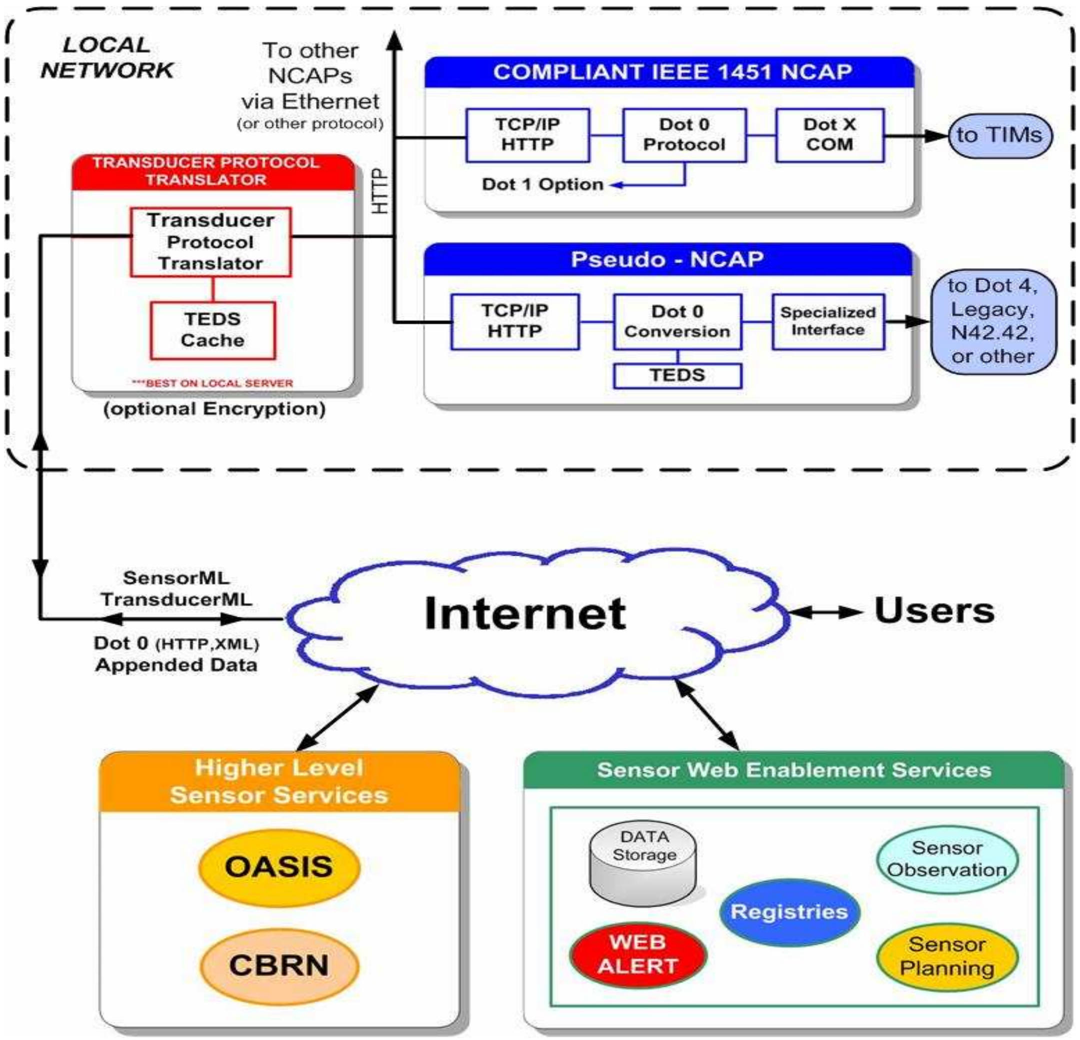
HVAC sensor with Internet Address

- Uses Ethernet as the Network
- Microcontroller has TCP/IP (mini-website) as protocol
- Data (temp/hum/light) can be read anywhere on Internet
- Polling/logging/display by remote websites
- This version is a smart sensor but does **<u>not</u>** have a IEEE 1451 standard interface

TEAM 1451 Gas Monitor Demo



Harmonization of IEEE 1451 with Internet sensor standards



Full Schematic of EVM

(EM09)