Smart Sensor in Wide Area Network Environment
How can sensors improve your safety?

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“To feel more is to know more”
Outline

• Introduction
• Need for monitoring system
• Issues of gas detection and measurement systems
• The concept of distributed monitoring system
  – Microprocessor based “Smart” sensor with semiconductor detector
  – TINI based control station
  – Utility software
  – Database for storing measurements
• Summary and Conclusions?
• Demo
Introduction

• “Smart Sensor in Wide Area Network Environment”

• Based on M.Sc. Thesis
  – Silesian University of Technology
  – ATEST-Gaz company

• Involved research
  – Gas measurements, signal processing
  – Monitoring systems
  – Java embedded systems

• Practical implications
  – Product currently manufactured and sold
  – National and EU (awaiting) certificate for industrial gas detectors
  – Entire system working in a prototype installation
Need for monitoring system (1)

- **Regulations**
  - Change in regulations for gas monitoring
  - Need for monitoring systems in new installations
  - Modernization of existing installations

- **Example applications of gas monitoring systems**
  - Coal mines
  - Chemical plants
  - Industrial plants
  - Petrol stations
  - Boiler houses
  - Underground parking places
  - Tunnels
  - Sewage treatment plants
  - Swimming pools
  - ...
Need for monitoring system (2)

• System Requirements
  – Efficient
  – Reliable (self diagnosis)
  – Easy to manage
  – Serviceable (remote access)
  – Modular
  – Database aware
  – Network aware
  – Secure
  – Low cost

• How existing systems satisfy this

• How this can be changed
Issues of gas detection and measurement systems

- Gas detection, signal processing
  - Variety of detection elements
  - Need for universal processing algorithm

- “In situ” sensor access
  - Means of access
  - Diagnostics and recalibration
  - Security issues
  - Compliance with EX regulations

- Measurement systems
  - Communication bus – capabilities and limitations

- Application of Java based controller
  - Areas of concern
    - Reliability
    - Speed
    - Resources
  - Internet technologies - implications on the system
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The concept of distributed monitoring system
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Issues of gas detection and measurements

- Different types of sensors used in measurement systems
  - Semiconductor
  - Electrochemical
  - Catalytic combustion (pellistor)
  - ...

- Analog signal acquisition
- Signal processing
- Measurements, threshold detection and output control
- Data transmission
Microprocessor Smart Sensor (2)

• What it is (input, output)

• Digital signal processing
  • Data acquisition
  • Extraction
  • Prenormalization
  • Environment compensation and normalization
  • Sensor diagnostics, output control

• Sensor calibration
  – Memory map
  – Storing multiple entries
Microprocessor Smart Sensor (3)
Piecewise linear approximation, dynamic data structures

- Sensor characteristics approximation

- Data structures
Microprocessor Smart Sensor (4)
Communication protocol

• Communication protocol – Modbus ASCII
  – Standard and common protocol
  – Can be easily integrated with PLC
  – Easy to implement on microprocessor with limited resources – class0 compliance

• Modbus memory map
  – Allows to identify type of device, product and software version
  – Sets standard for existing and future devices
Microprocessor Smart Sensor (5)
Implementation
• Introduction

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• Issues of gas detection and measurement systems

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Java based controller (1)
Controller functions

- reading sensor states
- local control
- connecting to TCP/IP network
- HTML pages generation
- storing measurements into database
- remote sensor (and controller) configuration
Claim: “Java based microcontroller can be successfully applied in distributed gas detector system with a limited number of sensors, carrying all required functions”

Verify the suitability of Java based embedded platform for the purposes of the system
- feasibility and ease of implementation of required controller functions
- system resources
- system performance - sensor read frequency (i.e. number of sensors that can be effectively handled, T₉₀ must be ensured)
- system reliability

System design should ensure features not inherent to the platform
- detection of missed deadlines
- failure of TCP/IP network should not cause the stop of system critical functions
Java based controller (3)

TINI architecture

- **TINI - Tiny InterNet Interface**
  - DS80C390 processor (51’ clone)
  - Operating System with Java VM, Ethernet controller and TCP/IP stack
  - Two types of memories EEPROM and static RAM
Java based controller (4)

DSTINI1

- Proven and fully functional SIMM-sized computer based on TINI platform
  - Ethernet 10 Base – T controller
  - processor data and address bus available
  - 2 serial ports
  - 512kB FlashROM i 1MB SRAM
  - RTC
Java based controller (5)
Java Operating System

- Multitasking
- Memory filesystem support
- **Standard Java classes**
  - TCP/IP connections handling
  - HTTP server
  - Serial interfaces
- **Other protocols can be easily implemented**
  - Modbus
  - XML-RPC
Java based controller (6)

XML

- WWW pages in XML format
  - Measurement results can be easily extracted and processed
  - Data can be used by many standard applications
  - Changes in visualization do not require software modifications

- Transformation XML + XSL -> HTML
  - Can be done in XML compliant browser (e.g. IE 6.0)

- Java applets and Macromedia Flash applications can be used
  - Client side processing
  - Greater capabilities than XSL
Java based controller (7)

XML-RPC

- Cross-platform standard for distributed processing
  - Uses XML encoding
  - HTML-POST envelope
  - Libraries available for most of operating systems
  - 80% SOAP's capabilities – 20% SOAP complexity
- Great capabilities - limited speed
- Remote sensor configuration and database access by means of XML-RPC
  - XML-RPC server implementation (remote access)
  - XML-RPC client implementation (DB)
Java based controller (8)
Prototype
Java based controller (8)

Verification

- Proved feasibility of TCP/IP network and embedded Java controller in the design of distributed sensor system.
- The resources of TINI platform limit the number of sensor devices to approximately 40 pieces (ensuring $T_{90}$)
- Prototype system proved to be reliable, however the system reliability should be supported by other means
  - Hardware
  - Software
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Utility software (1)

- Used for sensor’s configuration, calibration and diagnosis
- Modular architecture
  - Handles different sensors with different software versions
  - Different means of communication
- Java Swing Application
  - Can be integrated with existing code (e.g. TINI software device classes)
Utility software (2)
Utility software (3)
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Database for storing measurements (1)
Considered architectures

- **Local sensor databases**
  - Resources
  - Communication issues

- **Local controller databases**
  - TINI resources
  - Communication protocol

- **Global system database**
  - Another layer required
  - Security issues
Database for storing measurements (2)

Architecture

- Three layer architecture
- XML-RPC
- Java and JDBC technology
  - Acceptable speed
  - Database independent
  - Code reusability
Database for storing measurements (2)
Sample implementation
Conclusions?

- Universal method for gas detector signal processing
  - Applicability of piecewise linear approximation on low resources microcontrollers
  - Measurements and tests for different sensors

- Measurement systems
  - Protocol analysis, capabilities and limitations
  - Feasibility of implementation

- Distributed gas measurement systems
  - Use of Internet protocols in industrial systems
  - Application of low cost Java based controller
  - Remote access
    - Diagnostics, Configuration, Calibration

- Implementation and testing

- Areas of future work…
Summary

• Need for gas monitoring systems.
• Ideal system requirements
• Research areas
• The concept of distributed monitoring system
  – Smart – microprocessor based sensor with semiconductor detector
  – TINI – the application of Java based controller in the system
  – SmartSet – utility software – sensor configuration, calibration diagnostics
  – Database for storing measurement results
Questions
END
SmartSensor in Wide Area Network - ON-LINE SYSTEM STATE

Server: TINI Server - Zurich demo (IP: 10.0.0.22)
TINI system clock: Fri Nov 01 12:23:05 GMT 2002

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<th>Modbus Address</th>
<th>Transmissions OK</th>
<th>Transmissions Failed</th>
<th>Sampling Period [ms]</th>
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<td>Flag: STATEA</td>
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2. Carbon monoxide sensor #2

3. Carbon monoxide sensor (Ev)
### 3. Carbon monoxide sensor (EX)

**Modbus address:** 200  
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**Transmissions Failed:** 0  
**Sampling period [ms]:** 1750

**Sensor type:** 1  
**S/W version:** 0.0.1  
**Compile date:** 2/5/22  
**S/N:** 1100

**Sample counter:** 158  
**Sensor lifetime:** 36  
**Temperature:** 24 [°C]  
**Concentration:** 1604 [ppm]

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**S/W version:** 0.0.6, **H/W version:** 0.0.1, **Compile date:** 02/06/02, **TINI lifetime:** 0:0:170

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Digital Outputs Module DO-8
Modbus protocol

Controller

QUERY

Transmission OK

Controller

RESPONSE

QUERY

TIMEOUT

Controller

QUERY

Exception response

Controller

EXCEPTION-RESPONSE

Controller

QUERY

Broadcast transmission

Controller

BROADCAST QUERY
SB-95 Sensor

Active charcoal filter

Sensor

Identification mark

RS : sensor resistance
RH : heater resistance
Sensor structure

Measurement Head
- Sensor
- Temp

Analog Processing
- SWITCH
- vHEAT
- vDET
- vTEMP

A/D
- A
- B

uP PIC 16F873
- PWM
- Serial

Communication Interface
- RX
- TX
- DIR
- RS485
- 4-20mA

LED Signalling

+5V

4-20mA

uP

PIC 16F873