The Smart Transducer Interface Standard (IEEE P1451)

NIST Workshop on Data Exchange Standards at the Construction Site

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Sensor Development and Application Group

Manufacturing Engineering Laboratory

National Institute of Standards and Technology

United States Department of Commerce

Introduction

- Sensors are ubiquitous
  - Aerospace and automotive
  - Industrial control and automation
  - Manufacturing and process control
  - Building automation and security
  - Homland security and first responders
  - Construction site
- Increasing uses of digital communication and networked configurations for connecting sensors and actuators.
- The trend is moving toward distributed control with intelligent sensing architectures.
- Wireless sensor communications are becoming critical to rapid deployment and cost-effective utilization.

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Sensor Market Drivers

Total Smart Sensors Market: Market Drivers Ranked in Order of Impact (North America), 2001-2007

Rank	Driver	1-2 Years	3-4 Years	5-7 Years
1	Additional IEEE standards approvals prods smart sensors demand.	High	High	High
2	Microchip helps drive smart sensing.	High	High	High
3	Adaptive technology stimulates market growth.	High	High	High
4	Higher reliability and lesser downtime spur market revenues.	High	High	Medium
5	Integration of smart IR temperature sensors increases process control applications.	Medium	Medium	High
6	Extended sensor's useful life promotes demand.	Medium	High	High
7	Development of communication networks boost revenues.	Medium	High	High
8	Increasing applications for condition monitoring spurs demand.	Medium	Medium	Medium

Source: Frost & Sullivan

Sensor Market Restraints

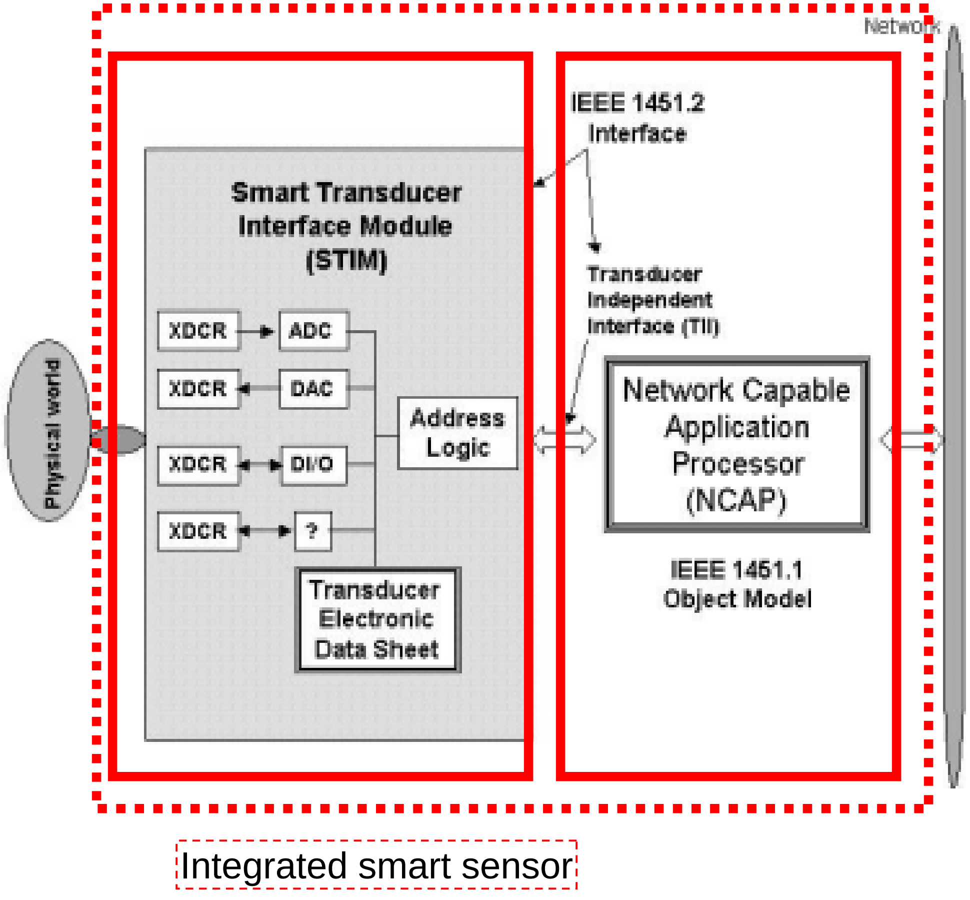
Total Smart Sensors Market: Market Restraints Ranked in Order of Impact (North America), 2001-2007

Rank	Restraint	1-2 Years	3-4 Years	5-7 Years
1	Absence of universal interface standards limits market growth.	High	High	Medium
2	New smart technology hinders market penetration.	High	Medium	Medium
3	High prices thwart market revenues.	High	Medium	Medium
4	Slow end user acceptance restrains smart sensors revenues.	High	Medium	Medium
5	Skepticism to adopt digital signal conditioning retards market expansion.	High	Medium	Medium
6	Smart I/O distributed systems retards smart sensors growth.	Medium	Medium	Low
7	United States economic slowdown impedes market growth.	Medium	Medium	Low

Source: Frost & Sullivan

Establishment of IEEE P1451 Smart Transducer Standard

- An industry-wide, open standard
- Providing common interfaces between sensors/actuators and instruments,microprocessors, or networks.
- Analog, digital, and wireless interfaces
- Self-describing sensor via the Transducer Electronic Data Sheet (TEDS)



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Goals of the IEEE P1451 Standard

- Develop network-independent and vendor-independent transducer interfaces,
- Provide standardized Transducer Electronic Data Sheets (TEDS) that contain manufacture-related data.
- Support a general transducer data, control, timing, configuration, and calibration model,
- Allow transducers to be installed, upgraded, replaced and/or moved with minimum effort,
- Eliminate error prone, manual entering of data and system configuration steps,
- Ease the connection of sensors and actuators by wireline or wireless means.

Status of the IEEE P1451 Standard

- **IEEE P1451.0,** **Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats --** ***In progress***

- **IEEE Std 1451.1-1999,** **Network Capable Application Processor (NCAP) Information Model for smart transducers --** ***Published standard***

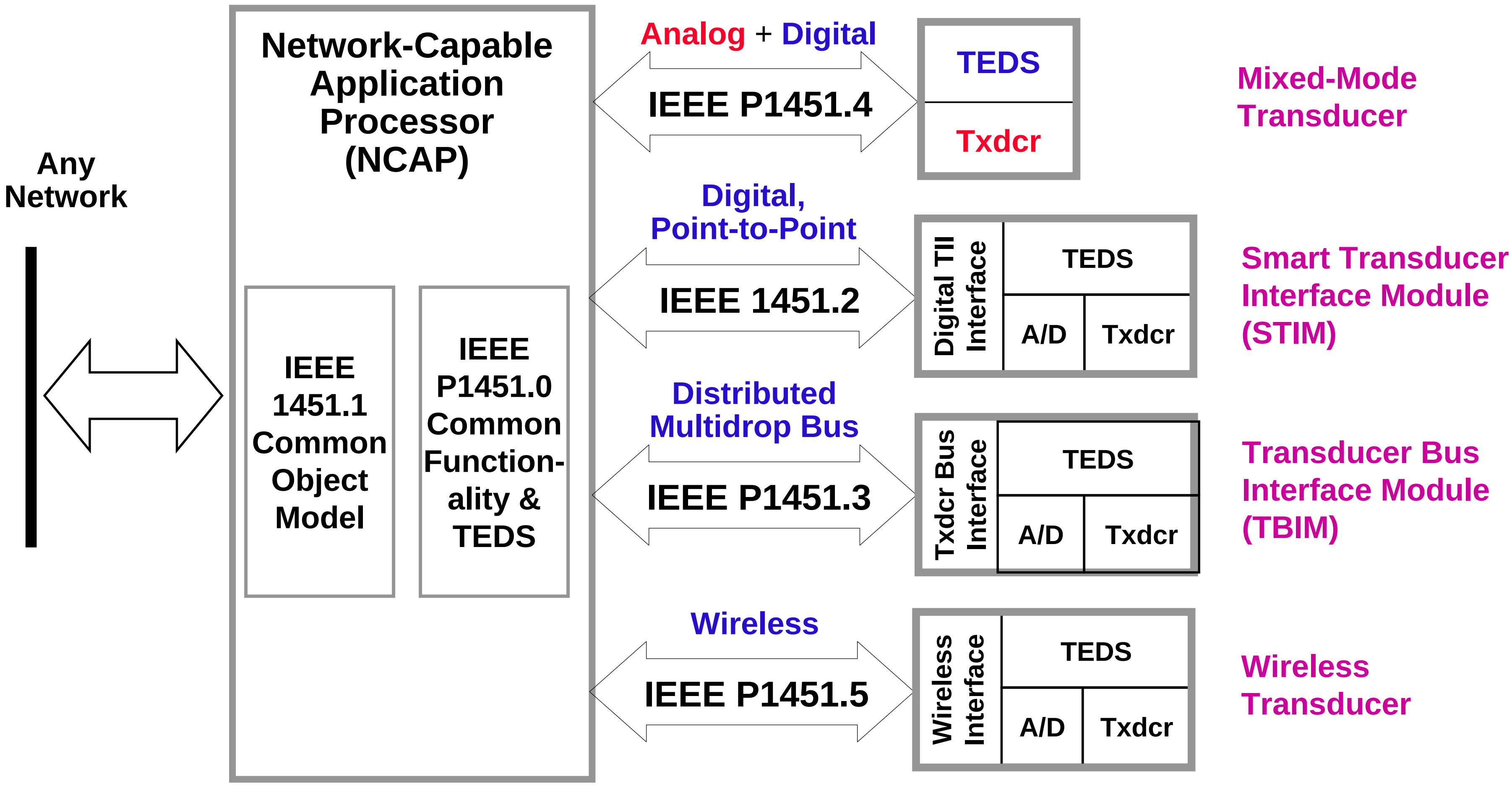
- **IEEE Std 1451.2-1997,** **Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats --** ***Published standard***

- **IEEE P1451.3,** **Digital Communication and Transducer Electronic Data Sheet (TEDS) Formats for Distributed Multidrop Systems --** ***Balloting in progress, May 2003***

- **IEEE P1451.4,** **Mixed-mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats --** ***Balloting in progress, May 2003***

- **IEEE P1451.5,** **Wireless Communication and Transducer Electronic Data Sheet (TEDS) Formats –** ***In progress***

IEEE 1451 Family of Smart Transducer Interface Standards



TII = Transducer Independent Interface

Txdcr = Transducer (Sensor or Actuator)

Transducer Electronic Data Sheet (TEDS)

Example: IEEE 1451.2

- **Meta-TEDS**
  - Data structure related information
    - version number
    - number of implemented channels
    - future extension key
    - ...
  - Identification related information
    - manufacturer's identification
    - model number
    - serial number
    - revision number
    - date code
    - product description
    - ...

Transducer Electronic Data Sheet (TEDS) - cont'd

Example: IEEE 1451.2

- **Channel TEDS**
  - Transducer related information
    - lower range limit
    - upper range limit
    - physical unit
    - unit warm-up time
    - uncertainty
    - self test key
    - ...
  - Data Converter related information
    - channel data model
    - channel data repetitions
    - channel update time
    - channel read setup time
    - channel write setup time
    - data clock frequency
    - channel sampling period
    - trigger accuracy
    - …

Transducer Electronic Data Sheet (TEDS) - cont'd
Example: IEEE 1451.2

- **Calibration TEDS**
  - Data structure related information
    - Calibration TEDS length
  - Calibration related information
    - last calibration date-time
    - calibration interval
    - number of correction input channels
    - multinomial coefficient
    - ….
  - Data integrity information
    - checksum for calibration TEDS

Transducer Electronic Data Sheet (TEDS) - cont'd

- TEDS data could be in
  - Binary format
  - Human readable format
  - XML format

Industry/Government Collaboration

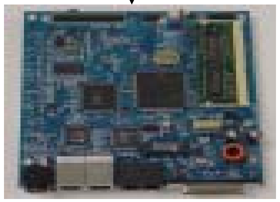
Control network providers participated in preliminary 1451.2 standards specification verification.

- ✓ **DeviceNet**
  by Allen-Bradley
- ✓ **LonWorks**
  by Echelon
- ✓ **Smart Distributed System (SDS)** by Honeywell Microswitch
- ✓ **Ethernet**
  by Hewlett-Packard

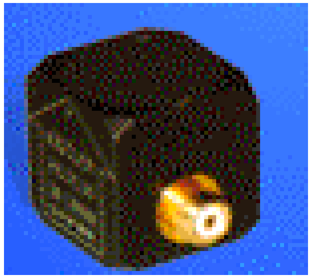
IEEE 1451

Enables "Plug and Play" of Transducers to Networks

Any Network



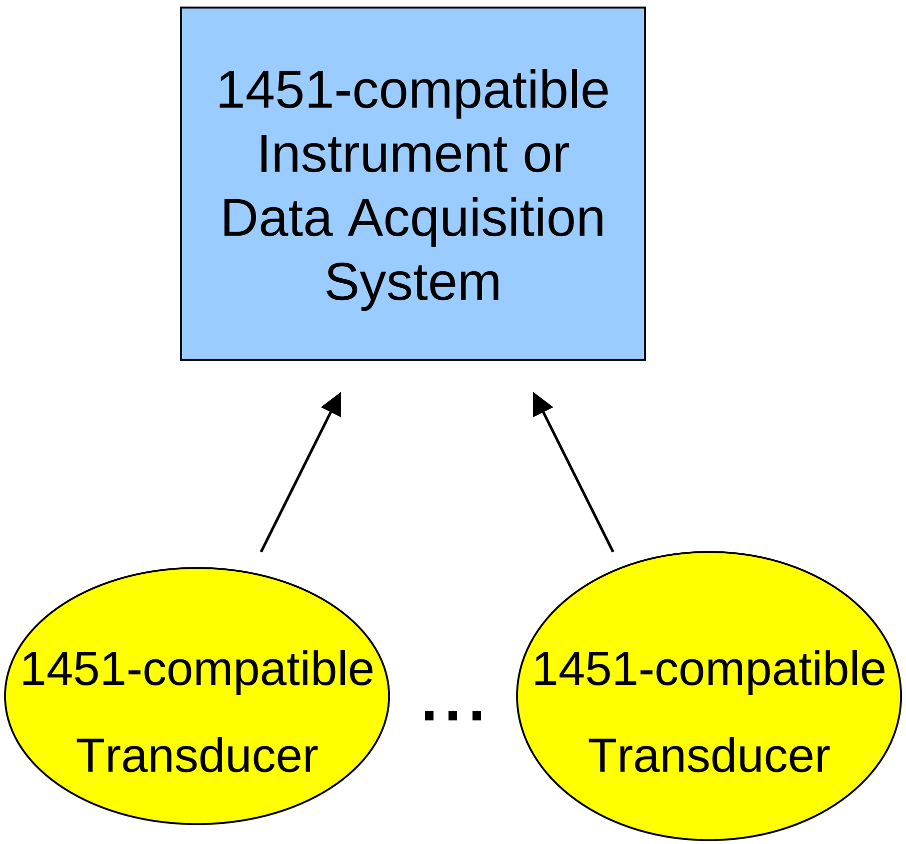
1451 NCAPs



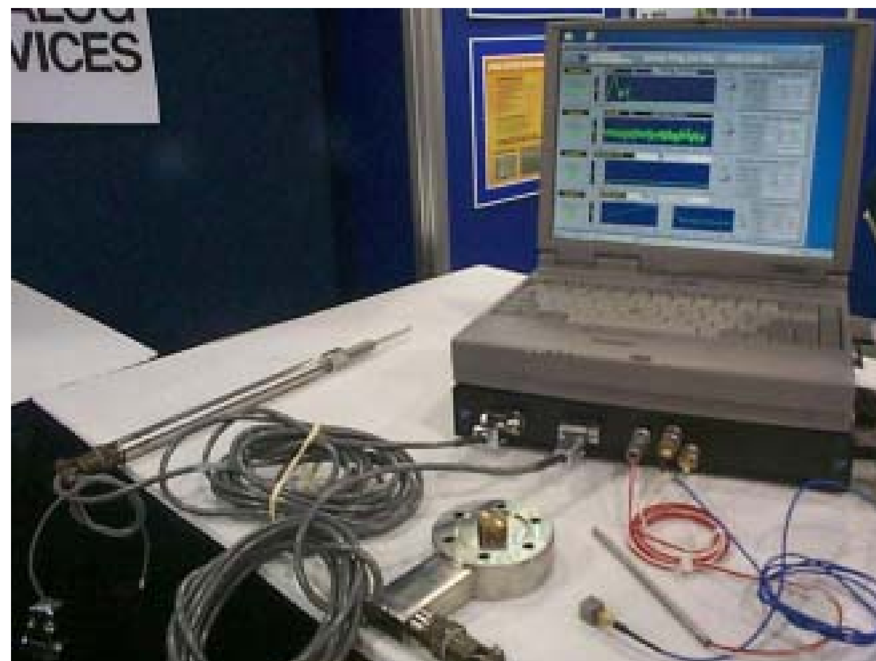
1451-compatible transducer

1451-compatible transducer

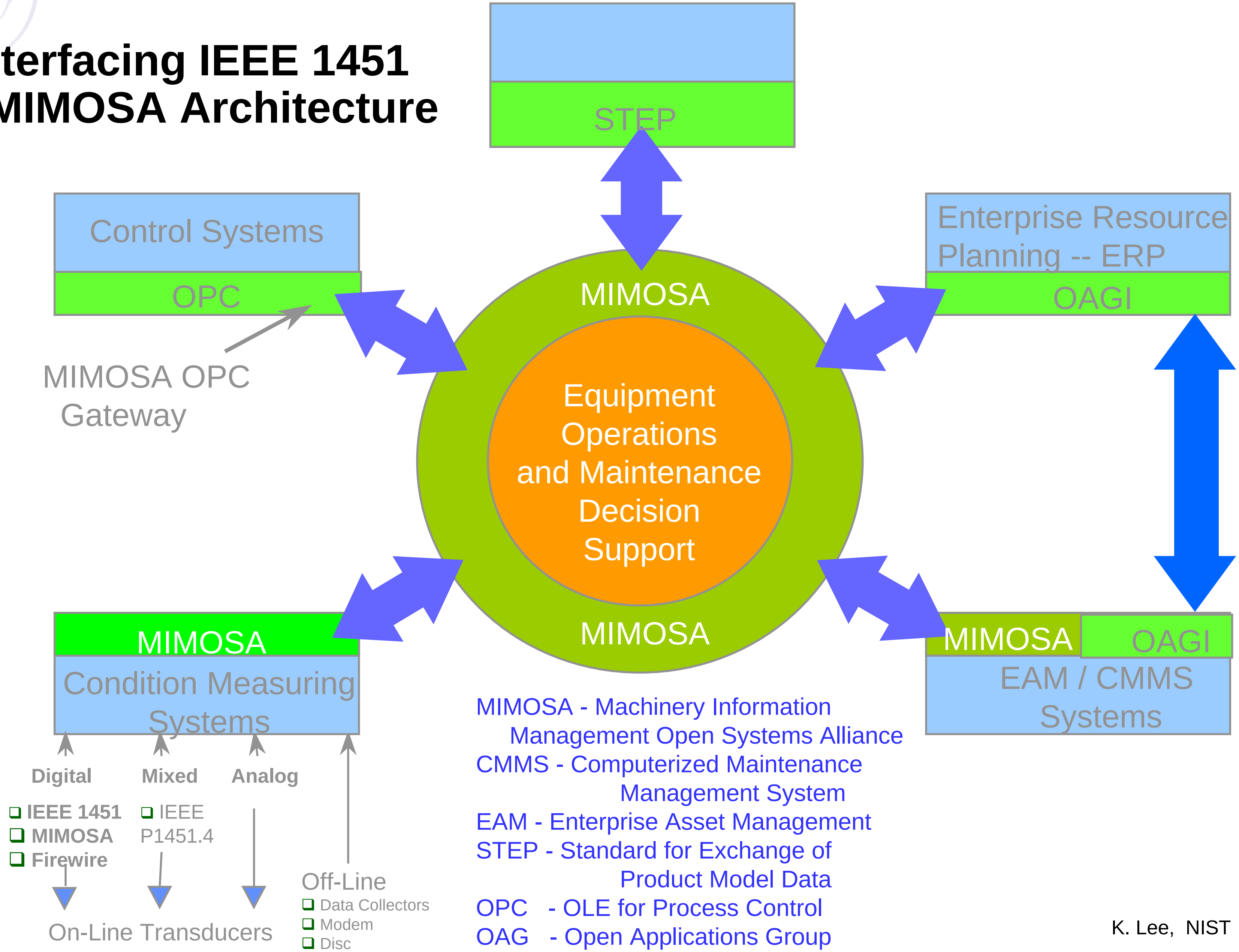
IEEE 1451
Enables “Plug and Play” of Transducers to instruments



Example: P1451.4 transducer demonstration (acceleration, load cell, position, and temperature sensors, etc)



Interfacing IEEE 1451 to MIMOSA Architecture

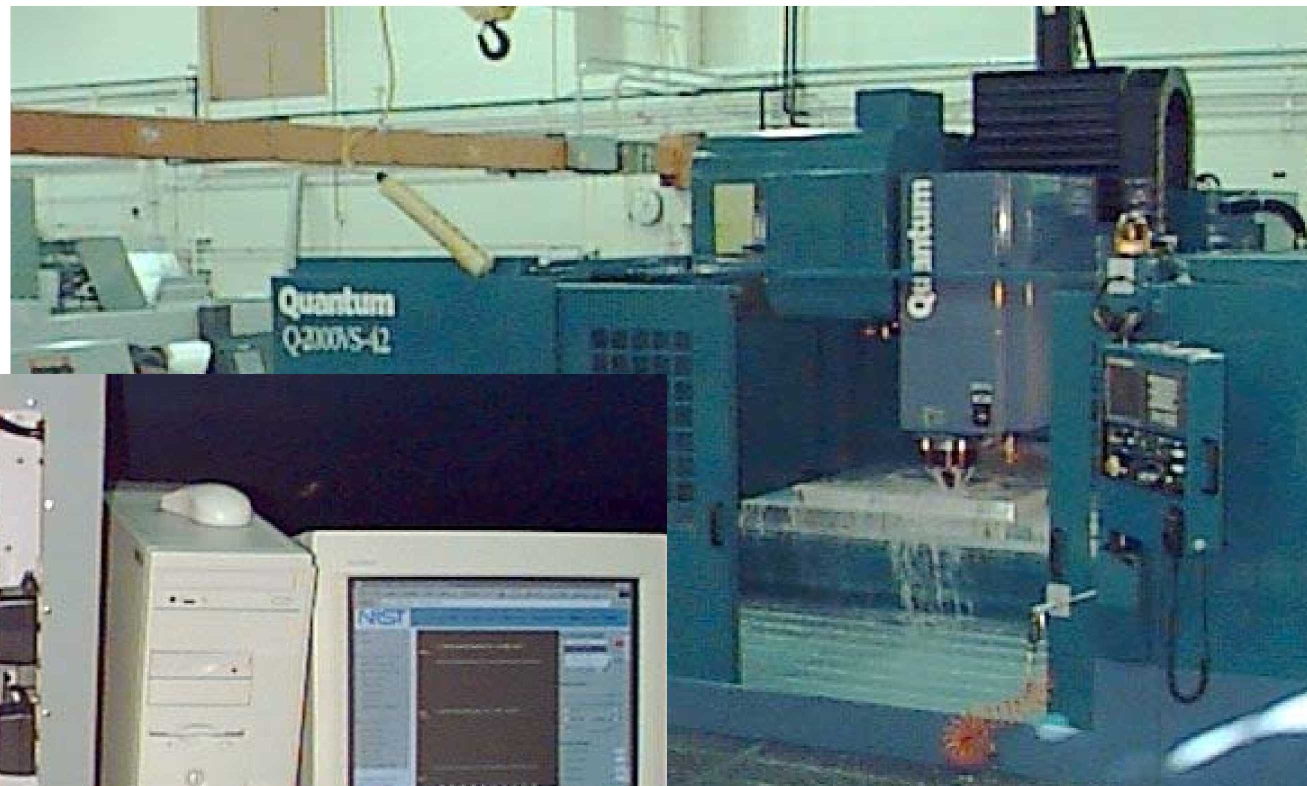


MIMOSA - Machinery Information Management Open Systems Alliance
CMMS - Computerized Maintenance Management System
EAM - Enterprise Asset Management
STEP - Standard for Exchange of Product Model Data
OPC - OLE for Process Control
OAG - Open Applications Group

Machine Condition Monitoring in the Shop

- Temperature sensors monitor spindle motors, bearings, axis drive motors.
- Allow monitoring of sensors over the Internet via any common web browser.

NCAP & STIM
in each box



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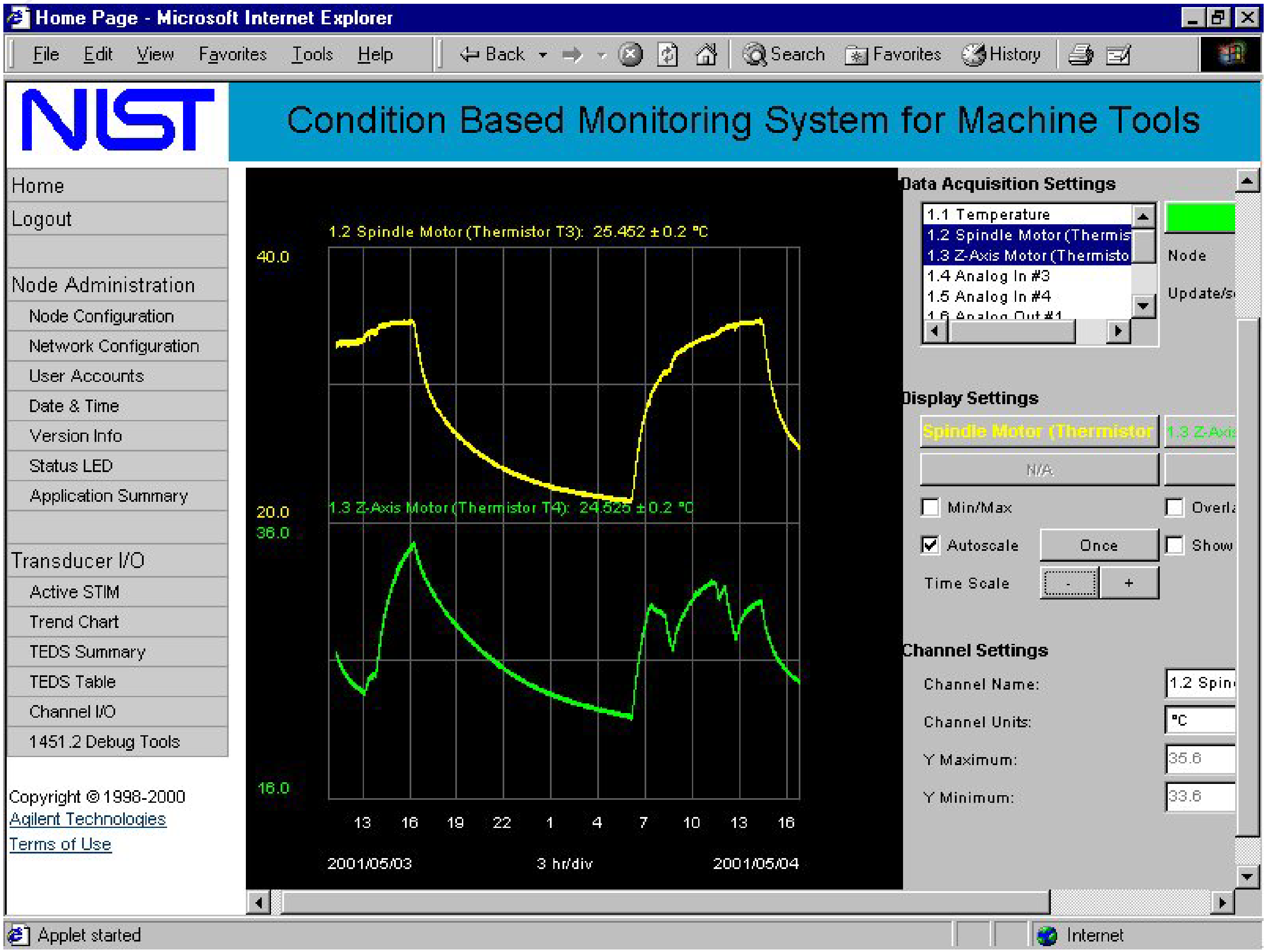
Home Page - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites History
Condition Based Monitoring System for Machine Tools
Home
Logout
Node Administration
Node Configuration
Network Configuration
User Accounts
Date & Time
Version Info
Status LED
Application Summary
Transducer I/O
Active STIM
Trend Chart
TEDS Summary
TEDS Table
Channel I/O
1451.2 Debug Tools
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1.2 Spindle Motor (Thermistor T3): 25.452 ±0.2 °C
40.0
20.0
1.3 Z-Axis Motor (Thermistor T4): 24.525 ±0.2 °C
36.0
16.0
13 16 19 22 1 4 7 10 13 16
2001/05/03
3 hr/div
2001/05/04
Data Acquisition Settings
1.1 Temperature
1.2 Spindle Motor (Thermis
1.3 Z-Axis Motor (Thermisto
1.4 Analog In #3
1.5 Analog In #4
Node
Update/s
Display Settings
Spindle Motor (Thermistor
1.3 Z-Axis
N/A
Min/Max
Overl
Autoscale
Once
Show
Time Scale
-
+
Channel Settings
Channel Name:
1.2 Spin
Channel Units:
°C
Y Maximum:
35.6
Y Minimum:
33.6
Applet started
Internet

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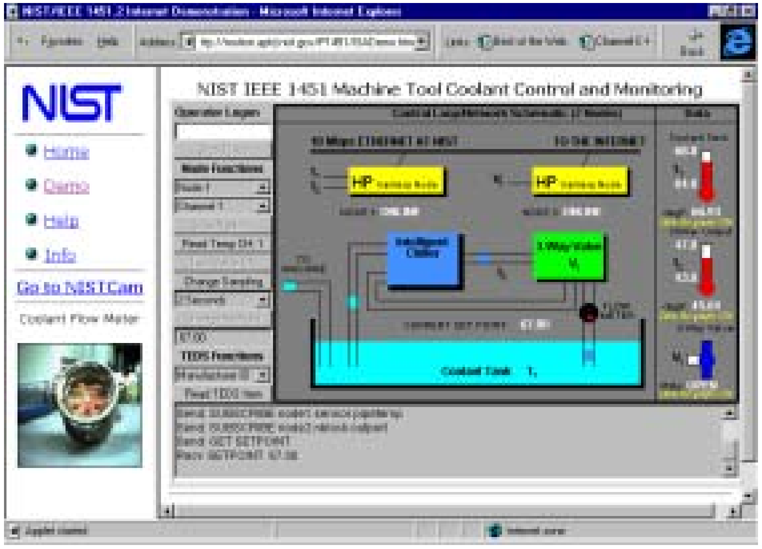
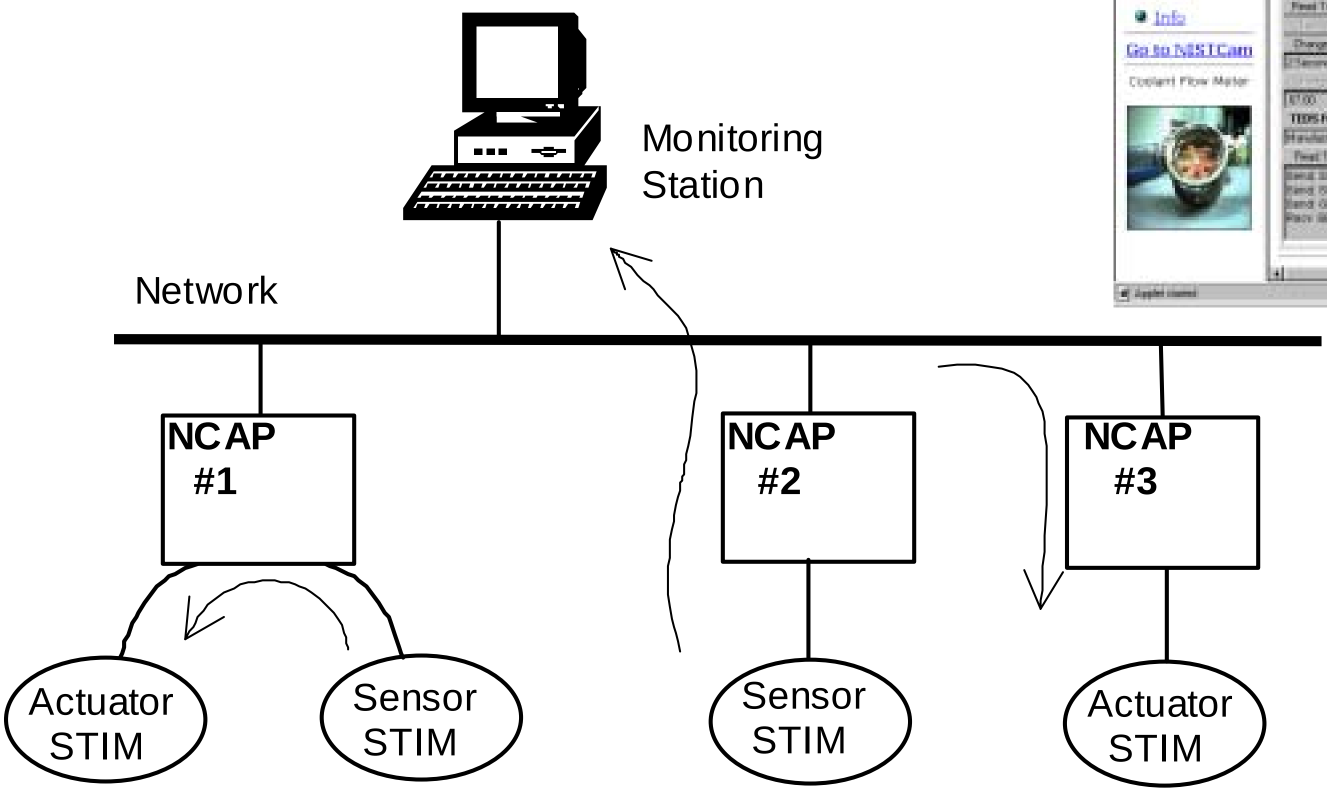
Web-based Distributed and Remote Monitoring and Control





Distributed Control **Remote Sensing** **Remote Actuating**

Wireless Sensor Interface IEEE P1451.5

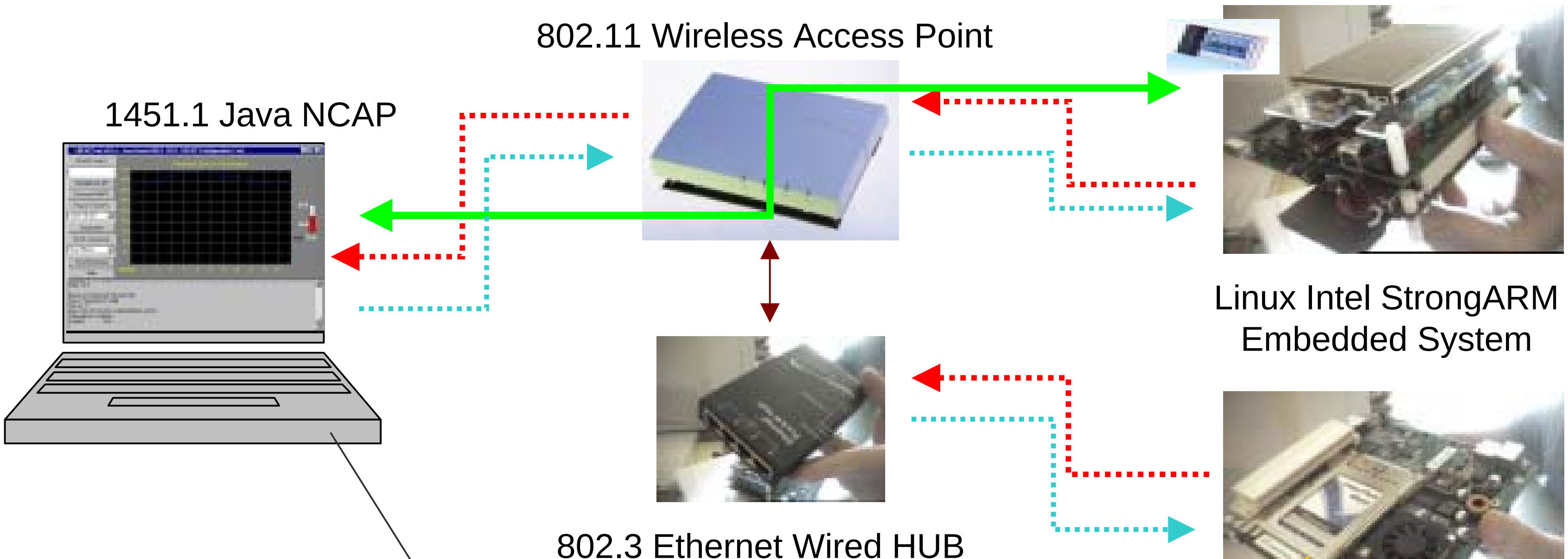
- Low-cost wireless links will
  - reduce and/or eliminate the cost-prohibitive cabling
  - decreased number of cable/LAN drops
  - greatly reduced sensor installation cost
  - reduced labor and training hours
  - faster installation and setup times
  - enable collection of data by easily installing condition-based monitoring of equipment at an affordable cost.
  - achieve cost saving realization of the predictive maintenance program

- What physical layer(s) to adopt in IEEE P1451.5?
  - IEEE 802.11 (FIWI)
  - IEEE 802.15.1 (Bluetooth)
  - IEEE 802.15.4 (PAN, lower power, lower rate, lower cost)
  - Others ?

NIST 1451.1 Platform-Independent Wireless Interface Demonstration

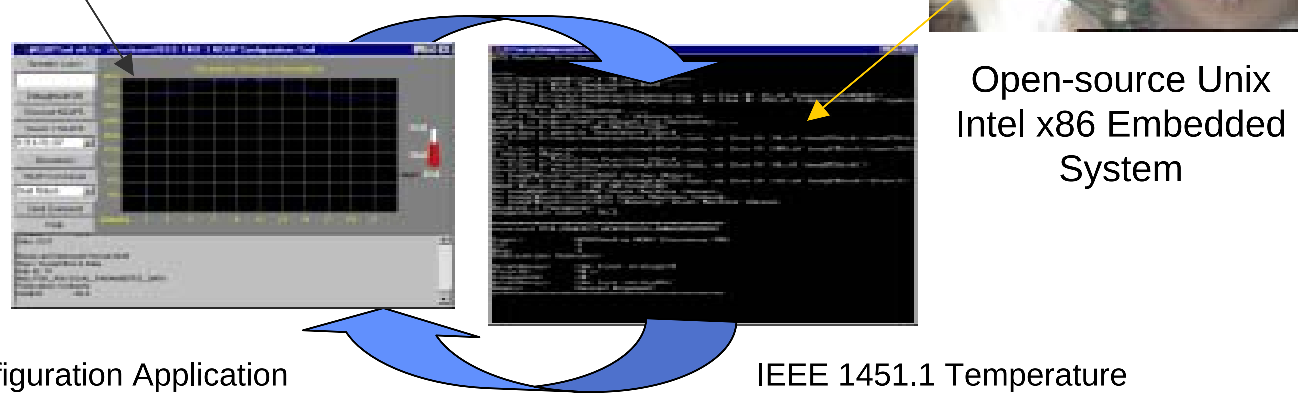
- Targets at the closed-loop control industrial automation area:
  - Three hardware platforms representing various NCAPs:
    - Windows NT Laptop
    - Open-source Unix based Intel x86 embedded single board computer (SBC)
    - Linux based Intel StrongARM SBC
  - All connected via an IEEE 802.11b Wireless Access Point and an IEEE 802.3 Wired Ethernet Hub based subnetwork
  - Each NCAP is executing a particular transducer application, i.e., temperature, pressure, and actuator applications
  - Each transducer application is linked with the NIST-developed 1451.1 library and “open-source” Adaptive Communication Environment (ACE)
- Use a Java-based IEEE 1451.1 NCAP Configuration Tool to connect, configure, control and monitor the NCAPs in our demonstration “control network”

1451.1 Demonstration Setup



Activities

1. Discovery
2. Connection
3. Configuration
4. Execution



In Summary - Benefits of IEEE 1451

✓A common transducer interface will

- Lower the cost to design sensors and actuators to a set of standardized interfaces.

✓Having TEDS with transducers will

- Enable self-description of sensors and actuators.
- Eliminate error-prone, manual configuration
- Provide easy self-documentation.
- Simplify field installation, upgrade, and maintenance of sensors by simply “plug and play” devices to instruments and networks.

Benefits of IEEE 1451- Cont'd

System integrators

- Self-documenting of hardware and software
- Sensor systems - easier to install, maintain, modify and upgrade
- Easy and quick transducer replacement (plug and play)
- Mean to store installation details (in the TEDS)
- Choose sensors based on merit

Application software developers

- Standard transducer model for control and data
- Facilitate distributed measurement and control applications
- Support for multiple languages - good for international developers

Benefits of IEEE 1451- Cont'd

Sensor Manufacturers

- Standard physical interfaces
- One set of standard interfaces to design and support
- Multi-level products developed based on TEDS.
- Standard calibration specification and data format

End Users

- Sensors are simple to use – basically just "plug and play"
- Based on the TEDS, software can automatically provide:
  - physical units
  - readings with significant digits as defined in the TEDS
  - complete transducer specifications
  - installation details such as instruction, ID, & location of the sensor

For More Information

- Contact: Kang Lee at kang.lee@nist.gov

- Visit IEEE 1451 and related websites:

1451: http://ieee1451.nist.gov

1451.2: http://grouper.ieee.org/groups/1451/2

1451.4: http://grouper.ieee.org/groups/1451/4

1451.5: http://grouper.ieee.org/groups/1451/5

1451.3: http://www.ic.ornl.gov/p1451/p1451.html

IEEE 1588: http://ieee1588.nist.gov

Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems