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# ***IEEE 1451 - A Suite of Sensor Interface Standards***

**NIST Workshop on Sensor Standards  
Harmonization**

**Gaithersburg, Maryland  
December 13, 2005**

**Kang Lee**

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National Institute of Standards and Technology  
United States Department of Commerce**



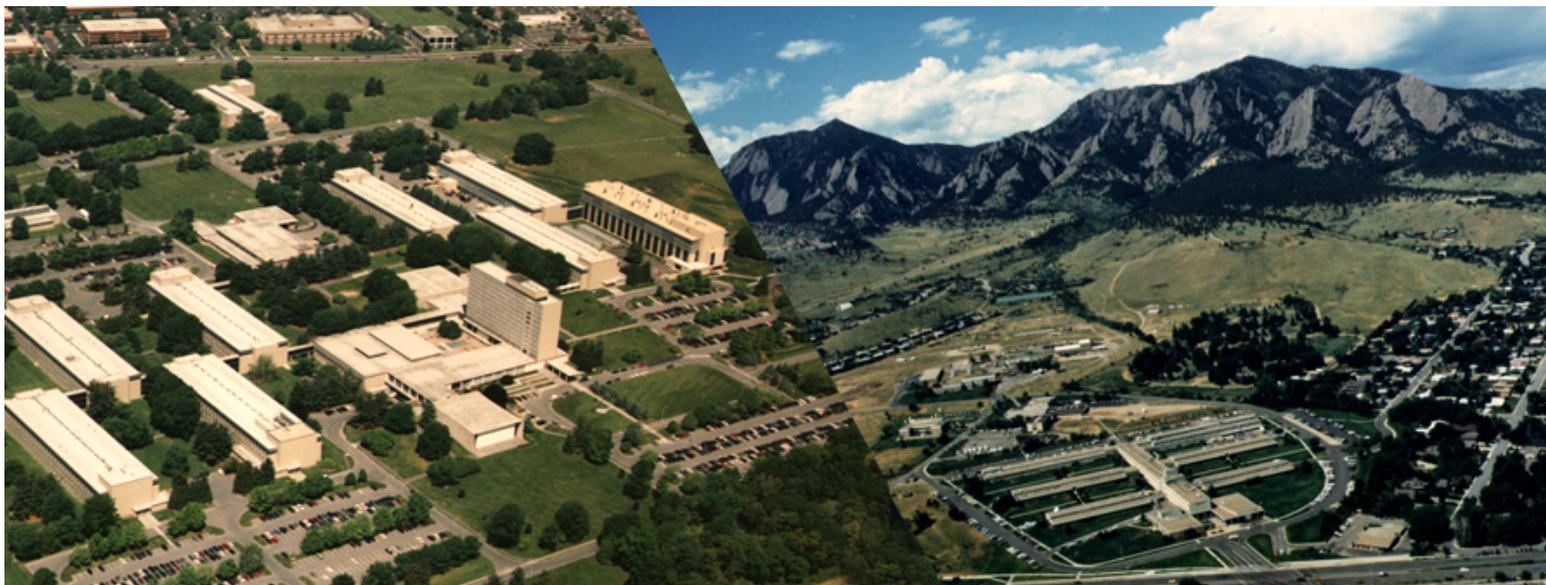
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# National Institute of Standards and Technology (NIST)

**Mission: Develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.**



**Gaithersburg, Maryland**

**Boulder, Colorado**



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## **NIST Roles in Collaboration with DHS**

- ***Assist DHS in identification of standards-related needs.***
- ***Provide critical technical expertise and support to DHS for standards development in key areas: CBRNE, technologies for incident response, cybersecurity and critical infrastructure protection, etc.***
- ***Coordination/facilitation of standards development activities – at NIST, with other agencies, and with industries.***



## Manufacturing Engineering Laboratory Programs

- Dimensional Metrology
- Homeland and Industrial Control Security
- Intelligent Control of Mobility Systems
- Manufacturing Interoperability
- Manufacturing Metrology and Standards for the Health Care Enterprise
- Mechanical Metrology
- Nanomanufacturing
- Smart Machining Systems



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## Sensors are Ubiquitous

- **Sensors are used everywhere** in many applications imaginable
- Tens of thousands of sensors will be connected through **wired and wireless networks** for homeland security (HLS)
  - to communicate and share sensor data and information among government agencies and private enterprises in order to effectively protect people and property
- **Sensors and networks** are key components in building distributed sensor networks nation-wide for
  - detecting weapon of mass destruction
  - monitoring and protecting critical infrastructure such as airports, bridges, buildings, railways, utility, and water supplies
- **Open, standardized sensor interfaces and sensor data formats** are needed to enable effective integration, access, fusion, and use of sensor-derived data in critical HLS applications.



# An Example Regional Sensor Network

Regional Analysis and Applications  
(Sensor Fusion / Processing)



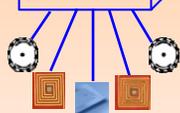
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Sensor/RFID  
Integration

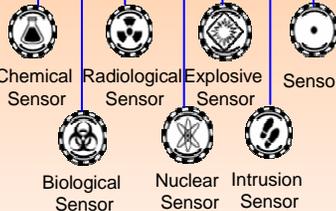
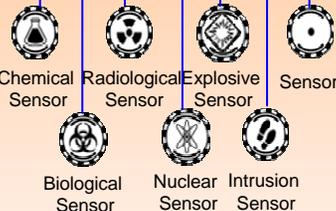
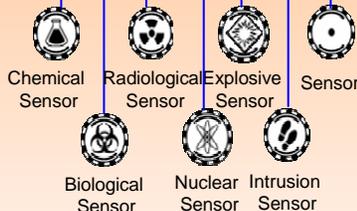


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CBRNE Sensor Interface

CBRNE Sensor Interface

CBRNE Sensor Interface



Wireless communications for first responders



Smart Containers



Buildings



Airports



Railways



Bridges



Water Supplies

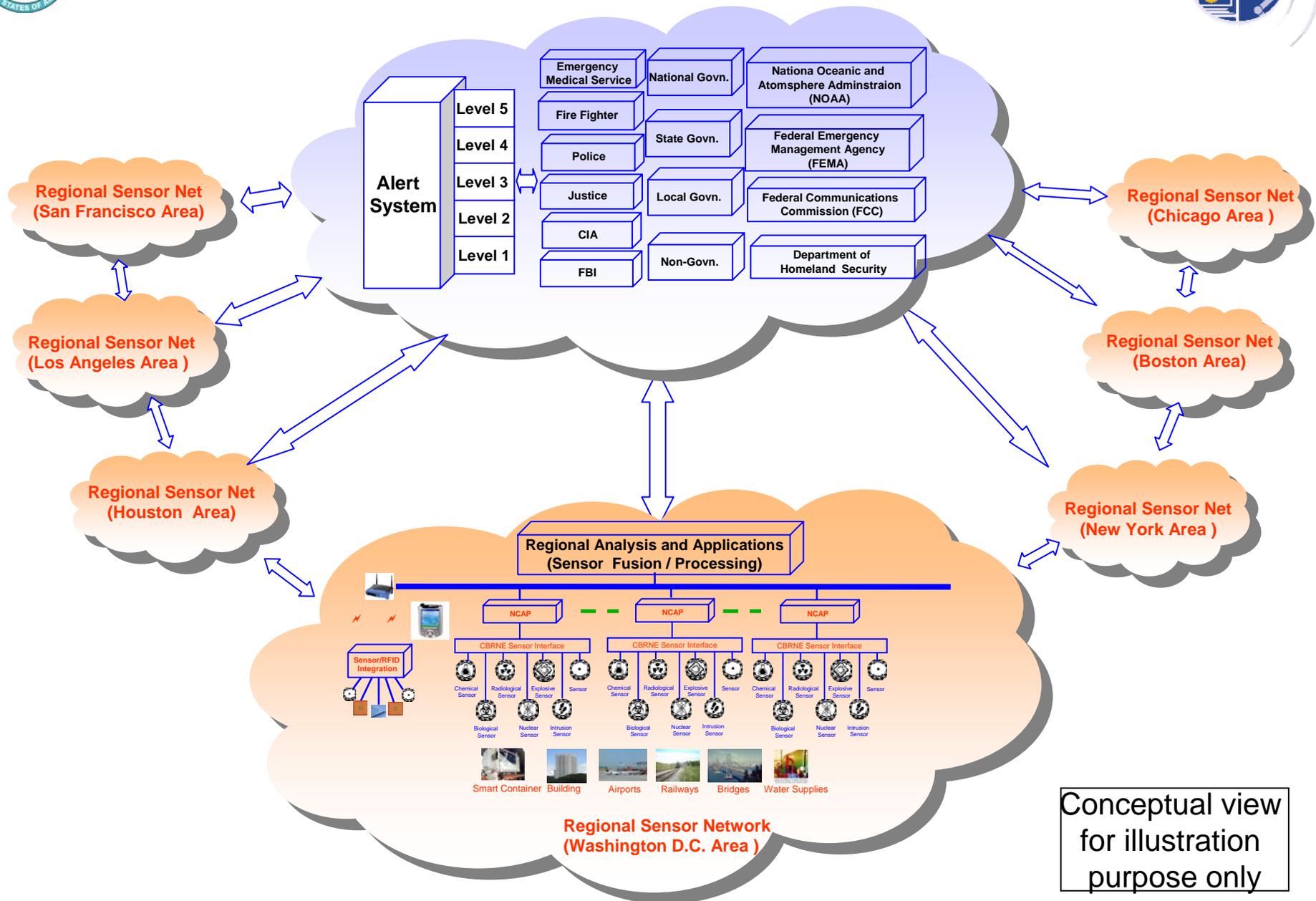
Regional Sensor Network  
(Washington D.C. Area)

Conceptual view for illustration purpose only



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## Complexity of a National Sensor Network



Conceptual view for illustration purpose only



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## Need Open Standards for DHS

- Need for a coherent framework of *open, consensus-based standards* that provide the "glue" for joining many sensor networks into one vast network nationwide.
- These open standards can enable *rapid and seamless* sensor interconnection, discovery, access, integration, and usage within and across systems, networks, and enterprises.



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## What is IEEE 1451 ?

**Standard ways to connect sensors and actuators to networks and systems that facilitate**

# ***Interoperability***

At the SensorGov Conference on Sept 13-14, 2004.

Dr. Vitalij Garber, Director of Systems Integration, Defense System, Office of Under Secretary of Defense summed it up very nicely,

“...from sensors perspective, let’s tie them together for interoperability...”

“...net all sensors and provide seamless operation.”

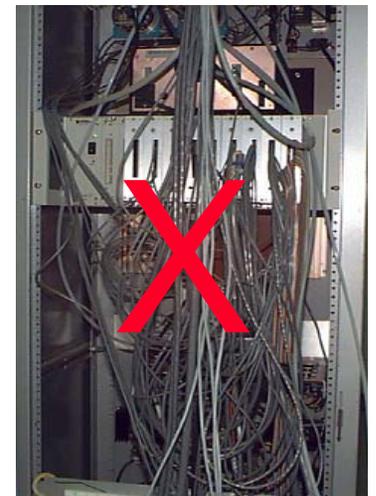
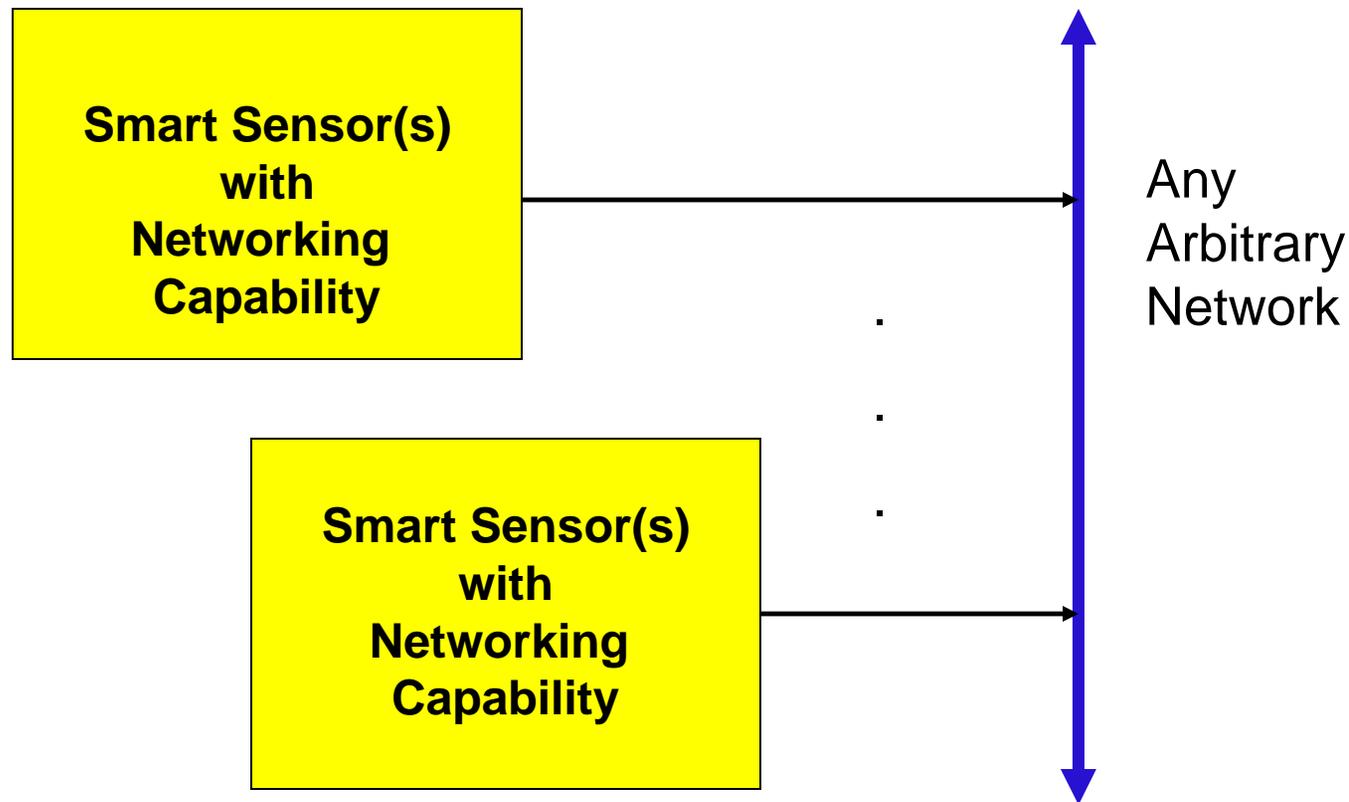
“...maximum use of commercial standards and approach.”



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# Vision in 1993 - Networking smart sensors with standardized interfaces

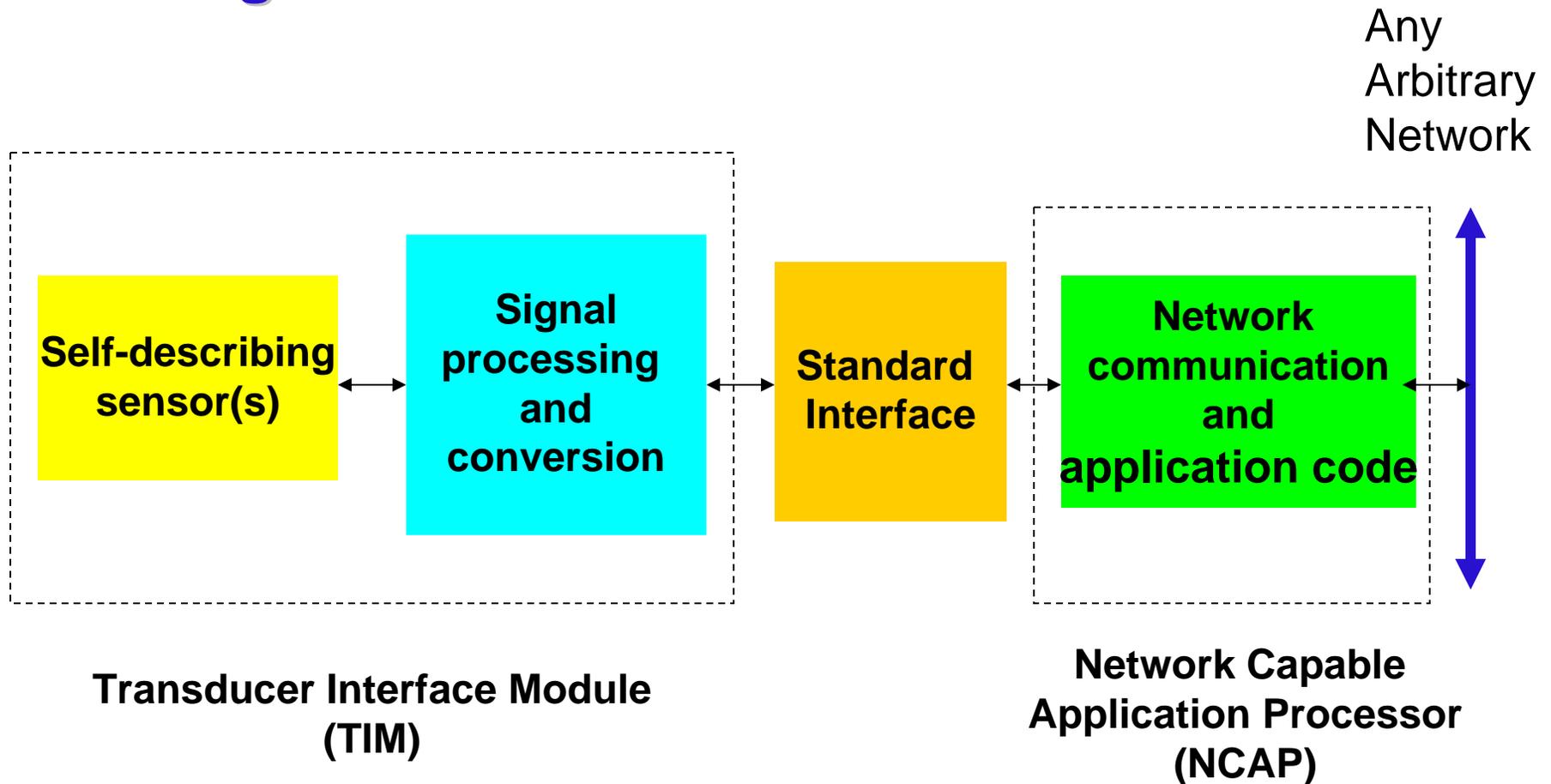




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# Migration Path for Integrated Network Smart Sensors





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## IEEE 1451 Standard

- 1451 is a set of **network-neutral** and **vendor-independent** transducer interfaces for connecting sensors to networks and instrumentation systems.
- It aims to facilitate sensor and data **interoperability** and allows users to get access to sensor data and information seamlessly in both **wired or wireless** networks and instrumentation systems.
- It specifies a set of standardized **Transducer Electronic Data Sheets (TEDS)** format for sensors and actuators. The TEDS contains manufacture-related data for **self-identification and self-description**.



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## Some Benefits of IEEE 1451 Smart Sensors?

Networking (wired or wireless) smart sensors can:

- enable **self-description** of sensors by using TEDS data
- enable **self-configuration**
- eliminate error prone, manual entering of data from data sheets by simply **Plug and Play** of sensors
- allow sensors to be installed, upgraded, replaced or moved with **minimum effort**
- **simplify wiring**, thus reduce costs
- **eliminate wiring**, in the case of wireless sensors
- enable bi-directional **digital communication**, more reliable than analog wiring
- enable system **time-stamping** of measurements
- enable **embedded processor** or ASIC implementation
- communicate messages in a **standardized data** format
- enable **global**, or **anywhere**, access of “sensor information” through networks and Internet



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## Transducer Electronic Data Sheets (TEDS)

***TEDS provide sensor ID, measurement range, calibration and user information and more ...***

***Some example TEDS:***

- **Meta-TEDS**
- **Transducer channel TEDS**
- **Calibration TEDS**
- **Frequency response TEDS**
- **Physical TEDS**
- **Manufacturer-defined TEDS**
- **End user application specific TEDS**
- ....
- **Geo-location TEDS**



Vibration sensor  
with a TEDS  
stored in a  
small memory chip



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## **Transducer Electronic Data Sheet (TEDS) – cont'd**

- **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
  - ...



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## Transducer Electronic Data Sheet (TEDS) – cont'd

### • 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
  - ...



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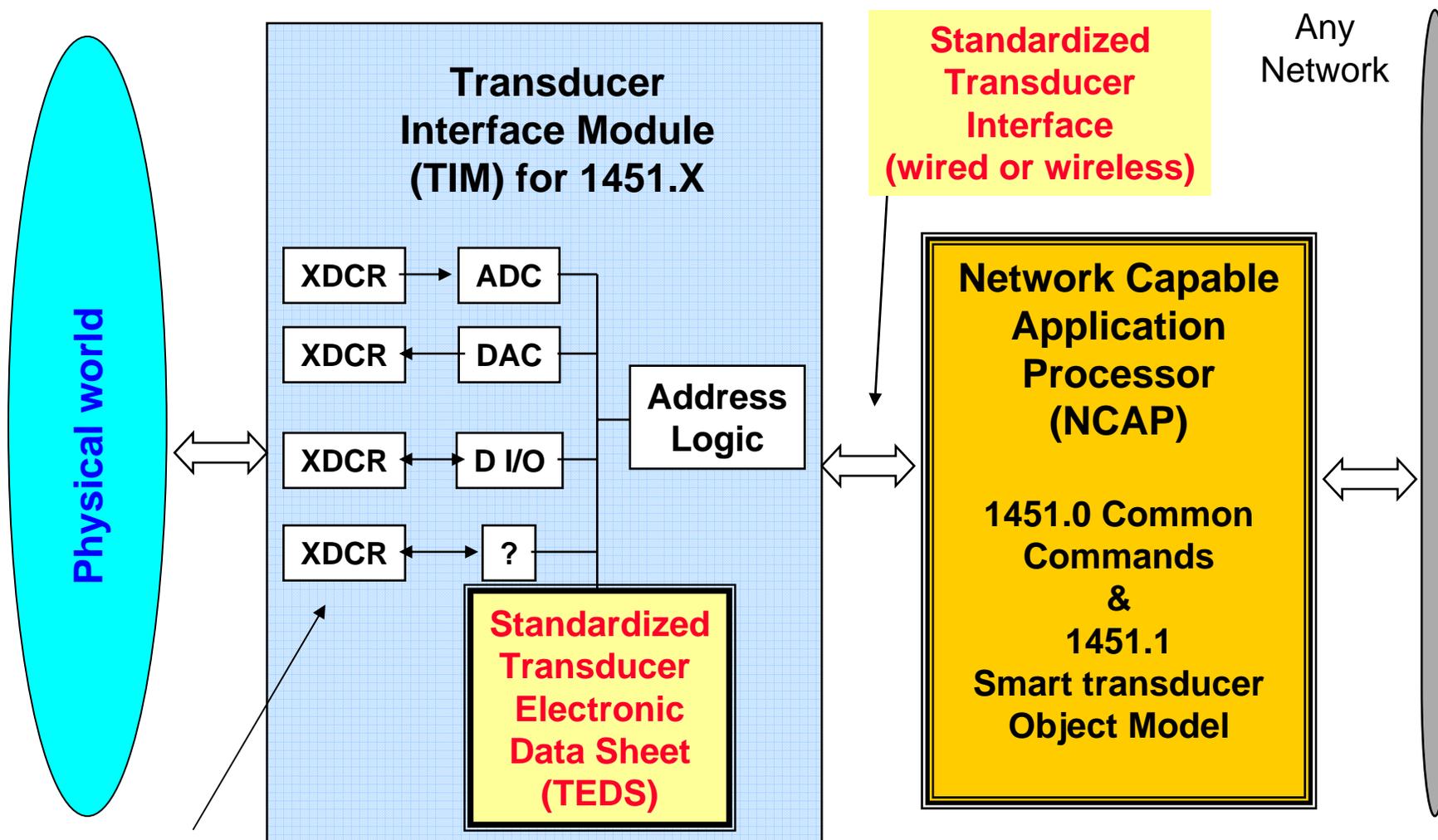


## **Transducer Electronic Data Sheet (TEDS) – cont'd**

- **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



# IEEE 1451 Adds Capability to Sensors/Actuators

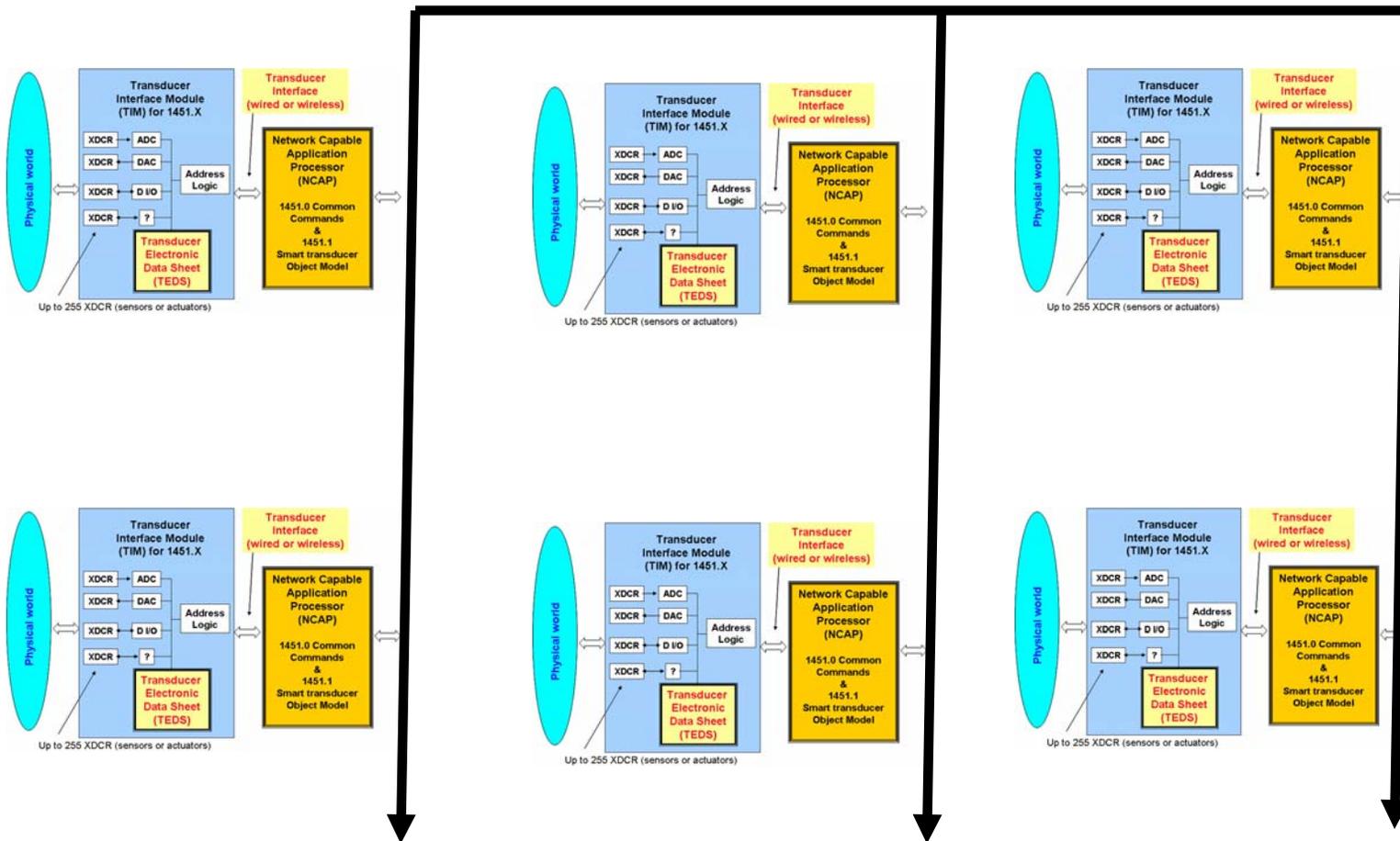


Up to 255 XDCR (sensors and/or actuators) in a TIM



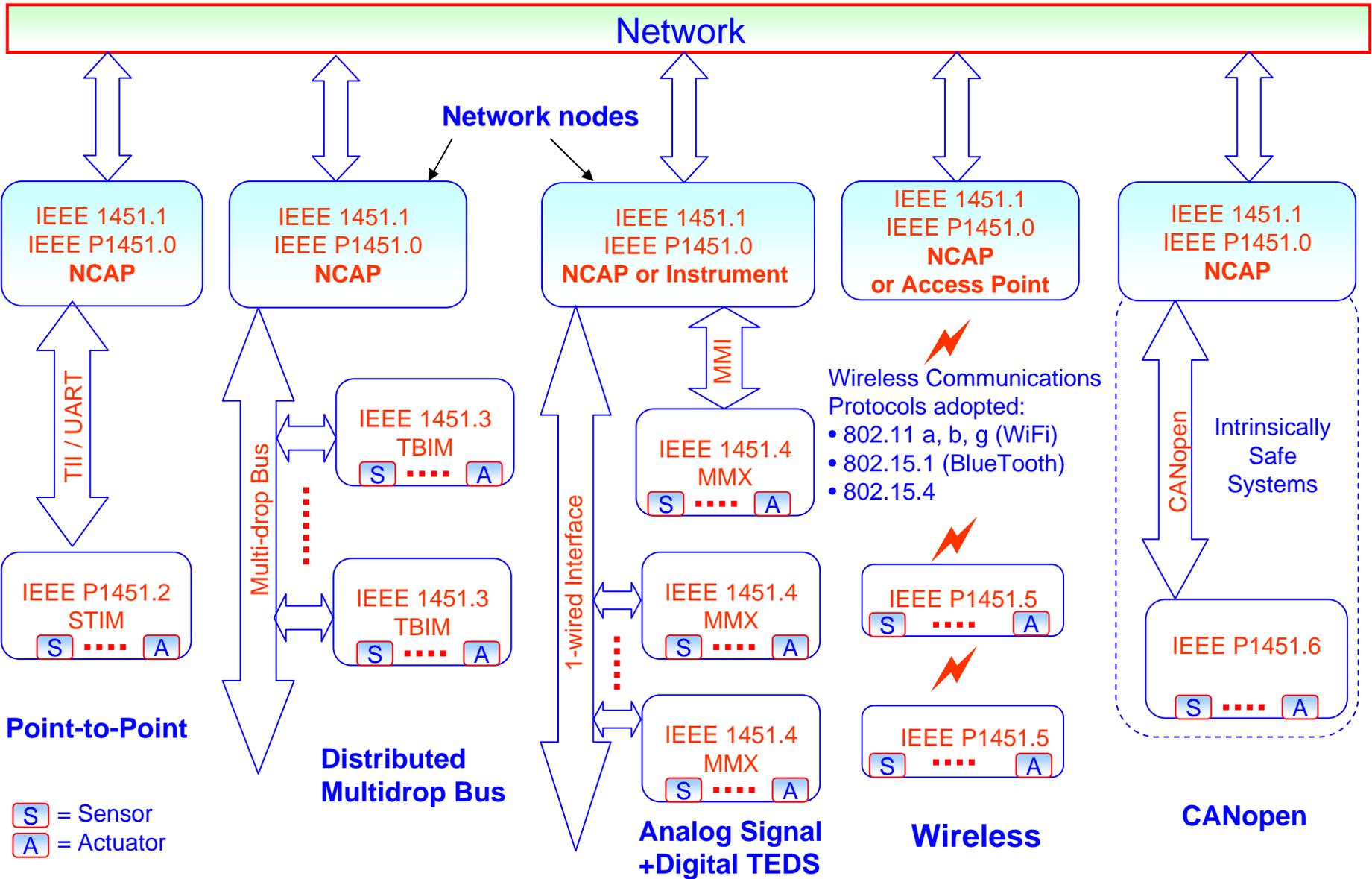
## A Large System of Sensor Networks

Many Sensor Networks connected by gateways, if appropriate





# IEEE 1451 Suite of Smart Sensor Interface Standards





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## Status of the Suite of IEEE 1451 Standards

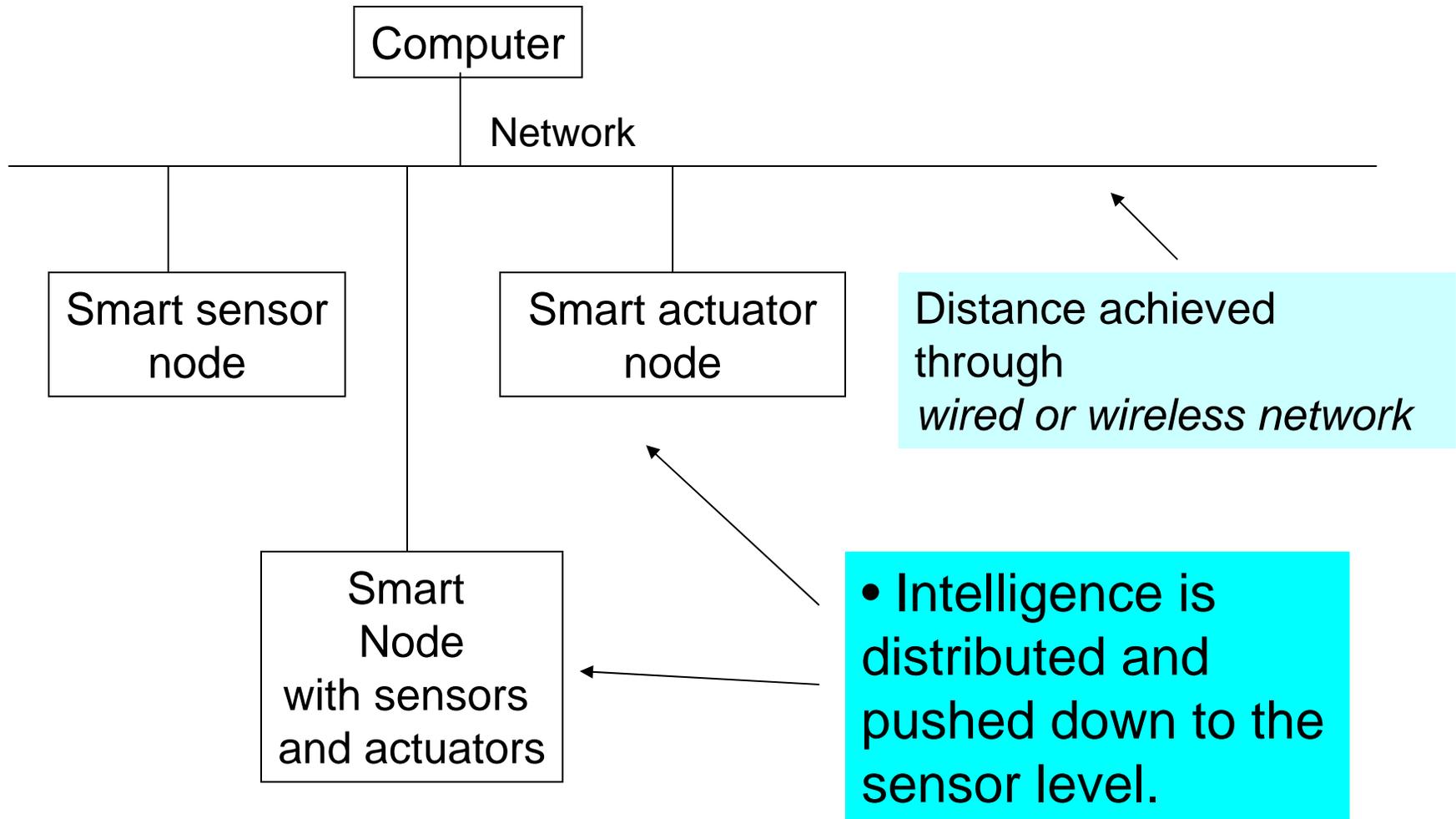
- **IEEE Std 1451.1-1999**, Network Capable Application Processor (NCAP) Information Model for smart transducers -- *Published standard, being revised*
- **IEEE P1451.0**, Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats -- *In progress*
- **Physical Layers:**
- **IEEE Std 1451.2-1997**, Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats -- *Published standard, being revised*
- **IEEE Std 1451.3-2003**, Digital Communication and Transducer Electronic Data Sheet (TEDS) Formats for Distributed Multidrop Systems -- *Published standard*
- **IEEE Std 1451.4-2004**, Mixed-mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats – *Published standard*
- **IEEE P1451.5**, Wireless Sensor Communication and Transducer Electronic Data Sheet (TEDS) Formats – *In progress*
- **IEEE P1451.6**, A High-speed CANopen-based Transducer Network Interface – *In progress*



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## IEEE 1451 Enables the Building of Distributed Smart Sensor/Actuator Systems





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## **Benefits from IEEE 1451**

### **Sensor manufacturers**

- Multiple products may be developed just by changing the TEDS.
- Standard physical interfaces
- Standard calibration specification

### **System integrators**

- Self-documenting hardware and software
- Systems that are easier to maintain
- Rapid transducer replacement
- Mechanism to store installation details in the TEDS



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## **Benefits from IEEE 1451 - cont'd**

### **Application software programmers**

- Standard transducer model for control and data
- Same model for accessing a wide variety of measurements
- “Hooks” for synchronization, exceptions, simultaneous sampling
- Support for multiple languages

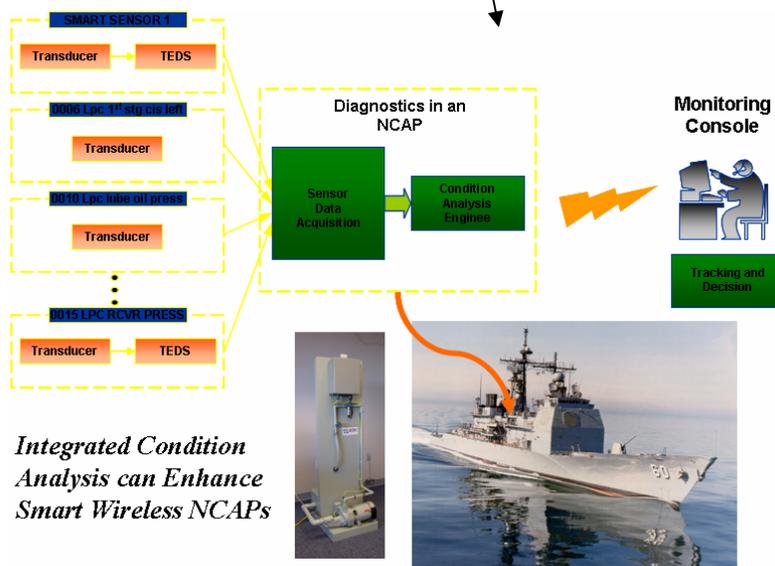
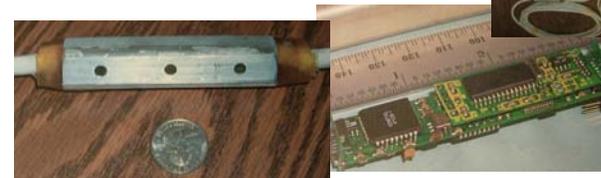
### **End users**

- Sensors that are easier to use; “just plug and play”.
- Analysis software that can automatically provide:
  - physical units
  - readings with significant digits
  - transducer specifications
  - installation details such as physical location and ID of transducer



## Examples of IEEE 1451 Applications

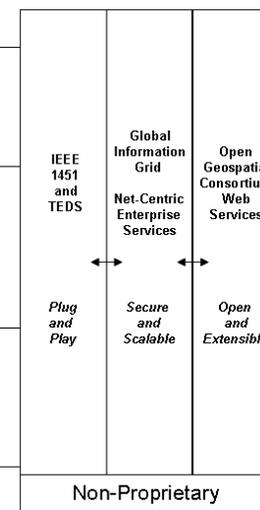
- IEEE 1451.4 interface in LabView.
- IEEE 1451.2 in health monitoring of casing for oil drilling.
- IEEE 1451 in SensorNet.
- IEEE 1451 wired and wireless systems in naval vessels for CBM.



Many Sensors



Many Applications





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## For More Information

- **Contact: Kang Lee at [kang.lee@nist.gov](mailto:kang.lee@nist.gov)**
- **IEEE standards can be purchased at <http://standards.ieee.org/reading/ieee/std/numerical.html>**
- **IEEE 1451 websites:**
  - 1451: <http://ieee1451.nist.gov>**
  - 1451.0: <http://grouper.ieee.org/groups/1451/0>**
  - 1451.4: <http://grouper.ieee.org/groups/1451/4>**
  - 1451.5: <http://grouper.ieee.org/groups/1451/5>**
  - 1451.6: <http://grouper.ieee.org/groups/1451/6>**
- **IEEE 1588, Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems**  
**website: <http://ieee1588.nist.gov>,**