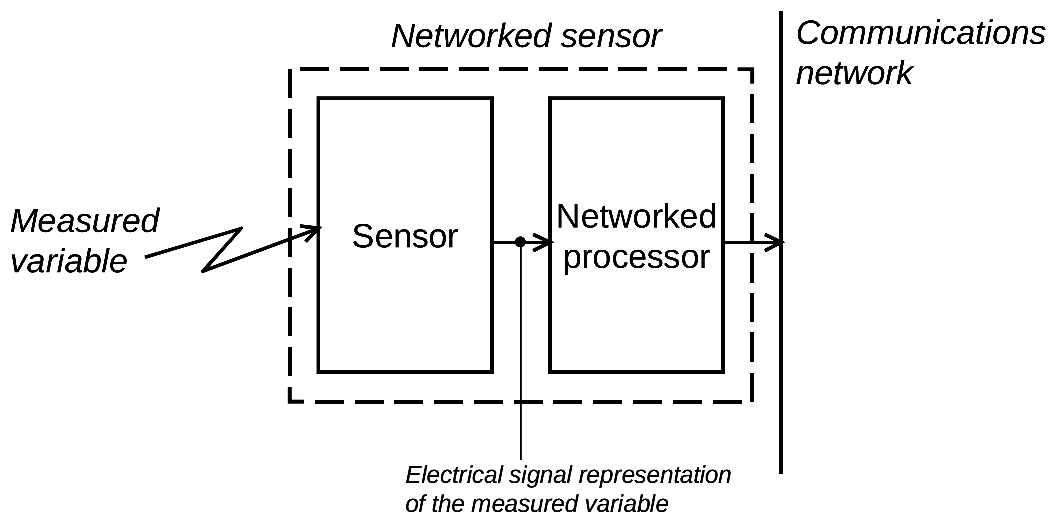
Lecture 15: ISS Communications

- Networked sensors, when and why?
- Sensor network standards
- The IEEE 1451 standards
- STIM and TEDS

Networked sensors

- **When?**
  - Used in applications where a number of sensors are needed or where the sensor devices are distributed geographically
- **Why?**
  - Simplification of the wiring required for signal transmission
    - Assuming N nodes, full connectivity would require 2^{N-1}-1 wires
  - Digital nature of networked signals
    - Digital transmission is relatively immune to the effects of distortion and signal degradation associated with carrying an analog signal over long distances
    - This implies that networked sensors have ADC capabilities



Networked sensors

- **Why? (Cont)**
  - Ability to communicate a much wider range of information in both directions
    - Networked sensors typically contain a local microprocessor that handles sensor signals and their transmission
    - No need to limit the microprocessor to transmission functions only
      - μP may be able to perform calibration or signal corrections
      - Sensors can be designed to have multiple sensing functions. Each signal can be handled and transmitted separately by the μP without extra connections
      - Sensors may be designed to store ID information (manufacturer, calibration parameters…)
      - Sensors may be designed to have intelligent functions, such as self-diagnostics or triggering of events
- **Potential problems**
  - More complex circuitry is required than for non-networked sensors
  - Quantization errors as a result of ADC
  - Network bandwidth, which may cause queuing delays or even lost data

Network technologies

- **A number of protocols exist, each one having its own interface requirements:**
  - Header formats, data word length and type, bit rate, cyclic redundancy check, etc

Automotive	Sponsor
J-1850	SAE
J-1939 (CAN)	SAE
J1567 C^{2}D	SAE (Chrysler)
J2058 CSC SAE	Chrysler
J2106 Token Slot	SAE (General Motors)
CAN	Robert Bosch GmbH
VAN	ISO
A-Bus	Volkswagen AG
D^{2}B	Philips
MI-Bus	Motorola
Industrial	**Sponsor**
Hart	Rosemount
DeviceNet	Allen-Bradley
Smart Distributed Systems	Honeywell
SP50 Fieldbus	ISP+World FIP=Fieldbus Foundation
SP50	IEC/ISA
LonTalk/LonWorks	Echelon Corp
Profibus	DIN (Germany)
ASI Bus	ASI Association
InterBus-S	InterBus-S Club
Seriplex	Automated Process Control (API Inc)
SERCOS	VDW (German tool manuf. assoc)
IPCA	Pitney Bowes Inc

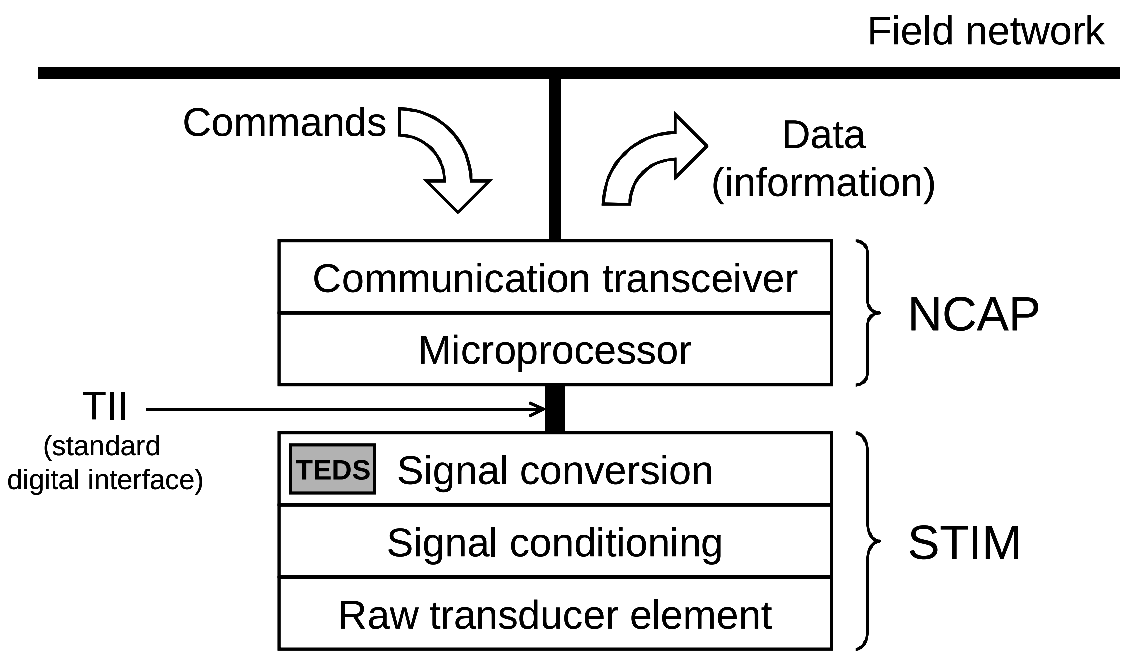
Building/office automation	Sponsor
BACnet	Building Automation Industry
LonTalk/LonWorks	Echelon Corp
IBIbus	Intelligent Building Institute
Batibus	Merlin Gerin (France)
EIbus	Germany
Home automation	**Sponsor**
Smart House	Smart House LP
CEBus	EIA
LonTalk/LonWorks	Echelon Corp
University protocol	**Sponsor**
Michigan Parallel Standard	University of Michigan
Integrated Smart-Sensor Bus	Delft University of Technology
Time-Triggered Protocol	University of Wien, Austria

Network technologies

- **The lack of a universal interface standard impedes the incorporation of "intelligent" features into the sensors such as**
  - On-board electronic data sheets, on-board ADC, signal conditioning, device-type identification and communications handshaking circuitry
- **In 1994, the IEEE and NIST decided against adopting any of the existing network protocols as a single standard (IEEE 1451)**
  - A new hardware-independent standard is being developed to lower the networking entry barrier for S&A small companies
- **The standard encompasses the formation of two separate software models**
  - IEEE 1451.1: developing a network-independent common object model for smart transducers
  - **IEEE 1451.2**: enabling connection of transducers to network processors

The P1451.2 standard

- **The basic building blocks**
  - NCAP: Network Capable Application Processor
  - STIM: Smart Transducer Interface Module
  - TII: Standard digital interface
  - TEDS: Transducer Electronic Data Sheet



The P1451.2 standard

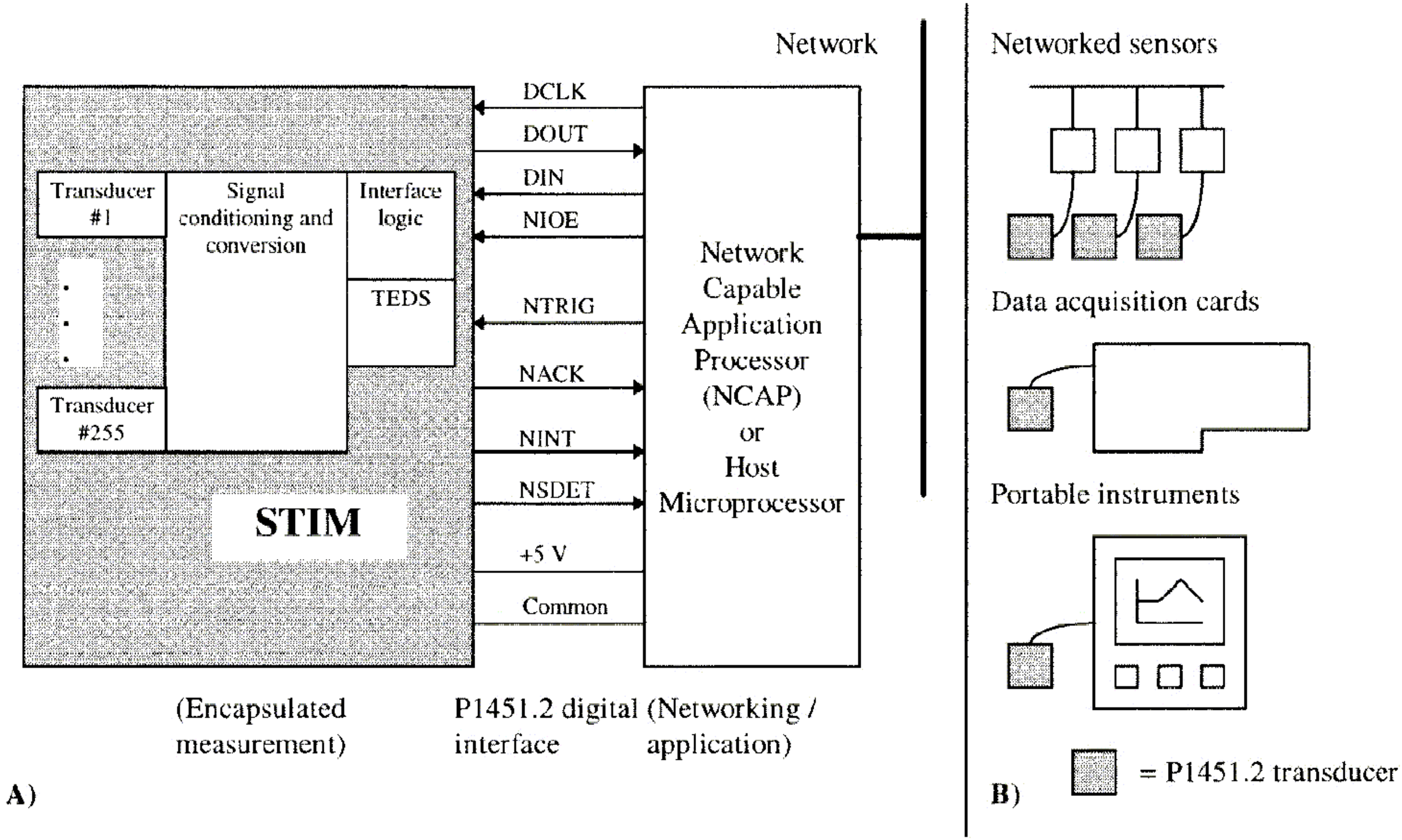


Fig. 1. A) Hardware partition proposed by P1451.2 and B) possible uses for the interface.

TII Signal and Control Lines

Line	Driven By	Function
DIN	NCAP	Address and data transport from NCAP to STIM
DOUT	STIM	Data transport from STIM to NCAP
DCLK	NCAP	Positive-going edge latches data on both DIN and DOUT
NIOE	NCAP	Signals that the data transport is active and delimits data-transport framing
NTRIG	NCAP	Performs triggering function
NACK	STIM	Serves as both trigger and data-transport acknowledge
NINT	STIM	Used by the STIM to request service from the NCAP
NSDET	STIM	Grounded in the STIM and used by the NCAP to detect the presence of a STIM
POWER	NCAP	Nominal 5-V power supply
COMMON	NCAP	Signal common or ground

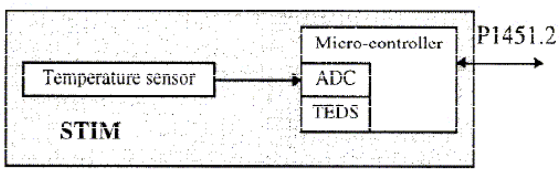
Features of STIM

- **Single general purpose TEDS**
  - A unique data structure that can support a wide variety of transducers
- **Representation of physical units**
  - A binary sequence encodes physical units as a product of the seven SI basic units and the 2 SI supplementary units, raised to a rational power
- **General calibration model**
  - Transducer calibration may be specified (linear, multi-variable, piece-wise polynomial with variable segment widths and offsets)
- **Triggering of sensors and actuators**
  - HW trigger lines allow the NCAP to initiate sensor measurements and actuator actions, and the STIM to report completion of the requested operations
- **Variable transfer rate between host and STIM**
  - A field in the TEDS specifies the maximum data transport rate that the STIM can support
    - This provides flexibility for matching STIMs and NCAPs
    - Alternatively, the STIM may use a hardware line (NACK) to pace the transfer of bytes

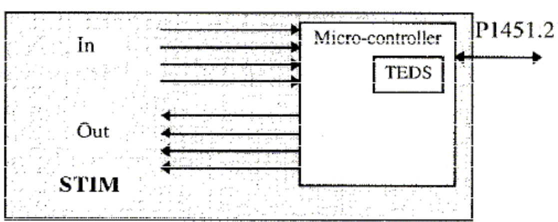
Features of STIM

- **Support for multi-variable transducers**
  - A STIM may have up to 255 inputs or outputs allowing the creation of multi-variable sensors, actuators or combinations of both (see examples below)
- **Hot Swap**
  - A separate HW line (NSDET) is provided to permit STIMs to be plugged into or removed from an NCAP without powering down the NCAP or the network

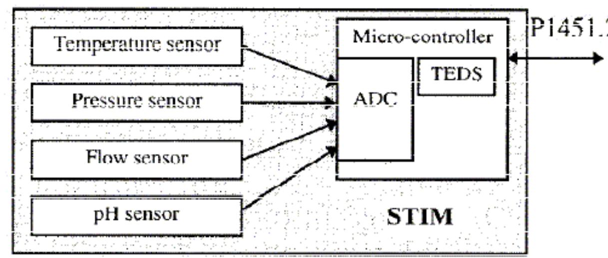
A) Temperature sensor STIM



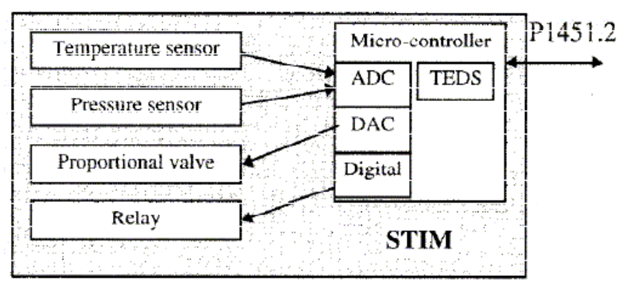
B) Eight channel digital I/O STIM



C) Four channel sensor STIM



D) Sensor and actuator STIM



Features of TEDS

- **TEDS contains fields that fully describe the type, operation and attributes of a transducer**
- **TEDS is attached to and moves with the transducer**
  - This way, the information necessary for using the transducer is always present
- **TEDS contents**
  - Mandatory
    - Meta TEDS
    - Channel TEDS
  - Optional
    - Calibration TEDS
    - Application specific TEDS
    - Extension TEDS

Features of TEDS

- **Meta TEDS (required, one per STIM)**
  - Contains the overall description of the TEDS data structure, worst case STIM timing parameter and channel grouping information
- **Channel TEDS (required, one per STIM channel)**
  - Contains upper/lower range limits, physical units, warm up time, presence of self-test, uncertainty, data model, calibration model, and triggering parameters
- **Calibration TEDS (optional, one per STIM channel)**
  - Contains the last calibration date, calibration interval and all the calibration parameters supporting the multi-segment model
- **Application specific TEDS (optional, multiple per STIM)**
  - For application specific use
- **Extension TEDS (optional, multiple per STIM)**
  - Used to implement future and industry extensions to P1451.2

References

[WLB97] S. P. Woods, K. Lee and J. Bryzek, 1997, “An Overview of the IEEE-P1451.2 Smart Transducer Interface Module,” in Analog Integrated Circuits and Signal Processing, 14(3), pp. 165-177

[Tra95] W. Travis, 1995, “Smart-sensor standards will ease networking woes,” EDN Magazine, June 22, 1995. Available at http://www.ednmag.com/reg/1995/062295/13df1.htm

[JW98] R. N. Johnson and S. Woods, 1998, “Overview and status update for IEEE 1451.2,”, Sensors Expo 1998, Chicago, IL. (available at http://www.smartsensor.com/doc/dot2_vg.pdf)

[Web99] J. G. Webster (Ed.), 1999, The measurement, instrumentation and sensors handbook, CRC/IEEE Press.