Intelligent Field Devices (IFD) in Networked Control Systems
(Lecture notes)

CONTENTS
1. IFD Features.
3. Aspects of distributed IFD intelligence.
4. Operational aspects of the IFD.
5. IFD Specifications.

1. IFD Features.
1. Connection of the IFD to the medium is all that is required for the IFD to become operational in the system.
2. Deletion of the IFD for any reason (e.g., disconnection or power-down) does not cause any failure of system behavior, other than those effects due to missing the production or consumption of data and messages associated with the IFD.
4. All IFDs are capable of accepting an “application script” that tailors the inherent behavior of the IFD to meet the requirements of the specific overall system application.
5. Central control is permitted but is not required as a means of managing the modification of IFD behavior for specific applications.
6. All IFDs implement the same standard data, control, and behavioral models.
7. The IFD contains clocks that are synchronized with the clocks in other IFDs of the system.
8. The IFD provides information sufficient to properly interpret communications with the IFD.

A device which meets these design criteria is referred to as “intelligent or smart node”.

2. Architecture of an Intelligent Field Device

Transducer → Signal Conditioning → A-D or D-A conversion → User Interface → Communication

Application Algorithms → Data Storage

**Figure 1. General architecture of a smart sensor**

Communication Medium

Smart Node

Communication Media Access

Network Interface

Control and Configuration

Application

Transducer Interface

Sensor or Actuator

Real World

**Figure 2. Intelligent Field Device architecture**
3. Aspects of distributed IFD intelligence:
- transducer-related intelligence;
- measurement-related intelligence;
- system- or application-related intelligence.

These aspects might be named “levels of smartness.” This section presents some properties of measurements that need to be considered when designing IFDs for a distributed system. In general, the more of these properties that are managed by the IFD, the more useful the IFD will be as a general component in distributed measurement systems.

3.1 Transducer-related properties of IFD:
Transducer-related properties include:
1. Physical variable: temperature, stress, etc.
2. Form of transducer input or output: voltage, change in resistance, digital signal
3. Calibration: relationship of transducer output to sensible value, e.g., converting the value of the voltage from a thermocouple to the measured temperature
4. Identity: transducer serial number, description, etc.
5. Limits of use: maximum and minimum values, acceptable operating environments, stability of calibrations, repeatability, etc.
3.2. Measurement-related properties of IFD:
1. Measurement timing management: timed, polled, random, etc.
2. Local data management: store until requested, broadcast upon collection, etc.
3. Local computation: average, peak value, etc.
4. Identity: IFD identification, description, etc.
5. Location: coordinates or identifier of the measurement point
For IFDs in distributed systems, these properties need to be managed within the IFD.

3.3. System or application-related properties of IFDs
1. Changing measurement properties in response to application-related messages, e.g., changing the sample rate in a collection of IFDs
2. Defining the communication patterns among IFDs, e.g., master/slave, client/server, peer to peer, etc.
3. Establishing and modifying communication patterns among IFDs, e.g., modifying multicast membership
4. Managing the transport properties of communication among IFDs: flow control, reliable delivery, etc.
5. Synchronizing the IFD clocks, if present
6. Conforming to system data and control models

4. Operational aspects of the IFD.
   The internal operation of the smart IFD may be divided into two phases; start-up and normal-operation. The start-up phase occurs after power-up or reset. During the start-up phase, the following sequence of events takes place within the IFD:
   1. The transducer uploads the information contained in the “electronic data sheet”.
   2. Based on this information, the IFD configures itself as a sensor or as an actuator. In addition, it configures the physical transformation, as well as operating characteristics imposed by the transducer, for example, warm-up time and minimum sampling interval. Thus it is possible to completely change the nature of an IFD by substituting a different transducer. For example, a temperature transducer could replace a pressure transducer, or perhaps another temperature transducer with lower accuracy. These changes are reflected automatically in the transducer-related IFD behavior.
   3. The contents of the application ROM upload. Based on this information, the IFD configures the application transformation.
4. The IFD monitors the network to detect the presence of other IFDs. Based on the information received, the IFD configures the relevant properties, e.g., data management options.

5. At the end of the warm-up time the IFD begins normal operation.

5. IFD Specifications.

**IEEE 1451 Specification for building intelligent transducers**

IEEE 1451 is part of a planned family of adopted and proposed standards whose objective is to simplify the complexities designers have traditionally faced in establishing communications between networks and transducers.

In its simplest terms, 1451 specifies a plug-and-play capability in a transducer (sensor/actuator) module. This isolates the choice of the transducer from that of the control network by specifying an electronic data sheet (memory) in a smart transducer module. The protocol also defines a serial digital interface that allows the control network to interrogate the sensor, access the data sheet, and monitor/configure sensor and actuator channels.

![Figure 4](image-url)
The Smart Transducer consists of the Smart Transducer Interface Module (STIM) and the Network Capable Application Processor (NCAP). Note that the transducers themselves are considered part of the STIM. In fact, to provide the critical self-identification features, the transducer must be inseparable from the TEDS during normal use.

**Network capable application processor (NCAP)**

The STIM is controlled by an NCAP, which mediates between the STIM and the control network and may provide local intelligence. IEEE 1451.1 defines an NCAP network-independent information model, or a meta language, that describes how NCAPs can adapt to various network standards and fieldbuses.

**Smart transducer interface module (STIM)**

The standard defines a STIM, which is your remote, networked, and intelligent transducer node. A STIM can support a single channel or many channels, linking both sensors and actuators. In fact, the standard specifies a maximum of 255 transducer channels per STIM. A transducer channel is “smart” in this context because it is described by a machine-readable transducer electronic data sheet. The control and data associated with the channel are digital. Triggering, status, and control are provided to support the proper functioning of the channel.