# Industrial Control Systems and ICT



## Topics

- Principles of Numerical Control
- Industrial Networks
- Integrated Control System
- Trends in ICT Control Systems



## Principles of Numerical control

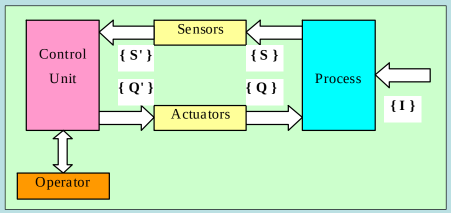
***Types of Numerical control:***

- **Individual control;**
- **Group Control;**
- **Distributed Control.**



## Individual Control

***General scheme***



# Individual Control

***Formal description***

{ Q' } = φ ( { S' } , { I }),

where **{I} – external perturbations**,

**{S} - internal states,**

**{Q} – control signals,**

**Δt – transformation and/or processing delay**

**{ Set } – prescribed new states**

**{ Q' (t + Δt) } = φ ( { S' (t)} , { I(t) })**

**{ S (t + Δt) } ⇒ { S et }**

***Real time control***

If **I(t)** is captured at the moments**: t, t + Δ T,..., t + n Δ T** ,

**the real time control requires :**

Δt ≤ Δ T

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# Individual Control

***Disadvantages:***

- ***appeared 60's, based on existing on that time computers;***
- ***for a single process (machine) – individual control unit;***
- ***for real time control if the controlled process is very fast, the performance of the control unit (computer) must be high enough;***
- ***the high performance computer price is very high;***

***Hence:***

***The individual control is used, when the ratio:***

***Price_Process / Price_control***

***is low***

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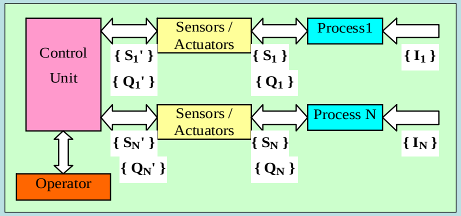
# Group control

***General scheme***

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# Group control

***Real Time control***

- **If the signals { I } are captured periodically with periods: Δ T1, Δ T2.., Δ TN, processing time for each process is Δti and the servicing by the control unit is a cyclic one Tc , then:**

**Tc = Σ Δtk / k=1, N/ ;**

- **Hence the real time control can be done only if:**

**Tc ≤ min (Δ Ti) / i=1, N /.**

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# Group control

***Specifics:***

- The ratio

  *Price_Process / Price_control*

  Is better, as one computer controls more than one process;
- But,

  as the Control unit has to control more than one process, its performance **must be higher**;
- But,

  if the performance is higher, the price of the control unit **will be also higher**

  and to keep the same price/performance ratio of the control, **more processes** have to be controlled by the same computer,
- And,

  again the performance (and the price) of the computer will be increased…

  **What to do???**

***The solutions are:***

- Decrease the price of the control units, by simplifying their functions AND
- Decomposing the Control points of the process, to simplify the algorithms of obtaining the Control reactions.

Using the achievements in the production of Integrated circuits (chips), a new scheme of control is introduced:

***DISTRIBUTED CONTROL***



# Distributed Control

**Distributed Control Systems (DCS) were developed in the mid-70's, representing the existing computing concepts at the time: integration of hardware, software and services for the needs of entire manufacturing process.**

- **In 1987 Foxboro introduced its Intelligent Automation I / A, as the first Open Industrial System (Open Industrial System, OIS).**
- **OIS is control and information system.**
- **The architecture of an OIS is similar to that of a DCS in regard to the functional distribution of tasks on multiple devices, and the interrelation of these devices via communications networks.**



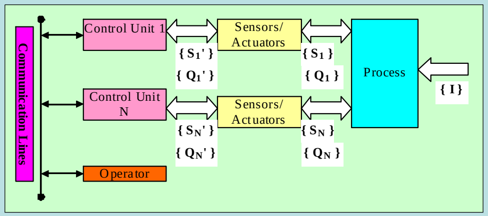
# Distributed Control

- **A DCS typically involves the existence of several coexisting networks: networks of controllers and information networks.**
- **PLC networks are separated or integrated through gateways, and in some cases, integrated into the computer network through another gateway.**
- **In the OIS, the lower level allows intercommunication between other transmitters, controllers, PLCs, barcode reader, etc..**
- **The network is called *fieldbus*, and connects with the real time processor through increased capacity.**
- **Some of these simply act as bridges, others are control processors running control strategies.**



# Distributed Control

***General Scheme***



# Distributed Control

***Real Time Control***

- If I(t) is captured at the moments: t, t + Δ T, .., t + n Δ T
  and the delay, introduced by each Control Unit is Δti / i=1, N /.
- Then the condition of real time control is:

$$\Delta T \geq \max(\Delta t_i) \quad / i=1, N /.$$

***Specifics:***

- As the function of each control unit are simplified, the processing time is shorter, and the complexity of the implementation of them is cheaper;
- But,
  other very important requirements are introduced:
  - the necessity of correct synchronisation between the different control units;
  - the necessity of communication between them, by introducing appropriate communication lines (cables, fibre optics, wireless, etc.)

# Industrial Networks

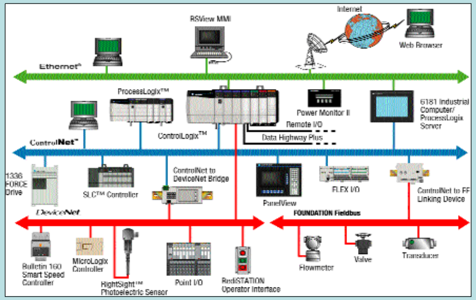
Used for the implementation of Computer Integrated Manufacturing (***CIM***)

**Main objective:**

***Increase the flexibility and the performance of the production.***



# Industrial Control System




by José Carlos Villajulca
/http://www.instrumentacionycontrol.net/en/curso-supervision-procesos-por-computadora/236-sistemas-de-control-abierto-entendiendo-la-supervision-de-proceso-por-computadora.html



# Specifics of the industrial networks

- ***structure***: hierarchical, depending on the application;
- ***data transfer rate***: depending on the level of network:
  - for information exchange: the same as in the information networks;
  - for control information and control SW download: very high;

# Specifics of the industrial networks

- ***network service execution time***: the service must be executed (no canceling) and within a guaranteed time: for the needs of synchronization between the different devices and machines.
- ***reliability (errors):*** depending on the level of network:
  - ***for information exchange –*** the same as in the information networks
  - ***for control information and control SW***: very high



# Specifics of the industrial networks

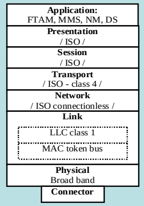
- ***communication media:*** depending on the level of network:
  - for information exchange – the same as in the information networks: metal cables (co-axial, twisted pairs), fiber optics, wireless;
  - for control information and control SW – very well protected against external electromagnetic fields: fiber optics.



# Integrated control systems architecture

***Architecture MAP (Manufacturing Automation Protocol):***

- **Created in 80's by General Motors**;
- **the main purpose – integration of existing information networks with the specific fieldbuses;**
- **Formal description – similar to OSI of ISO, but with specific applications (services) : DS (*Directory Service*), NM (*Network Management*), FTAM (*File Transfert Access and Management*), MMS (*Manufacturing Message Specification*).**





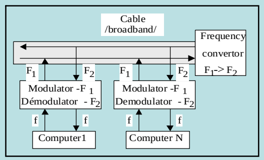

# Standards for integrated systems

**The standards include: the frequency band and the specific protocols.**

- **Frequency bands**

| Channel MAP | Direct F1 /MHz/ | Reverse F2 /MHz/ |
|---|---|---|
| A | 59.75 - 71.75 | 252 - 264 |
| B | 71.75 – 83.75 | 264 - 276 |
| C | 83.75 – 95.75 | 276 - 298 |

- **Broadband transmission**



# Protocols

- *Implement the communications.*
- *Different protocols from different manufacturers.*
- *More confusing is the status of fieldbus case in which attempts have been locked mutually: SP50, Profibus, FIP, ISP, World FIP, etc.*
- ***Problem:***

*How to create and an "unique" and "accepted-by-all" protocol?*

- *Example – Protocol TELWAY*

| Header | Length | Function | Address | Data | Control |
|---|---|---|---|---|---|

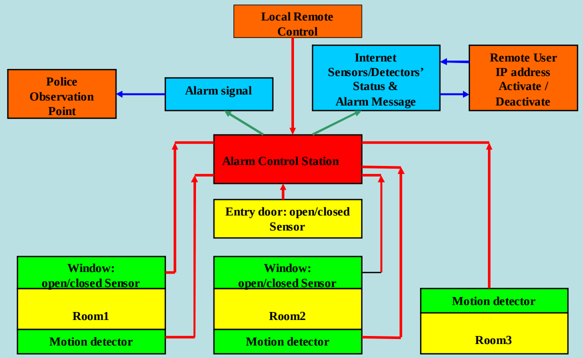


# New trends in Control Systems

- *New types of communication:*
  - *Wireless communication;*
  - *INTERNET connectivity.*
- *New applications:*
  - *Integrated control systems;*
  - *Introducing "intelligent" sensors / actuators.*

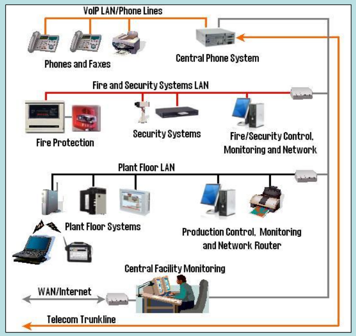


# Simple wireless home security systems






# Simple plant integrated system



# Wireless sensor and actor networks (WSAN)

This material is taken from draft FP7 project proposal, written by

***Davcev Danco, Petre Lameski, Eftim Zdravevski***

- WSAN is an extension from Wireless Sensor Networks (WSNs),
- WSAN tend to enrich the use case scenarios that were available through WSNs.
- WSNs are mainly used for monitoring certain environments and systems.
- WSANs are able not only to monitor the environment, but also to influence the environment on the basis of the data obtained from the sensors
- WSANs have actors that can execute different tasks.

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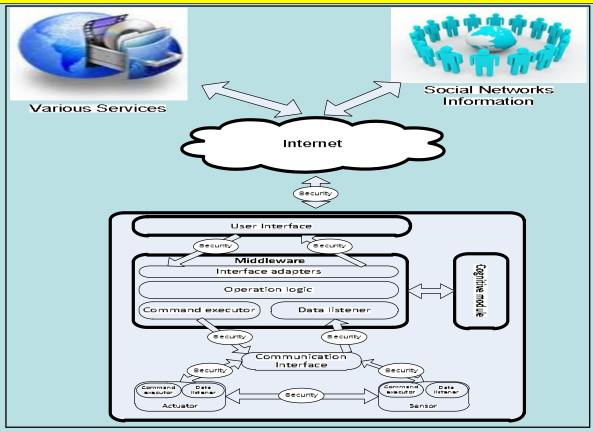
# Architecture of WSAN

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# Architecture of WSAN

***Components:***

- **The user interface is the part of the architecture that is in direct contact with users or operators of the WSAN.**
- **The middleware consists of several modules**:
  - **"Interface adapters"** module is responsible for communication with the user interface;
  - **"Logic module"** implements the communication between all other modules of the middleware, but has interface to the independent Cognitive module;
  - **"Command executor"** translates the command given from the operator and sends it to the corresponding actor or sensors;
  - **"Data listener"** waits for new data from the sensor nodes or from the actor nodes.
- **The Communications Interface** allows multiple communication links to be able to communicate with the middleware.
- **WSAN nodes** are nodes that can be actors or sensors by communicating with the Communications interface.
- **Cognitive layer** allows the middleware to change and adopt itself towards the needs of the user on one side and on the configuration of the WSAN on the other.
- **Security** would allow authenticated users to reach resources that are available to them and prevent unauthorized access to resources that are off limits. Encryption must be introduced and key sharing mechanisms must be developed for making the network more resistant to external attacks.

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# Conclusion

- It is very hard to predict the new applications in the field of control systems
- But, it is obvious, that:
  - Such systems will enlarge their applications
  - New communication technologies will be more often used
  - New industrial digital devices or industrial machines / tools, convenient for digital control will appear
  - Based on the achievement of integrated circuits technologies (nano technology), more specialised and cheap industrial controllers will appear.

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## Conclusion

**Thank you for your attention!**

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