



Concept of SCADA System



SCADA Terminology

- ❑ SCADA is an acronym for ***Supervisory Control and Data Acquisition***
- ❑ *Data Acquisition* :
Gathers information from widely distributed processes
- ❑ *Supervisory Control* :
Calculate and give limited control instructions to distant process facilities



Terms & Terminology

- ☐ Field Instrumentation
- ☐ Data Acquisition
- ☐ Control Loop
- ☐ Supervisory Control
- ☐ Remote Terminal Unit (RTU)
- ☐ Master Terminal Unit (MTU)
- ☐ SCADA Server
- ☐ Communications Equipment



Why SCADA?

- ❑ Saves Time and Money
 - Less traveling for workers (e.g. helicopter ride)
 - Reduces man-power needs
 - Increases production efficiency of a company
 - Cost effective for all systems
 - Saves energy
- ❑ Reliable
- ❑ Supervisory control over a particular system



What is SCADA?

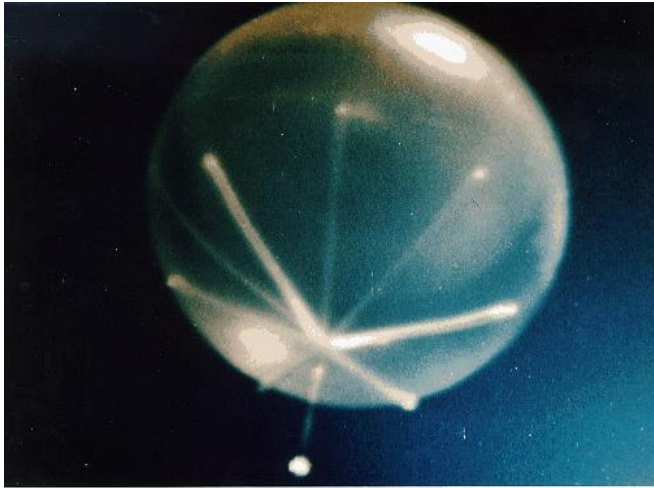
- ❑ Supervisory Control and Data Acquisition
- ❑ Supervisory
 - Operator/s, engineer/s, supervisor/s, etc
- ❑ Control
 - Monitoring
 - Limited
 - Telemetry
 - Remote/Local
- ❑ Data acquisition
 - Access and acquire information or data from the equipment
 - Sends it to different sites through telemetry
 - Analog / Digital



Use Case Diagram for SCADA System

- ❑ Description: The goal is to supervise, control, monitor and acquire data for critical infrastructure systems, operate from remote end and ensure security and safety
- ❑ Actors:
 - Field Devices
 - Local Control Center (LCC)
 - Remote Telemetry Units (RTU)
 - Master / Central Control Terminal Unit (MTU)
 - Operator
 - Supervisor

Historical Background (1)



□ 1960s:

- *Radio Telemetry* : weather monitoring using unmanned balloon/rocket
- *Hardwired Remote Monitoring* : oil & gas and processing industries

□ 1970s :

- *Two-way radio telemetry*
- *Mini-computer*
- *Distributed Process Control System (DCS)*
- *Programmable Logic Controller (PLC)*



Historical Background (2)

□ 1980s :

- *Low cost microcomputer (PC)*
- *Satellite Communications*
- *Cellular Telephone*

□ 1990s :

- *Local Area Network (LAN)*
- *High Speed Communication Devices*
- *Internet*



Classifications

- ❑ Anatomy of a SCADA system?
 - Elements of SCADA
 - Levels of SCADA
- ❑ Where is SCADA used?
 - Different applications of SCADA systems?
- ❑ What types of SCADA are there?
- ❑ Component manufacturers and system manufacturers of the SCADA systems?
 - Automation Solutions
 - Software
 - Hardware



Elements of SCADA

Elements of a SCADA system

- ☐ Sensors and actuators
- ☐ RTUs/PLCs
- ☐ Communication
- ☐ MTU
 - Front End Processor
 - SCADA server
 - Historical/Redundant/Safety Server
 - HMI computer
 - HMI software



Sensors

Types of sensors:

- ☐ Pressure sensors
- ☐ Temperature sensors
- ☐ Light sensors
- ☐ Humidity sensors
- ☐ Wind speed sensors
- ☐ Water level sensors
- ☐ Distance sensors

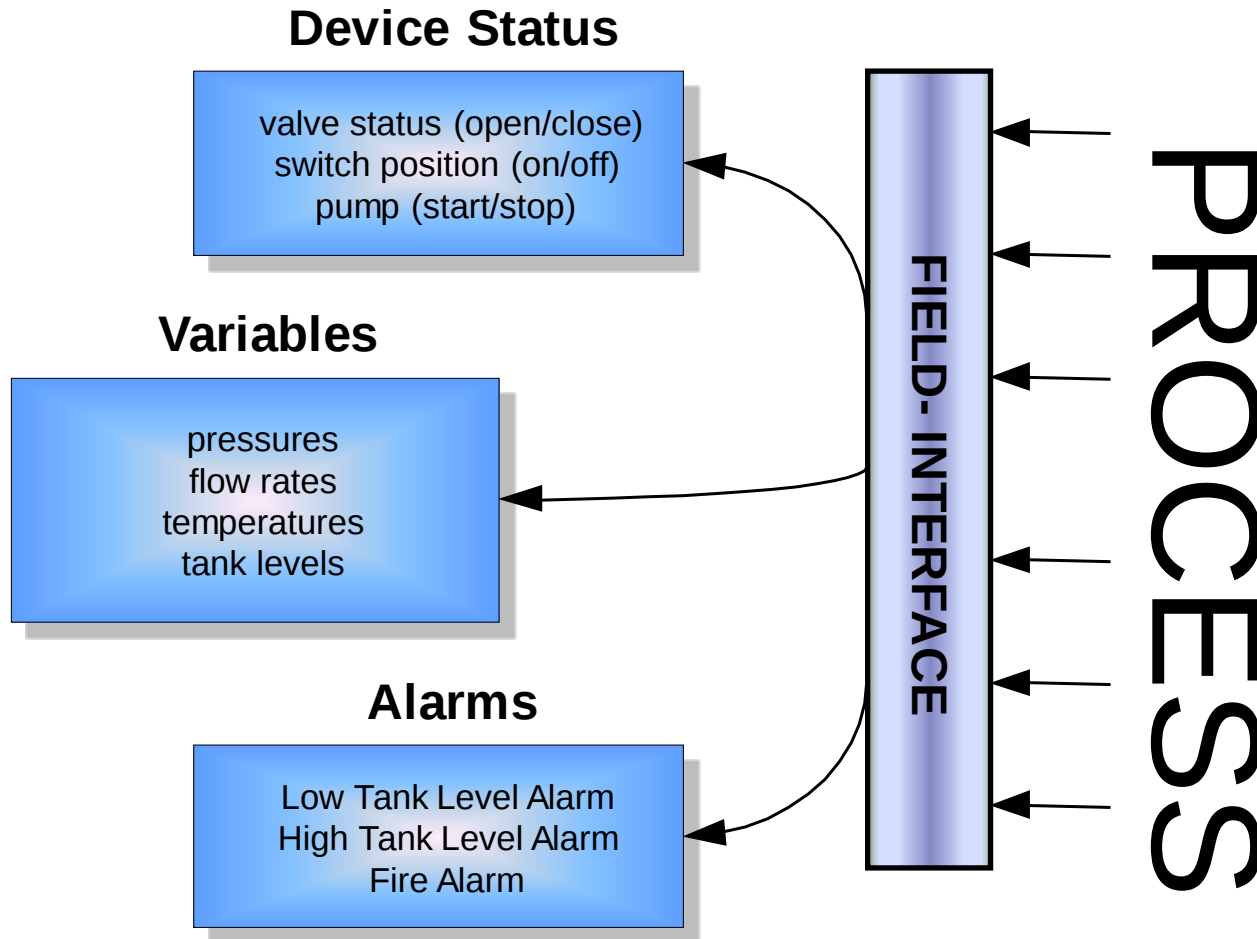


Actuators

Actuators:

- ☐ Valves
- ☐ Pumps
- ☐ Motors

Data Acquisition





Alarms

- Types of alarms:
 - Good alarms
 - Critical failure alarms

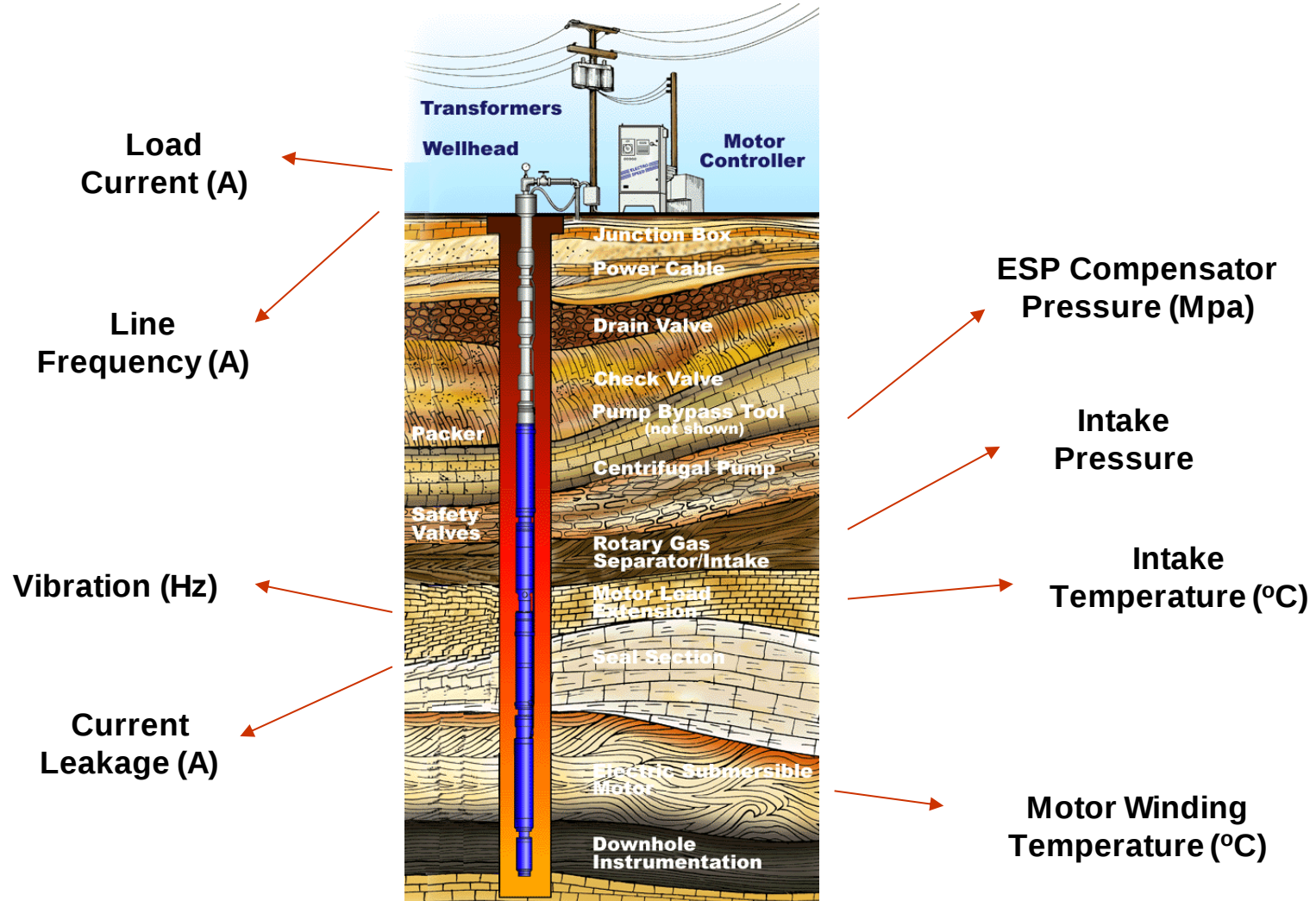


Safety Instrumented Systems

☐ Actions:

- Override the normal control system
- Take over the actuators

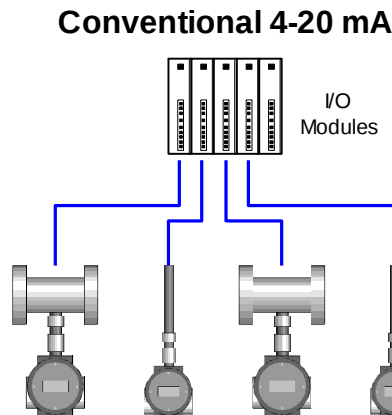
Data Acquisition on an ESP System



Types of Field Devices

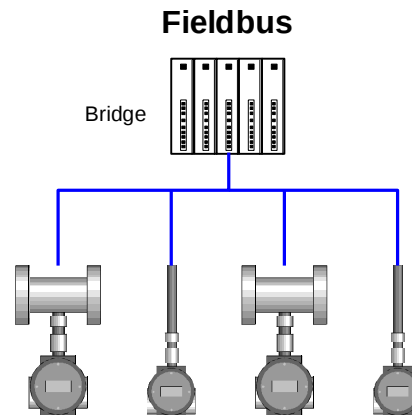
❑ Conventional

- 4-20 mA analog signal
- Discrete status (0/1)
- Point-to-point configuration
- Dedicated wiring for each device

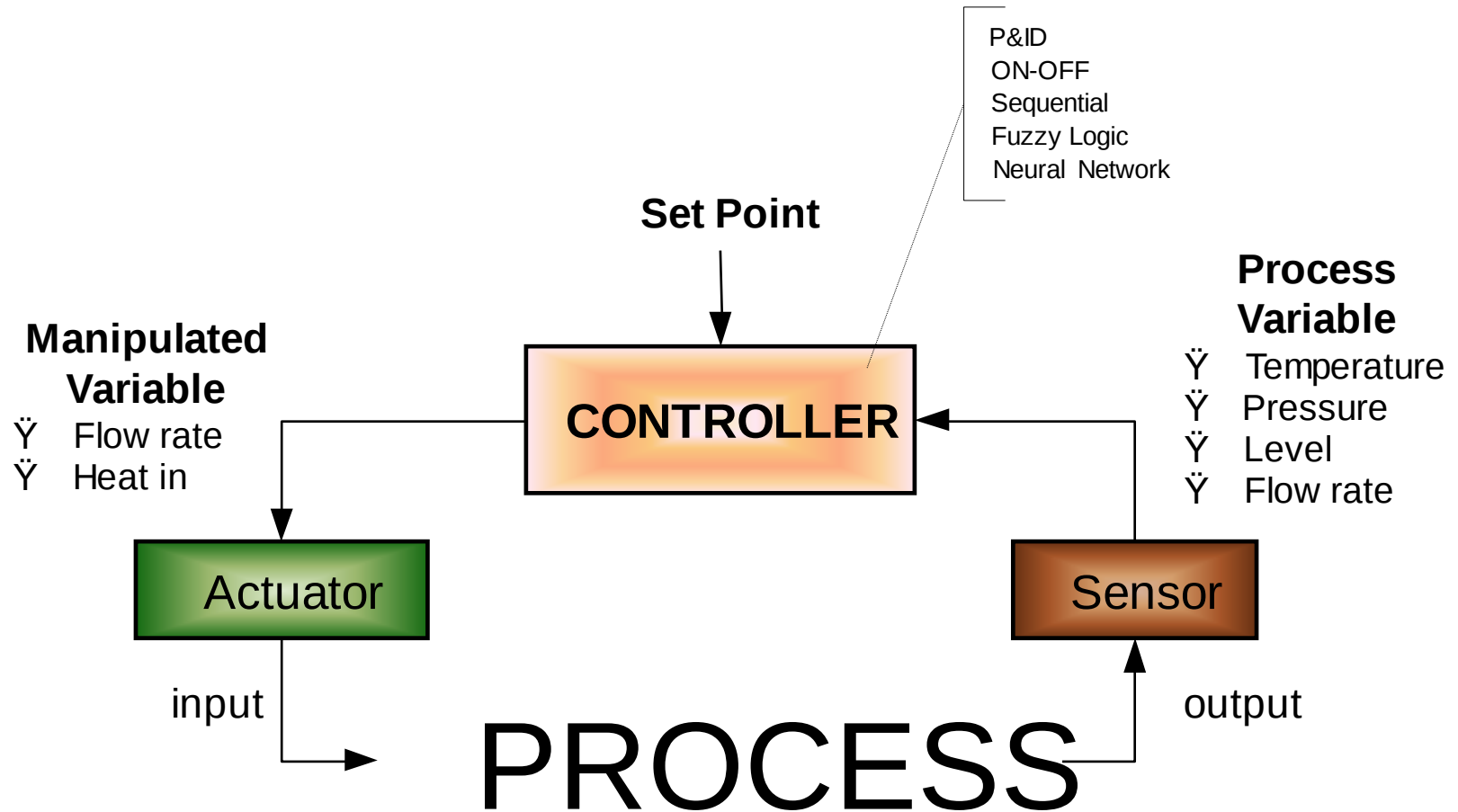


❑ Fieldbus based

- Microprocessor and embedded system technology
- Digital signal
- Point-to-point or point-to-multipoint
- Simplified wiring, drawings, and control engineering
- Embedded control algorithm
- example :
 - Foundation Fieldbus Transmitter
 - Profibus Transmitter
 - HART transmitter



Control Loop



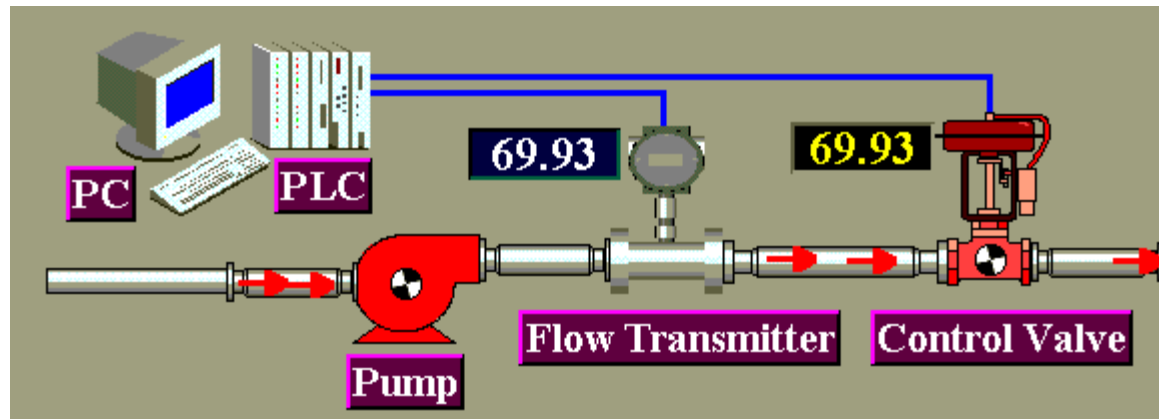
Example : Flow Control Loop

❑ Objective :

- maintain flow rate at a desired value (set point)

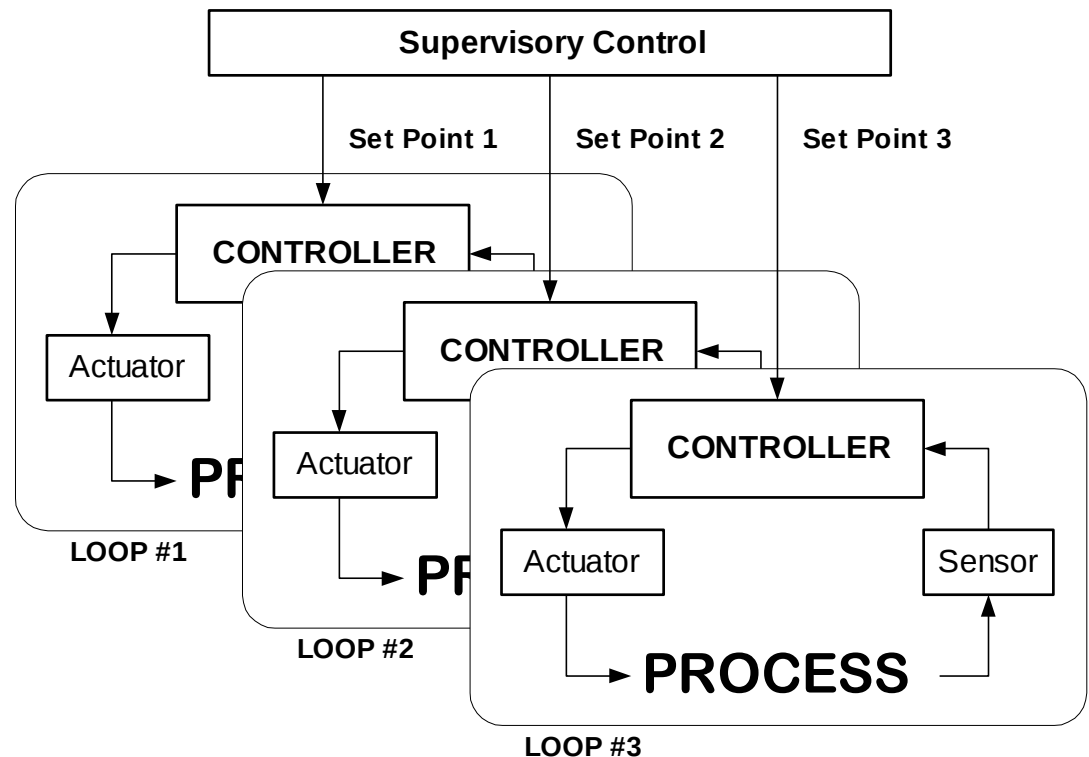
❑ Control elements :

- Sensor : Flow Transmitter
- Controller : PLC (PID)
- Actuator : Control Valve



Supervisory Control

- ❑ Set point management for several control loops
- ❑ Optimization to achieve “the best operating point”
- ❑ Use advanced control algorithm
 - cascade controller
 - ratio controller
 - override control
 - etc





Goals to Achieve

❑ Technical :

- Safety
- Increased productivity
- Equipment protection and maintenance
- Operational optimization
- Energy saving
- Immediate access to inventories, receipts, deliveries, etc.

❑ Economical :

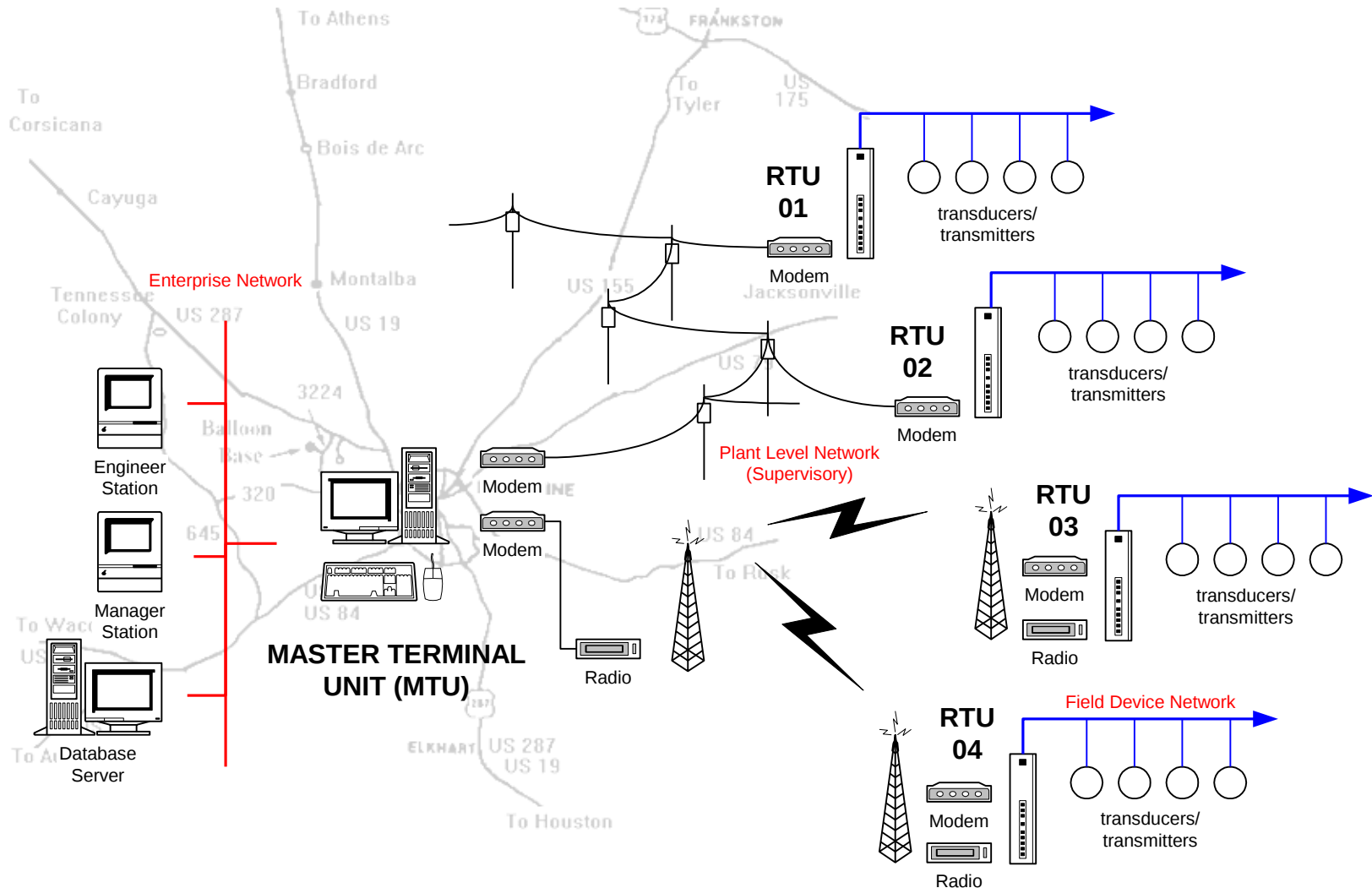
- Plant-wide optimization
- Optimization of personnel utilization



Applicable Processes

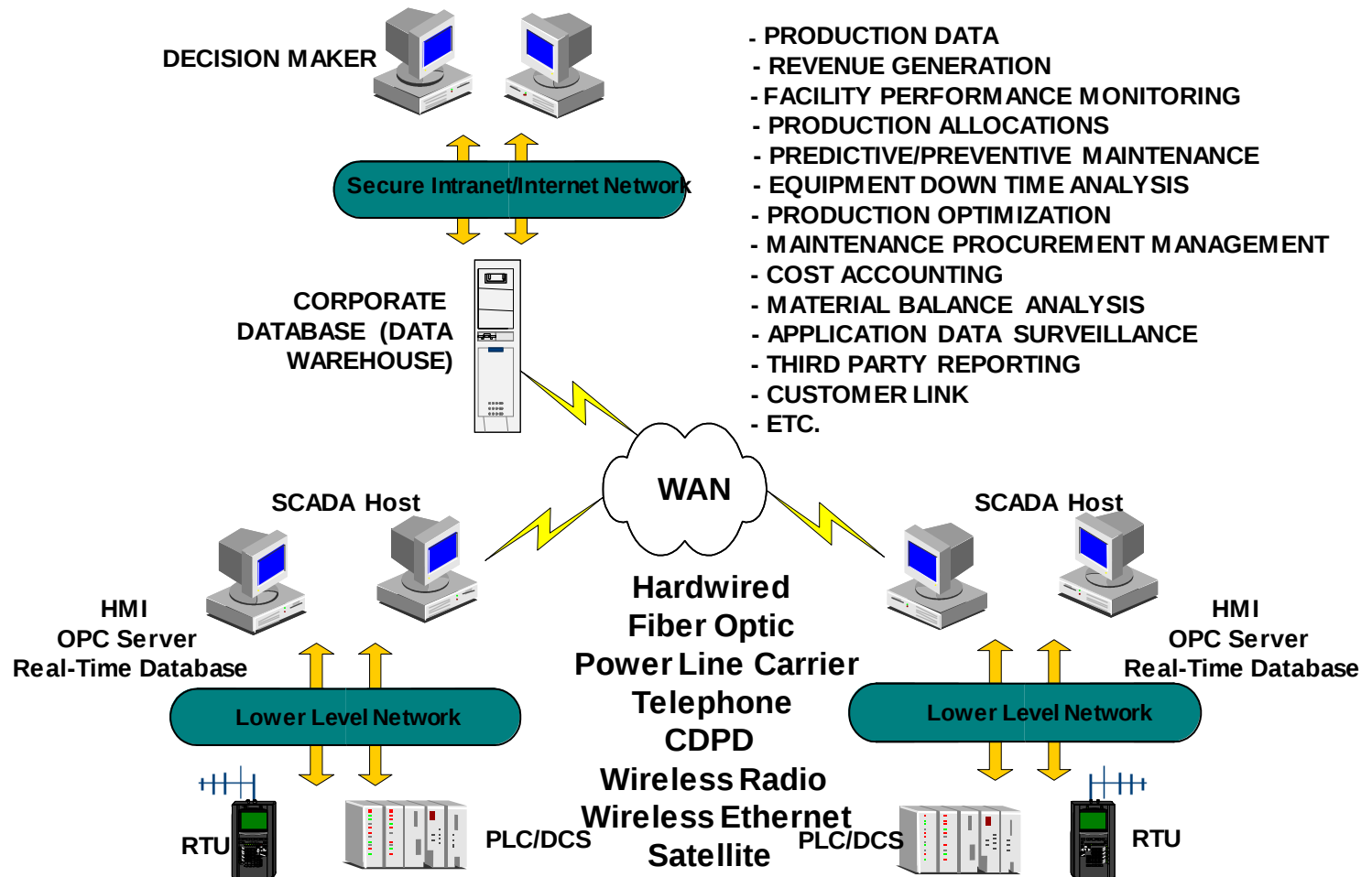
- ❑ Widely distributed processes; spreading over large areas
- ❑ Require frequent, regular, or immediate intervention
- ❑ High cost of routine visits to monitor facility operation
- ❑ Examples :
 - Oil and gas production facilities
 - Pipelines for gas, oil, chemical, or water
 - Electric power transmission system
 - Railroad traffic
 - Feed water purification plant
 - Building automation

SCADA System Architecture



SCADA SYSTEM ARCHITECTURE

APPLICATIONS:





SCADA System Platform

- ❖ Discrete Pneumatic/Electronic System (Old Technology)
- ❖ Personal Computer (PC) Based System
- ❖ Programmable Logic Controller (PLC) Based System.
- ❖ Distributed Control System (DCS) Based



RTUs

RTU – Remote Terminal Unit

- ☐ Intelligent to control a process and multiple processes
- ☐ Data logging and alarm handling
- ☐ Expandable
- ☐ Asks the field devices for information
- ☐ Can control IEDs (Intelligent Electronic Device)
- ☐ Slave/Master device



PLCs

PLC – Programmable Logic Controller

- ☐ Ladder logic
- ☐ Industrial computer that replaced relays
- ☐ Not a protocol converter
- ☐ Cannot control IEDs
- ☐ Communication compatibilities
- ☐ Takes actions based on its inputs



DCS

DCS – Distributed Control System

- Process oriented – tendency to do something
- Not event oriented – does not depend on circumstances
- Local control over the devices
- Subordinate to SCADA

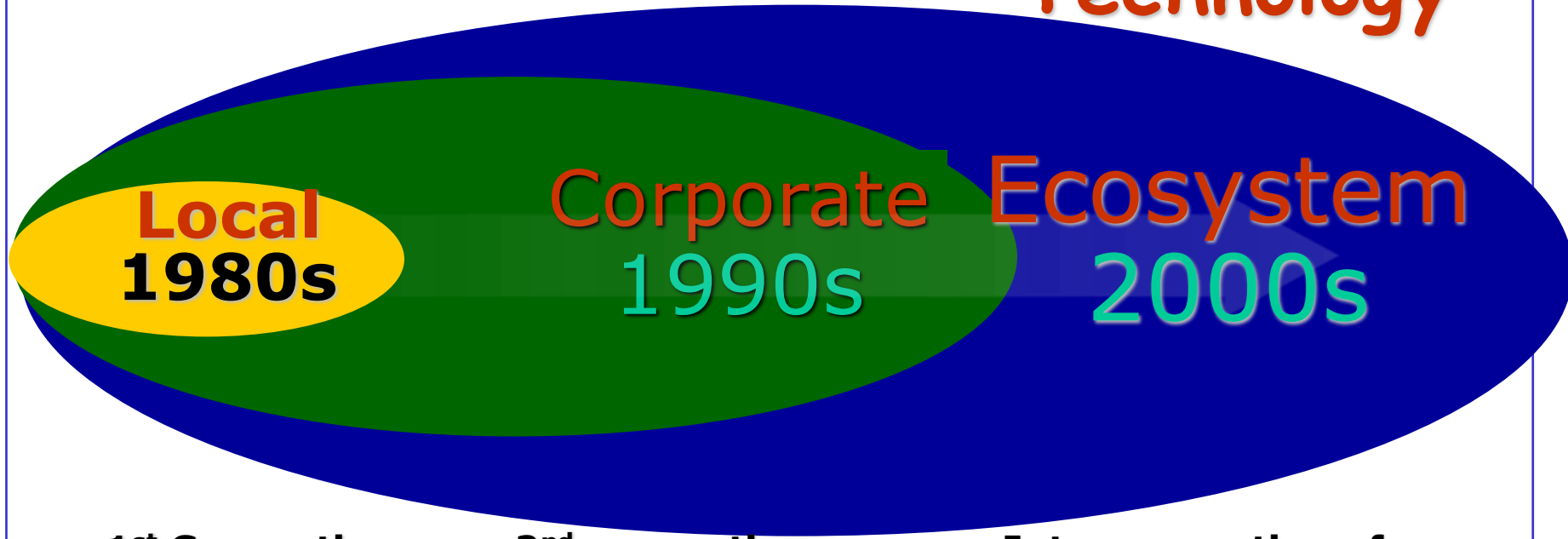
Old Automation Technology



New Automation Technology



Evolution of Automation Technology



- **1st Generation DCS / PLCs**
- **Proprietary systems/networks**
- **Introduction of workstations**
- **2nd generation DCS/PLCs, starting to enable connections**
- **PC based supervisory systems**
- **Internet/Intranet**
- **Business process integration: ERP, CRM, SCM...**
- **Interconnection of:**
 - **Customers/Plants/Suppliers**
 - **All systems & workers**
 - **Workers in all roles**
 - **Business & manufacturing processes**
 - **Effective use of information**



Communication

Communication systems:

- ☐ Switched Telephone Network
- ☐ Leased lines
- ☐ Private Network (LAN/RS-485)
- ☐ Internet
- ☐ Wireless Communication systems
 - Wireless LAN
 - Global System for Mobile Communication (GSM) Network
 - Radio modems



Communication

Protocols:

- MODBUS
- DNP 3.0
- Fieldbus
- Controller Area Network (CAN)
- Profibus
- DirectNet
- TCP/IP
- Ethernet



Data Communications

- ❑ One MTU can exchange data with one or more RTUs
- ❑ Data exchange within MTU and RTUs follows a pre-defined set of rules called *communication protocol*
- ❑ Data is encoded as *binary signal* (series of ones and zeros)
- ❑ This binary signal is modulated before it propagates through communication medium
- ❑ Two-way communications (half or full duplex)
- ❑ serial transmission (asynchronous/synchronous)
- ❑ Leased or non-leased line
- ❑ Guided or wireless medium :
 - radio link (UHF, VHF, microwave, satellite)
 - cable link (telephone, twisted pair, coaxial, power line carrier)
 - fiber optic
 - etc

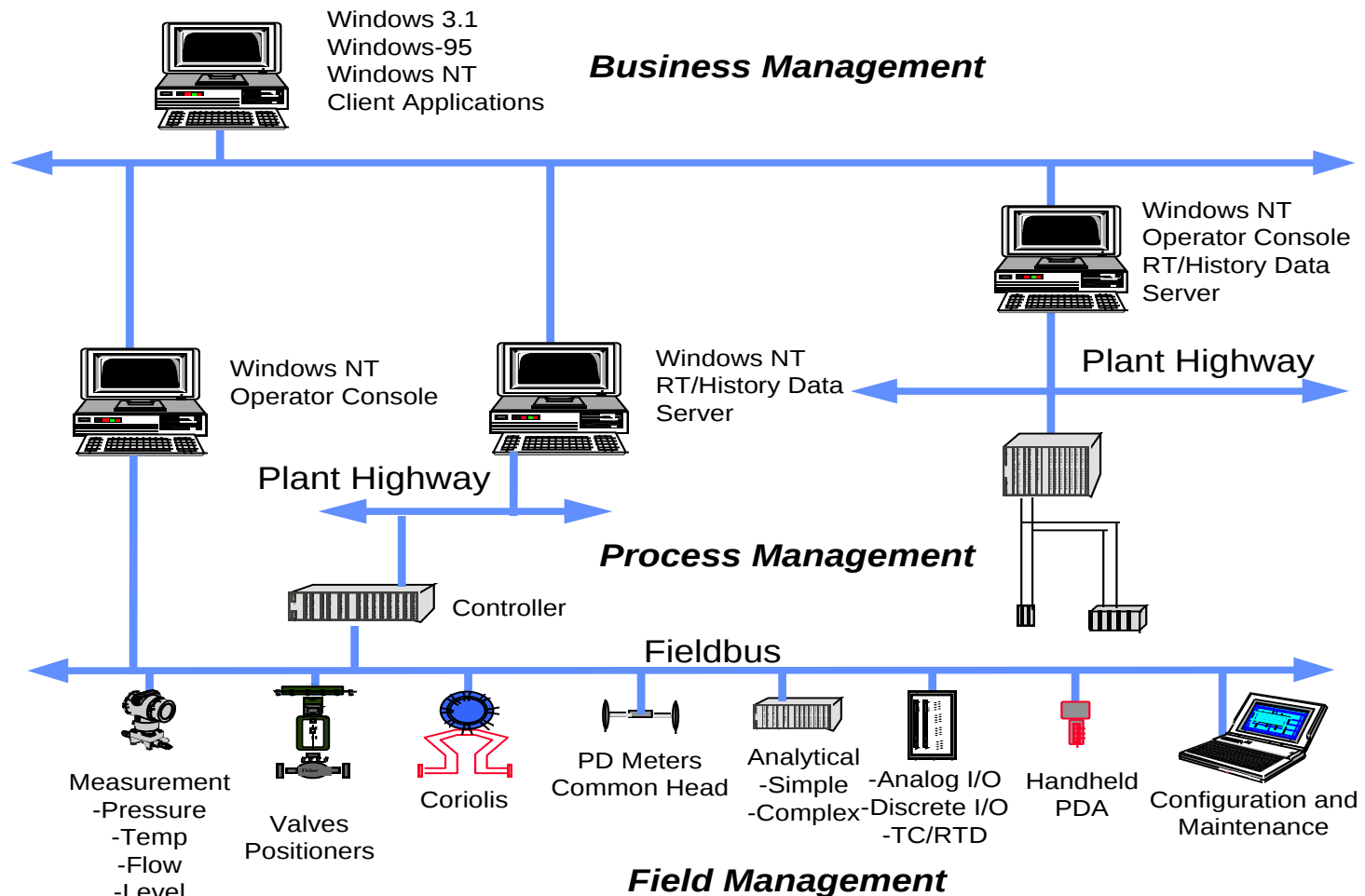
Remote Terminal Unit (RTU)



- ❑ Placed at remote plant location
- ❑ Integrated with instrumentation and control systems (PLC or DCS)
- ❑ Functions :
 - Gathers information from the field
 - Send the information to MTU
 - Process the supervisory control instruction from MTU



Communications



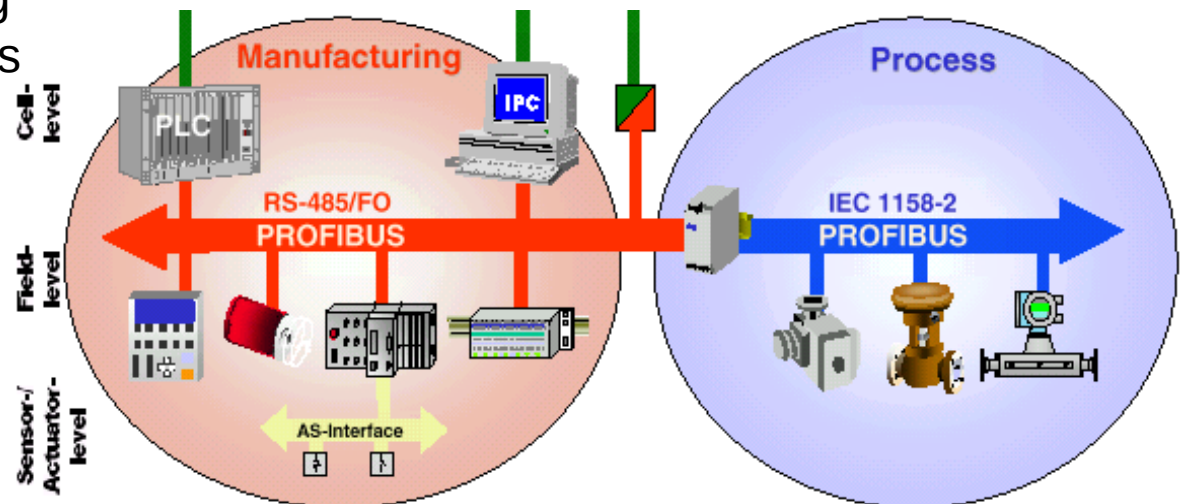
Device Network

Actuator/Sensor Level

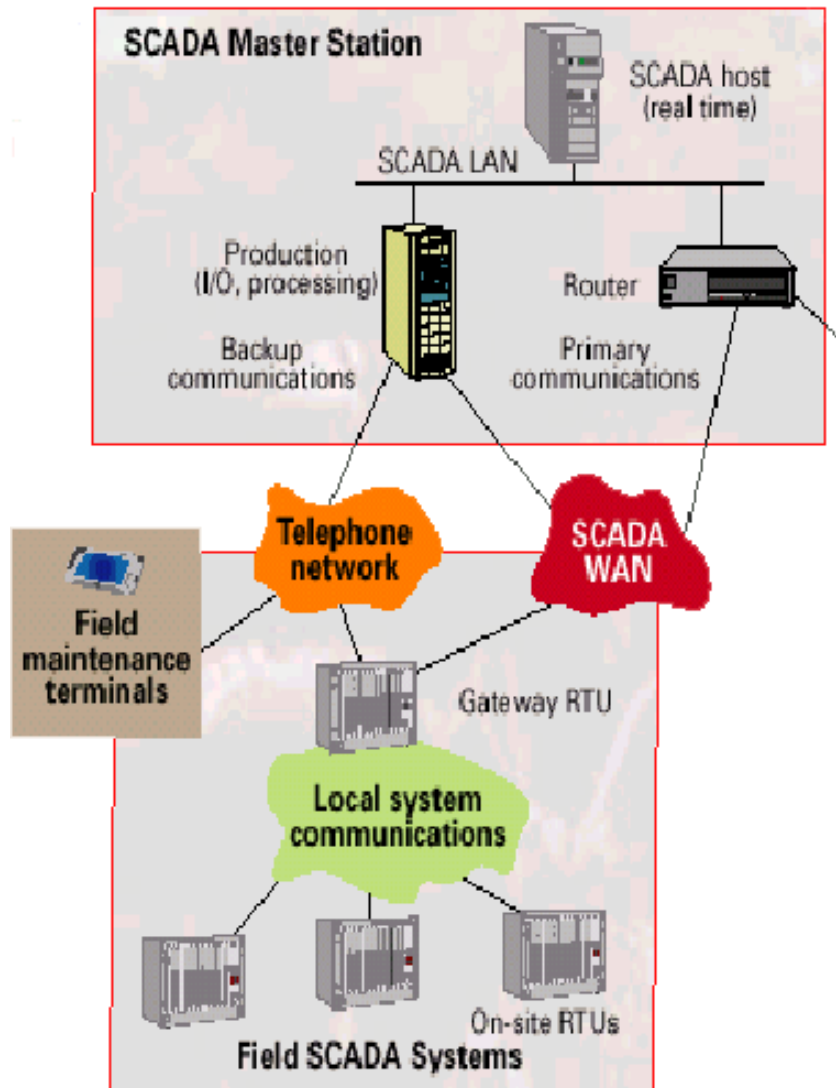
- ❑ Analog signals of the conventional sensors and actuators are transmitted via two-wire cable
- ❑ One dedicated two-wire cable is required for each sensor/actuator
- ❑ Analog-to-digital and digital-to-analog converters are required to enable interfacing and communications with other intelligent devices (programmable controllers, smart transmitter, fieldbus devices)

Field Level

- ❑ Intelligent field devices are configured in multidrop/bus topology
- ❑ Single or multi-master mode is supported
- ❑ The numbers of field devices in a field level network is limited
- ❑ Interoperability issue



Plant Network



❑ RTU to Sub-MTU to MTU connection

❑ Medium

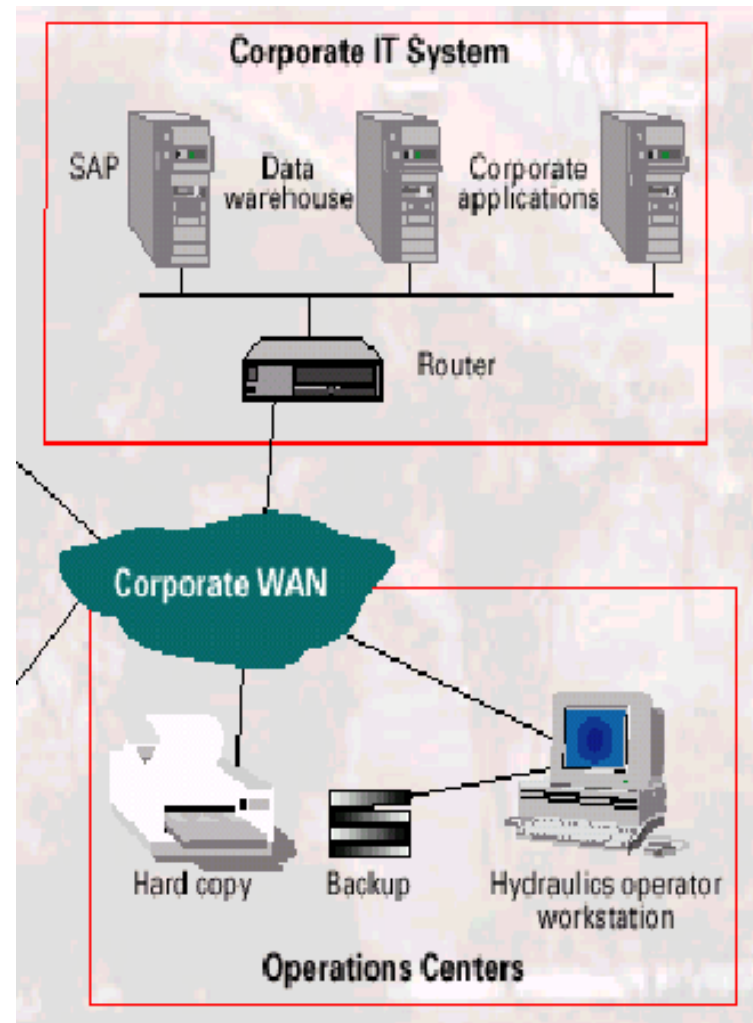
- guided : cable, telephone, ISDN, optical fiber, etc.
- wireless : broadcast radio, microwave, satellite

❑ Protocol

- DH, DH+, DH-485, ControlNet
- Modbus, ModbusPlus, ModbusTCP
- Hostlink
- DNP

Corporate/Enterprise Network

- ❑ Ethernet
- ❑ TCP/IP
- ❑ Corporate Applications
 - Real time asset management
 - Business support
 - Marketing & sales
 - Procurement
 - Manufacturing
 - Distribution
 - Data warehouse





Levels of SCADA

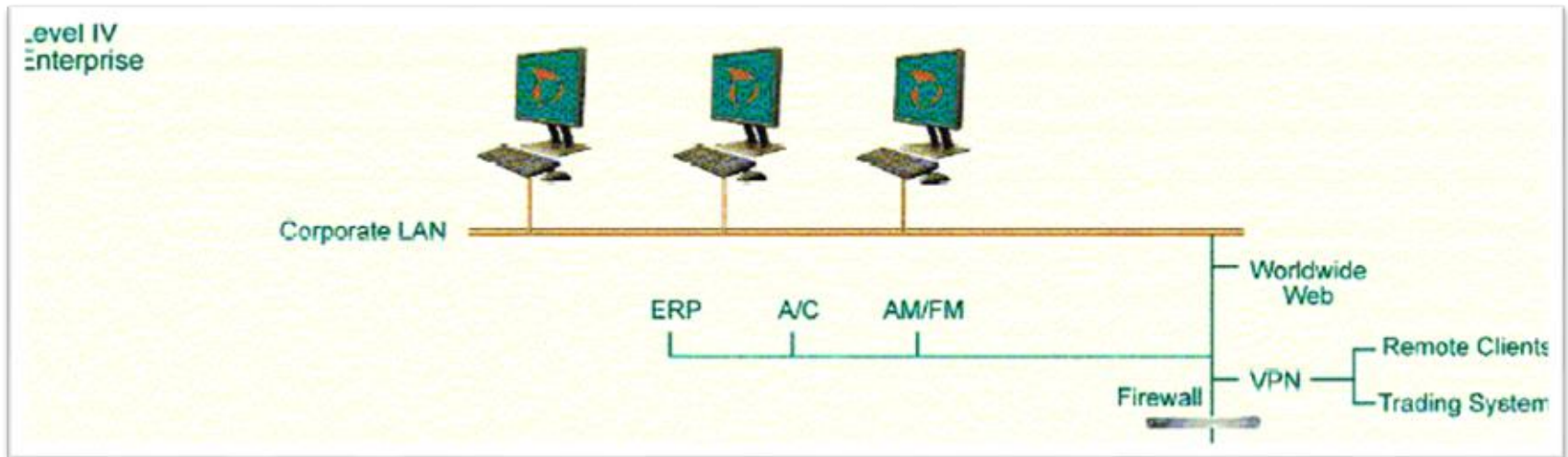
- Four levels of SCADA system
 - Level IV - Enterprise
 - Corporate LAN/WAN
 - World Wide Web
 - Virtual Private Network
 - Firewall for remote users
 - Level III – SCADA / MTU
 - Operator Workstations
 - Control
 - Engineering Workstations
 - Servers – Data logging



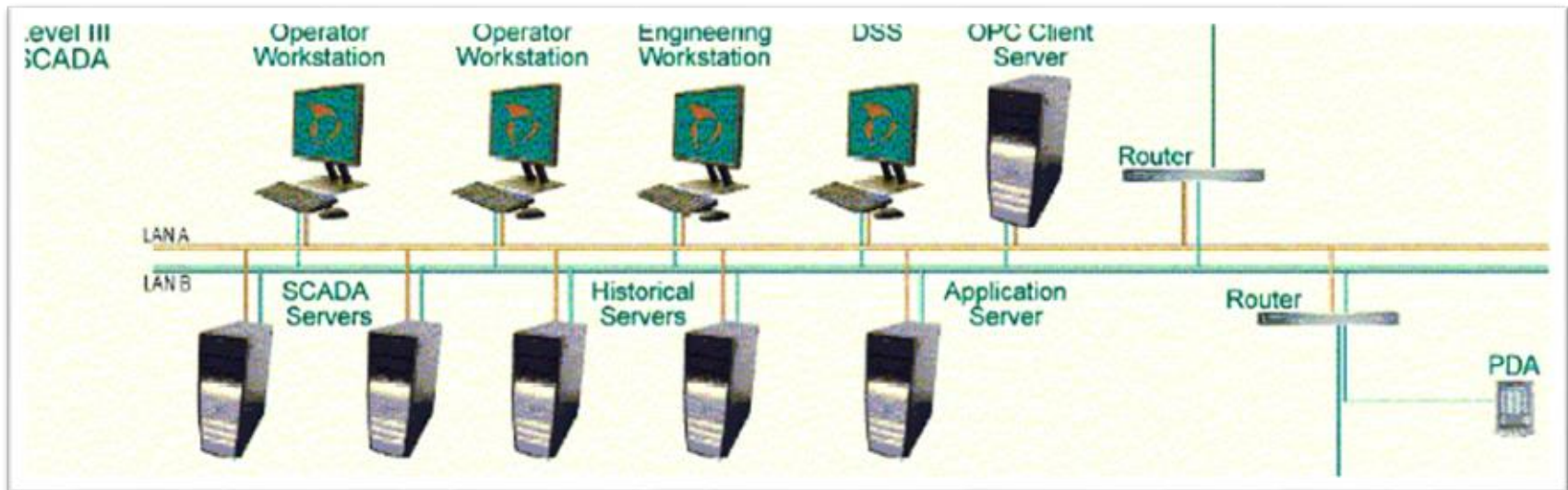
Levels of SCADA

- ❑ Four levels of SCADA system
 - Level II – Telecommunication
 - Fiber
 - Radio
 - Telephone leased line
 - Protocols
 - Level I – Field
 - Devices
 - RTUs / PLCs
 - Sensors

Level IV - Enterprise

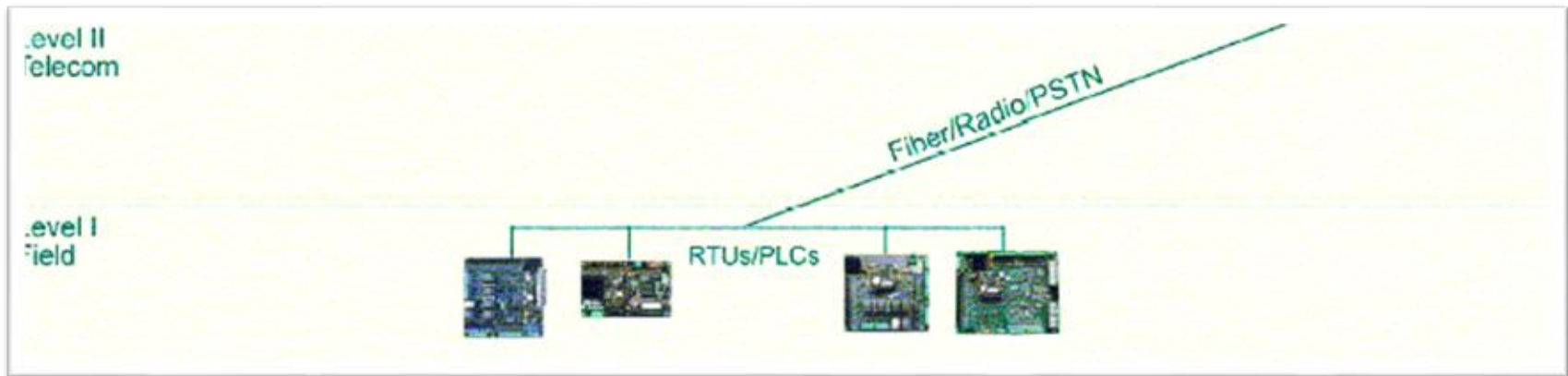


Level III - SCADA



Level II and I

□ Telecommunication and Field





Master Terminal Unit (MTU)

- ❑ Customized configuration for each applications
- ❑ Connected to Local Area Network (LAN)
- ❑ Equipped with auxiliary devices (data storage, console, pointing devices, etc)
- ❑ Functions :
 - Collect process information from RTUs and share the information on the LAN
 - Online operator interface (MMI)
 - Send supervisory control instruction to RTUs
 - Alarm management
 - Report generation
 - System security
 - Central data processing



Front End Processor

Front End Processor

- ❑ Gathers all communications and converts them into SCADA friendly communication
- ❑ Communication interface between several RTU channels and the host Master Station computer



SCADA server

SCADA Server

- ☐ It can be a Web server
- ☐ Data logging
- ☐ Analyzing data
- ☐ Serve the clients through a firewall
- ☐ Clients connected in the corporation or
connected
outside through internet
- ☐ Real-time decision maker
- ☐ Asks RTU for information



Historical server

- ❑ Historical/Safety/Redundant Server
 - ❖ Logs the data from the SCADA server and stores it as a backup, in case of a disaster
 - ❖ It is basically a safety server



HMI Computer

- ❑ Human Machine Interface Computer
 - Access on the SCADA Server
 - Control the system
 - Operator Interface
 - Software
 - User friendly
 - Programmable (C, C++)



Man Machine Interface (MMI)

❑ Provides human access to field automation system

- Operational
- Maintenance & troubleshooting
- Development

❑ Function :

- Communicates with field I/O from Programmable Logic Controllers (PLCs), Remote Terminal Units (RTUs), and other devices.
- Gives up-to-date plant information to the operator using graphical user interface
- Translates operator instruction into the machine
- Engineering development station
- Operator station

Man Machine Interface

❑ Plant information :

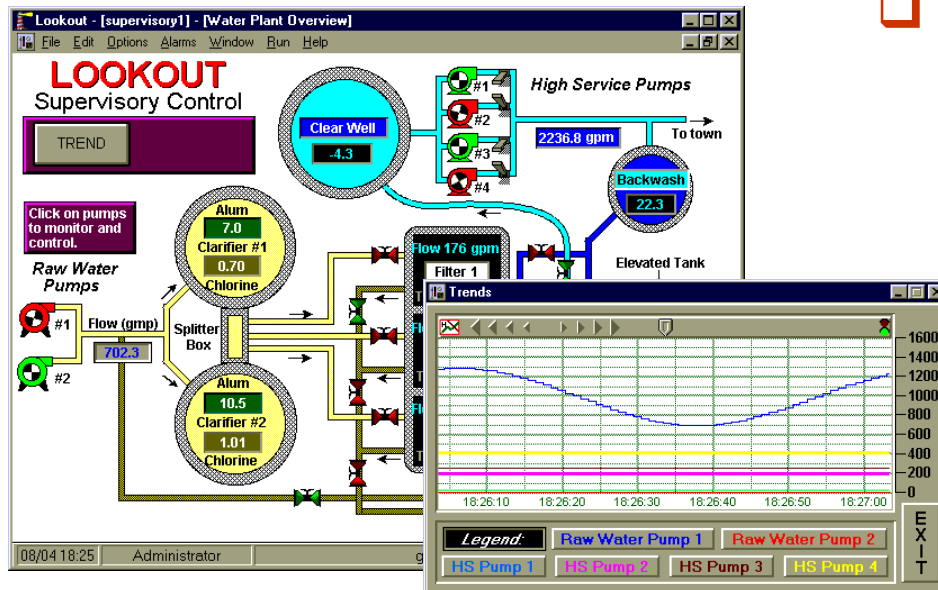
- Process Variables
- Device status
- Alarms
- Control Loops
- etc

❑ Presentation Method :

- Graphics Trending
- Charts
- Reports
- Animation
- etc

❑ Equipment :

- Keyboard
- Mouse or other pointing devices
- Touchscreen or CRT
- etc.

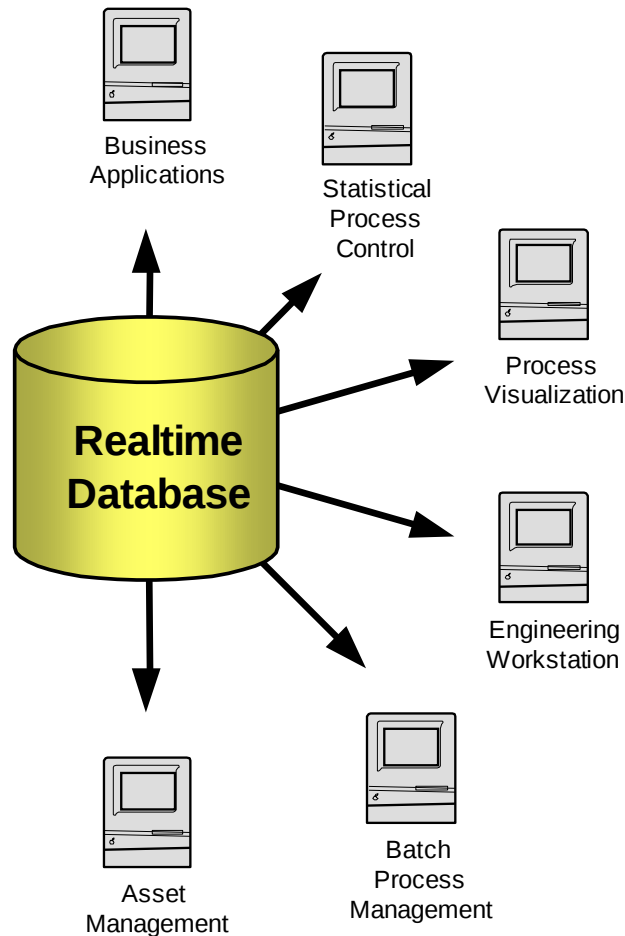




User Applications

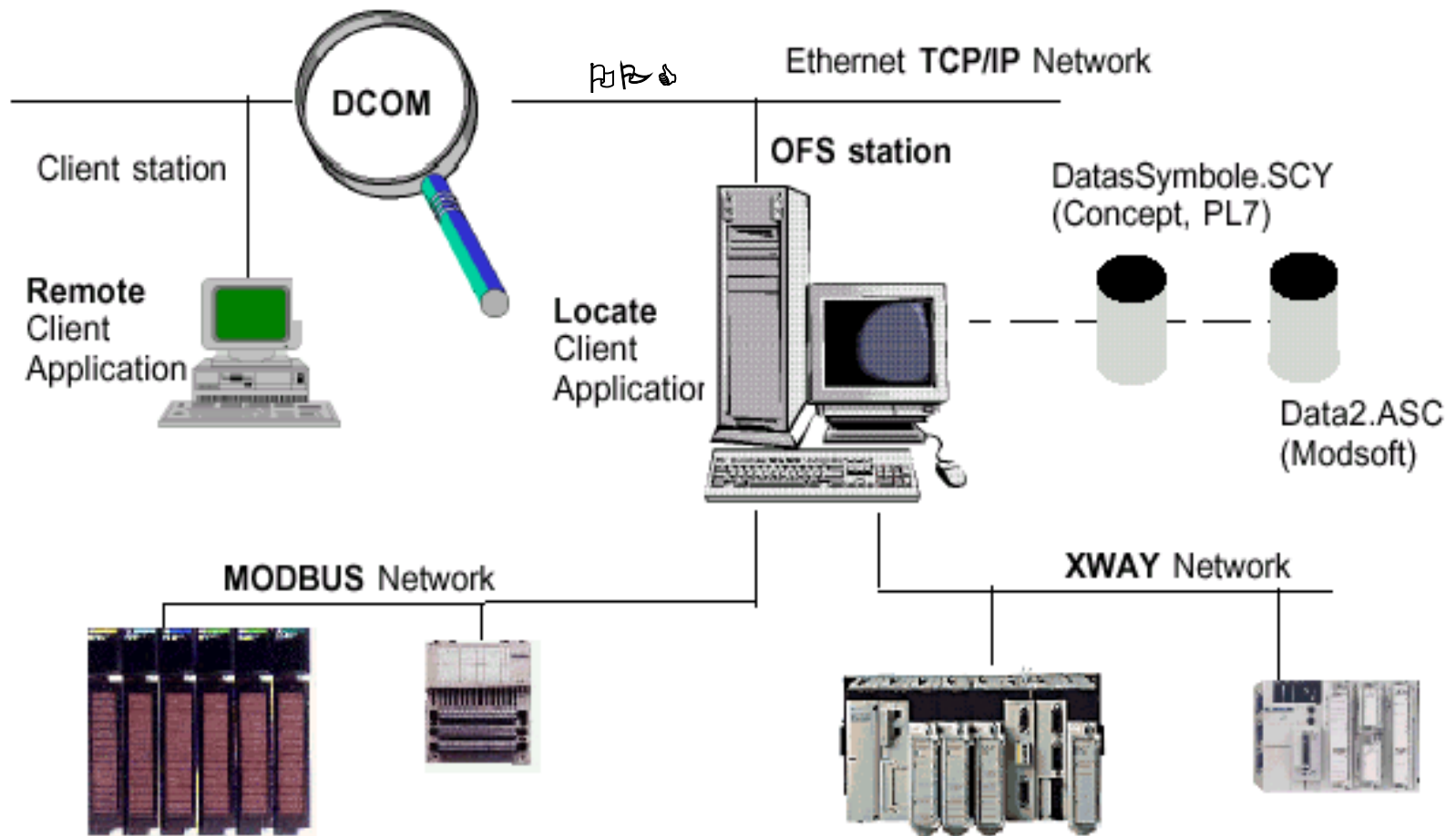
- ❑ Development tools is provided by SCADA system supplier (scripting tools)
- ❑ Examples :
 - Meter gross/net computation
 - Pipeline terminal display
 - Pipeline inventory
 - Transient modeling systems
 - Dynamic leak detection
 - Pipeline simulator
 - Compressor optimization
 - Automatic well testing
 - Well revenue calculation
 - etc.

System Database



- ❑ Store historical process information for engineering, production, maintenance, and business purposes
- ❑ Features :
 - Engineering units conversion
 - Analog value filtering
 - Value limit checking
- ❑ Standardized Data Structure
 - Analog point structure
 - Status point structure
 - Accumulator point structure
 - Container points
 - User defined structure
- ❑ Each point in the database has a number of associated parameters, all of which can be referenced relative to a single tag name

Industrial Automation Server



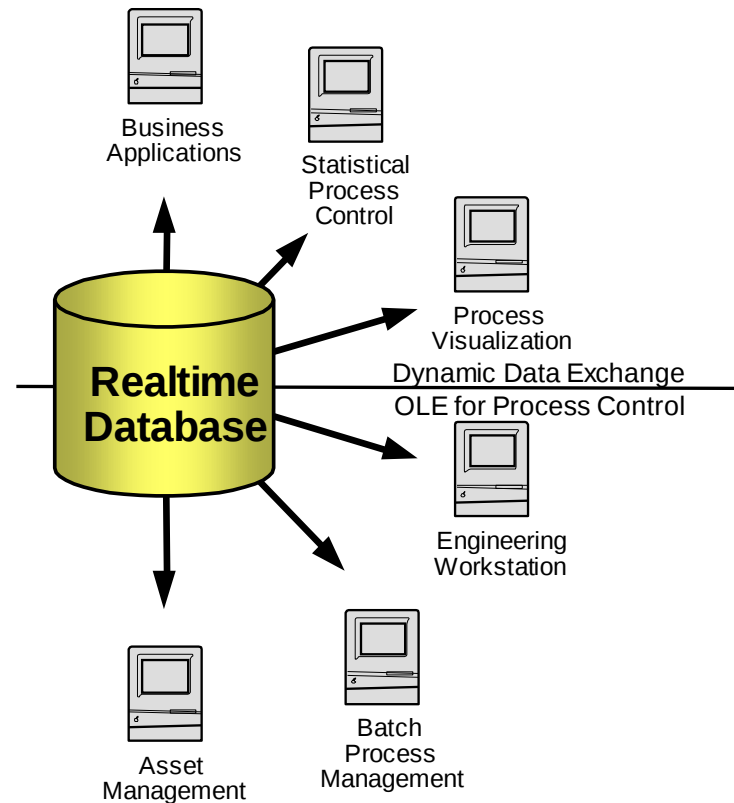


OLE for Process Control (OPC)

- ❑ Object Linking and Embedding (OLE) for Process Control
- ❑ A standard for process automation (SCADA) communications
- ❑ A standard software mechanism for sharing data between process automation (SCADA) of different manufacturers
- ❑ OPC is based on Microsoft OLE (Object Linking and Embedding) and DCOM (Distributed Component Object Model)
- ❑ OPC advantage :
 - Simple to implement
 - Flexible to accommodate multiple vendor needs
 - Provide a high level of functionality
 - Allow for efficient operation

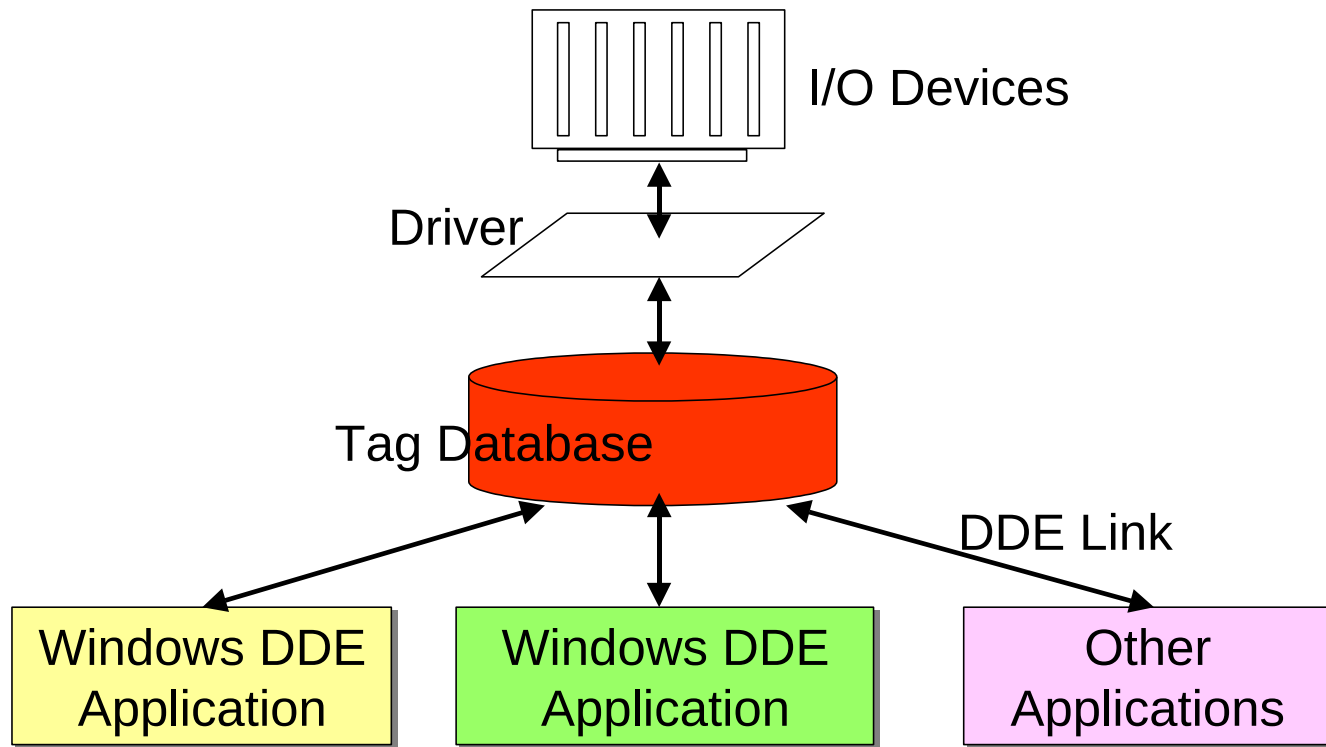
Plant-Office Data Integration

- ❑ Networking has been successfully implemented from field device level up to management level.
- ❑ Data can easily be interchanged between applications in the same computer or different computers over a network.
- ❑ SCADA system can give an immediate response needed from field device to management system.
- ❑ Real-time plant information can be transferred to office application.
- ❑ Corporate information system must be designed to meet its business process.

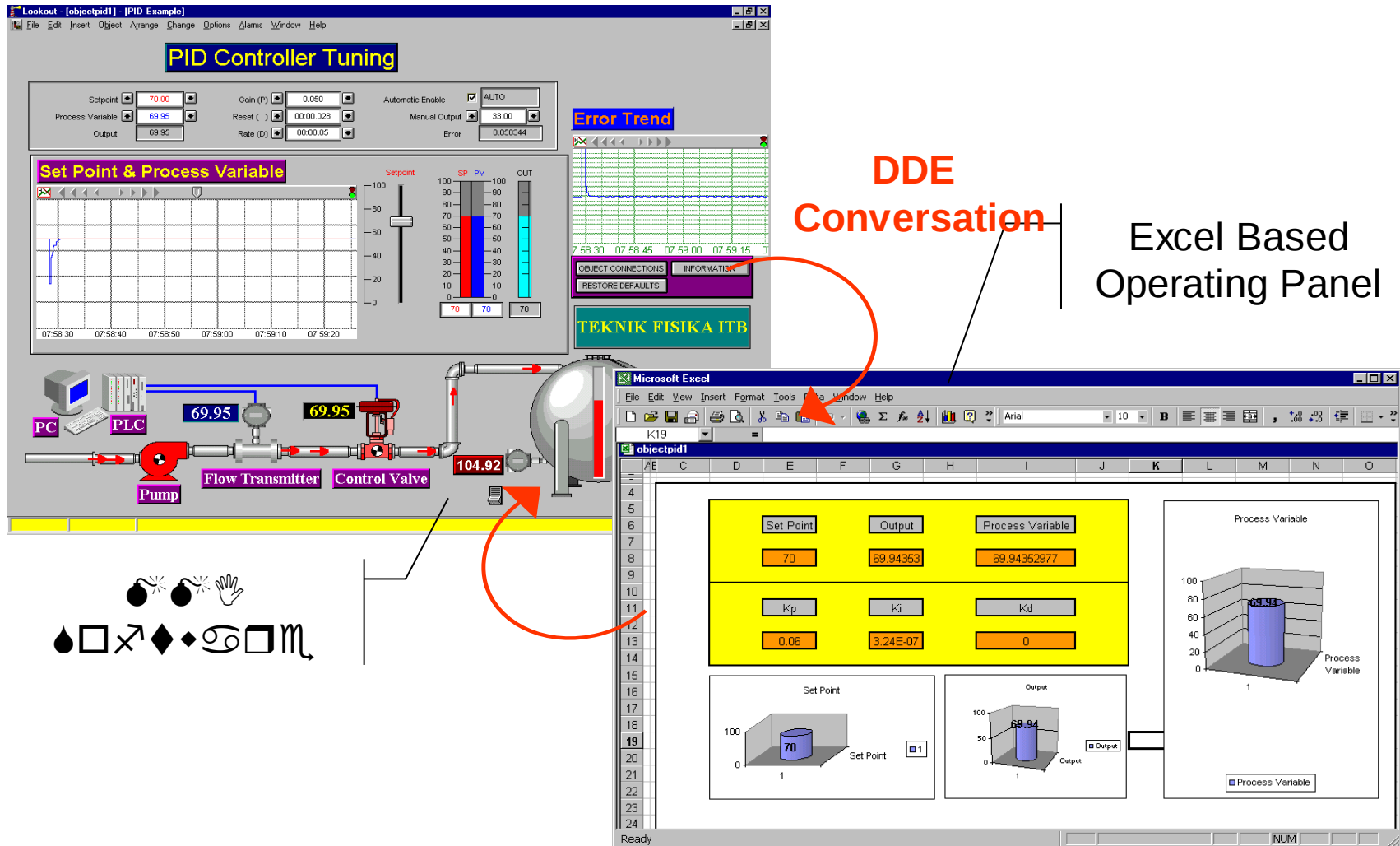


Dynamic Data Exchange (DDE)

- ❑ An application protocol that allows data exchange on real-time basis on Windows/WindowsNT platforms
- ❑ NetDDE = Dynamic Data Exchange over network



Sample of System linked to Excel

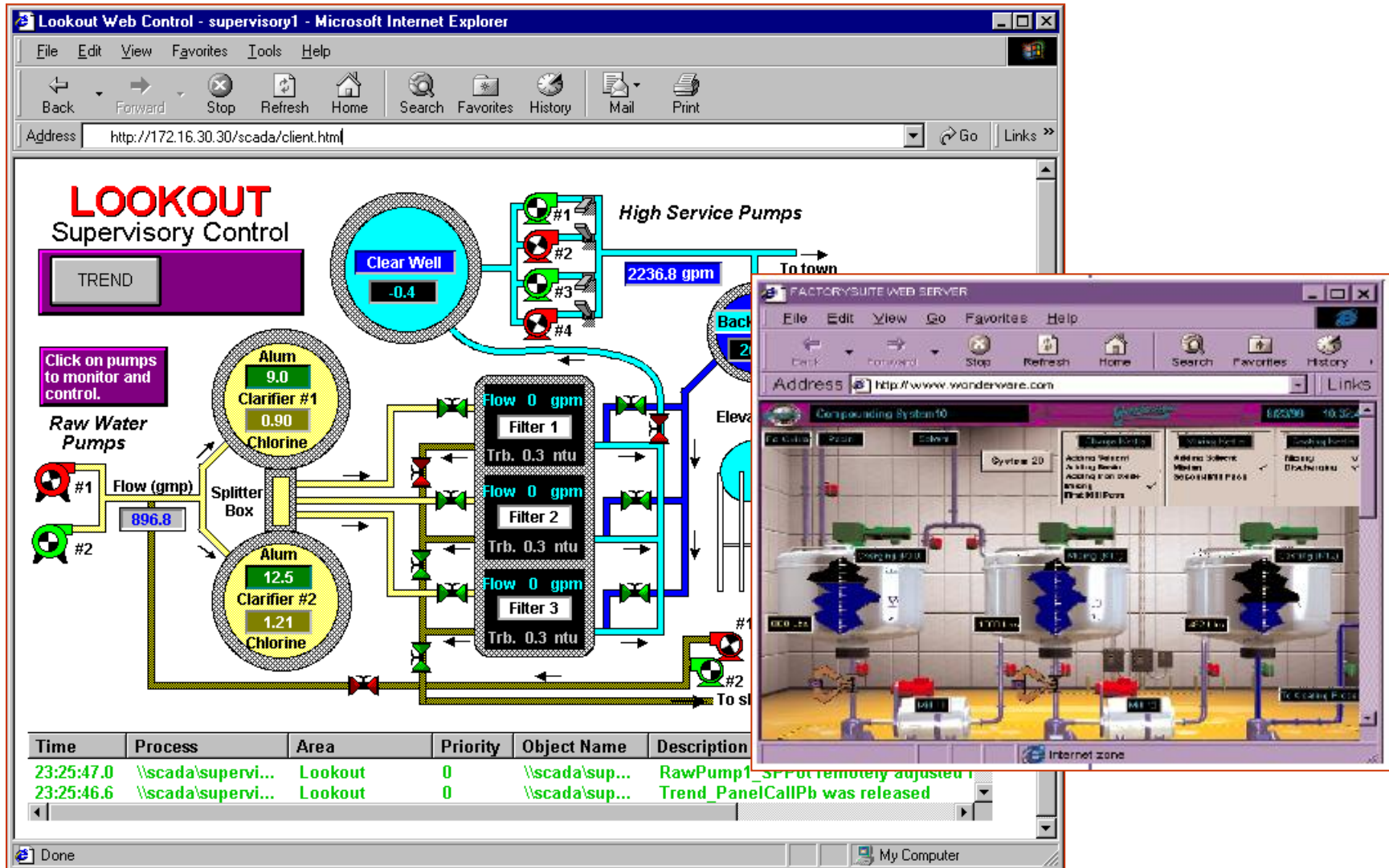




Web-based Process Monitoring

- ❑ Internet browser as an acceptable MMI standard will minimize operator/user training by providing a familiar operating environment
- ❑ Many visualization techniques are available (JavaScript, Java, Shockwave/Flash, etc)
- ❑ Extra development effort is not needed since SCADA supplier software usually provide integrated web-based and application specific MMI development
- ❑ Allows the users (e.g. : supervisor/manager) to monitor process operation, documents and reports either in the Intranet or Internet
- ❑ Secured network design is a must to avoid cyber risk such as hacking attempts and virus

Web Based Monitoring Example



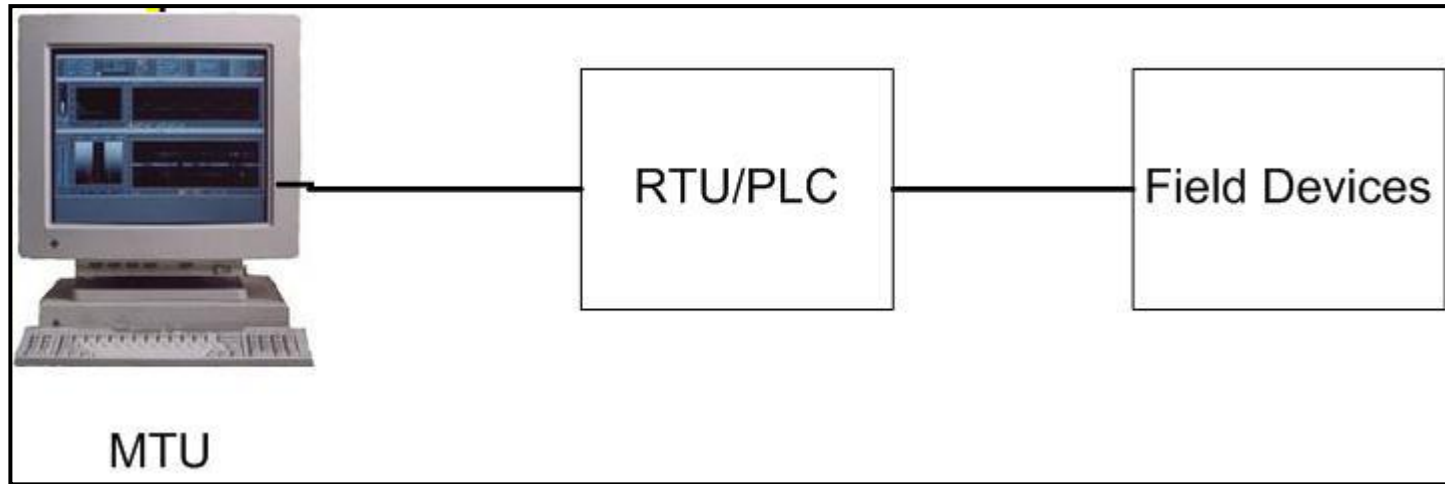


SCADA system types

□ Three types of basic SCADA systems:

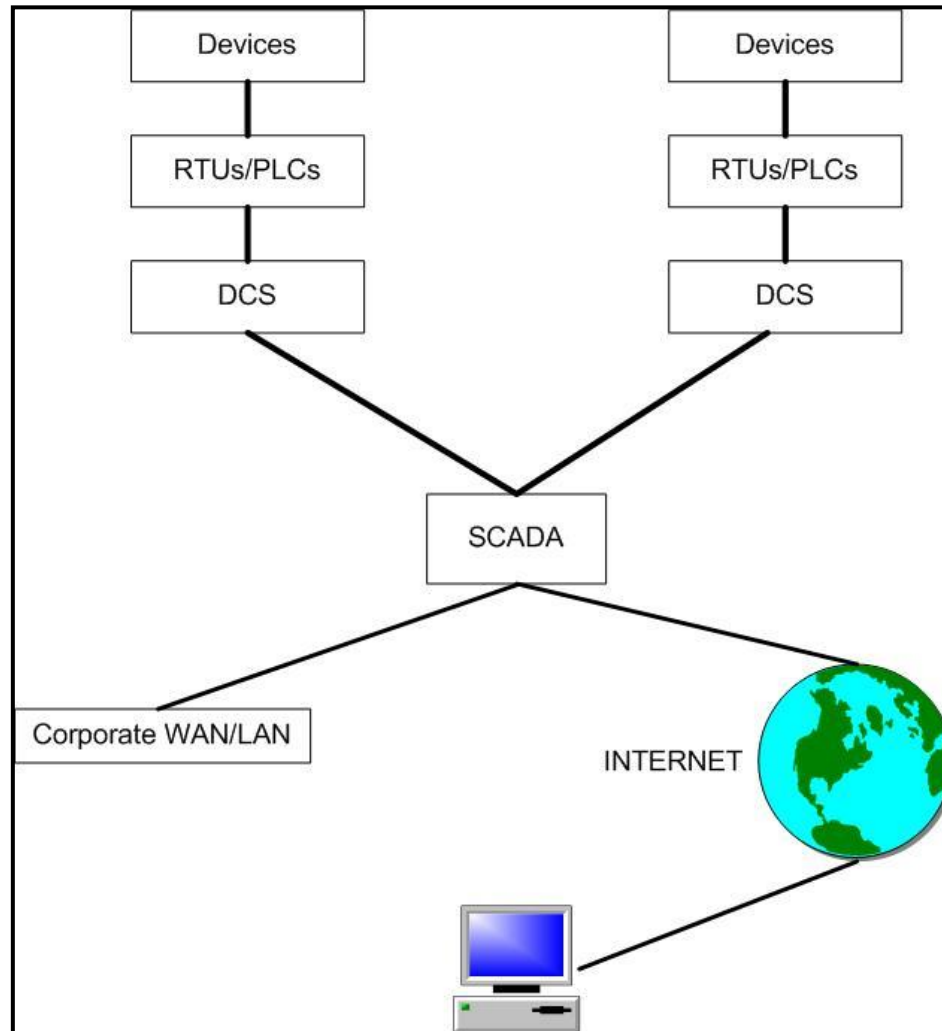
- Basic SCADA
 - One machine process
 - One RTU and MTU
- Integrated SCADA
 - Multiple RTUs
 - DCS
- Networked SCADA
 - Multiple SCADA

Basic SCADA



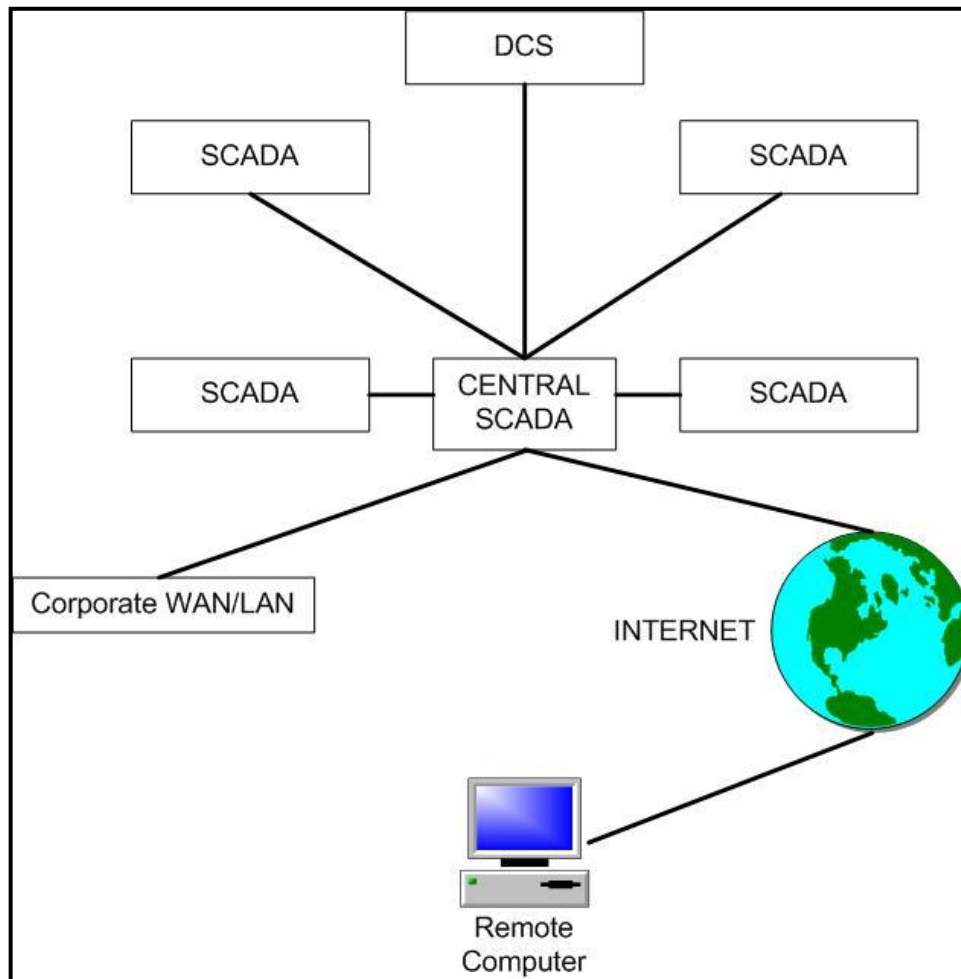
- ☐ Car manufacturing robot
- ☐ Room temperature control

Integrated SCADA



- ☐ Water systems
- ☐ Subway systems
- ☐ Security systems

Networked SCADA



- ☐ Power systems
- ☐ Communication systems



Where is SCADA used?

☐ Main SCADA applications:

- Water and Wastewater
- Power
- Oil and Gas
- Research facilities
- Transportation
- Security systems
- Siren systems
- Irrigation
- Communication control



Electric power generation, transmission and distribution: Electric utilities detect current flow and line voltage, to monitor the operation of circuit breakers, and to take sections of the power grid online or offline.



Manufacturing: manage parts inventories for just-in-time manufacturing, regulate industrial automation and robots, and monitor process and quality control.

Buildings, facilities and environments: Facility managers use SCADA to control HVAC, refrigeration units, lighting and entry systems.



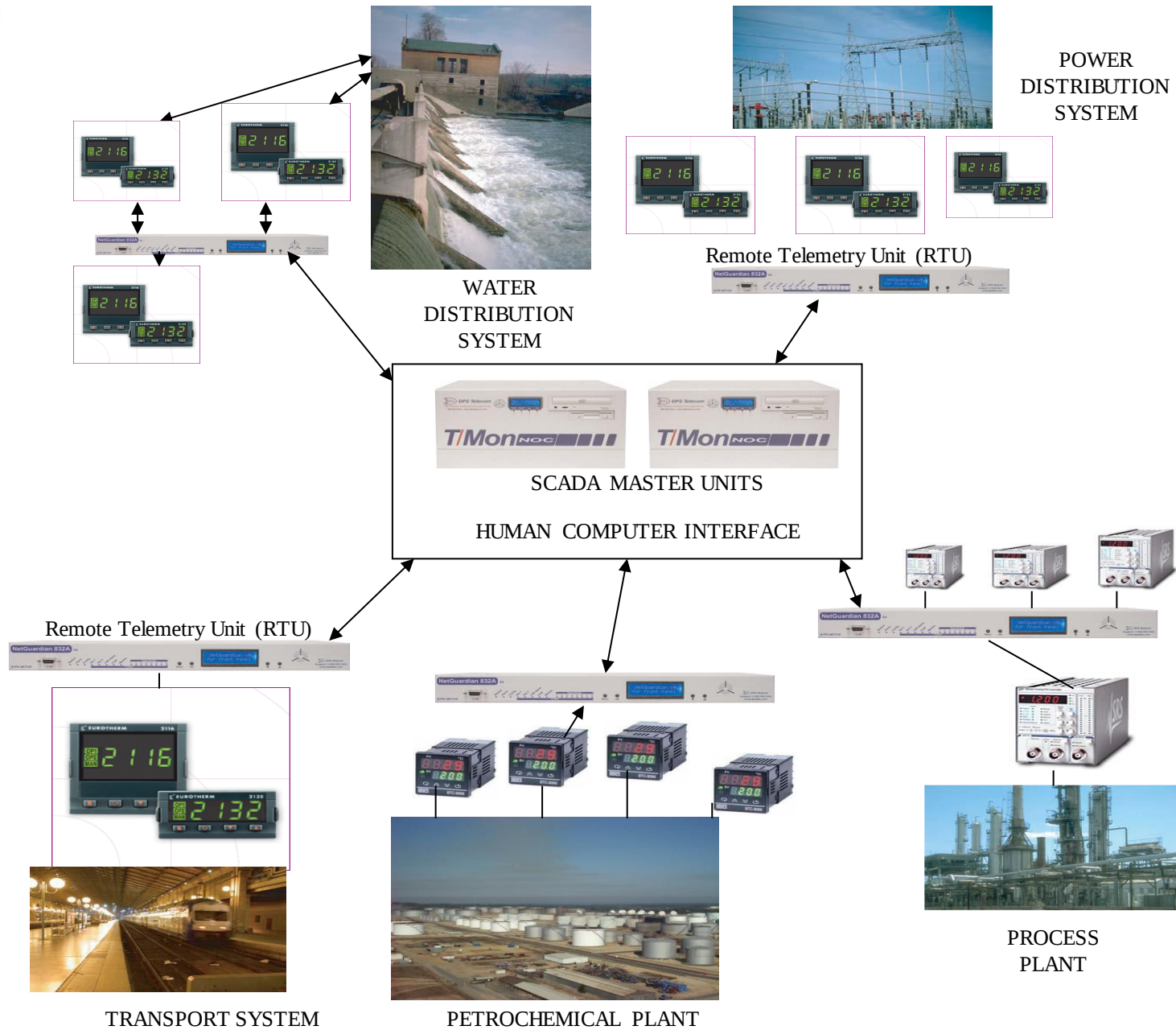
Mass transit: regulate electricity to subways, trams and trolley buses; to automate traffic signals for rail systems; to track and locate trains and buses; and to control railroad crossing gates.



Water and sewage: State and municipal water utilities use SCADA to monitor and regulate water flow, reservoir levels, pipe pressure and other factors.



Traffic signals: regulates traffic lights, controls traffic flow and detects out-of-order signals.

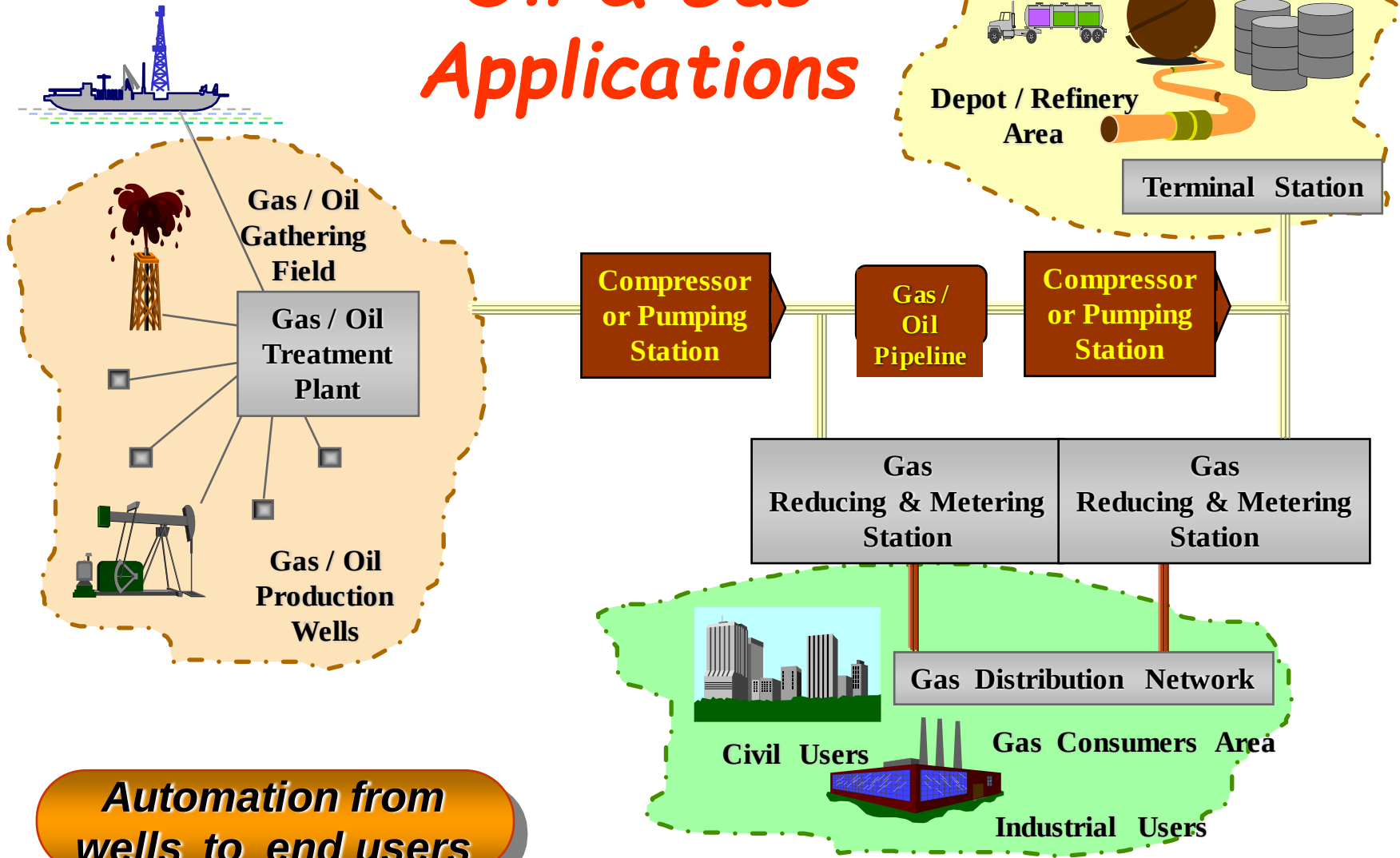




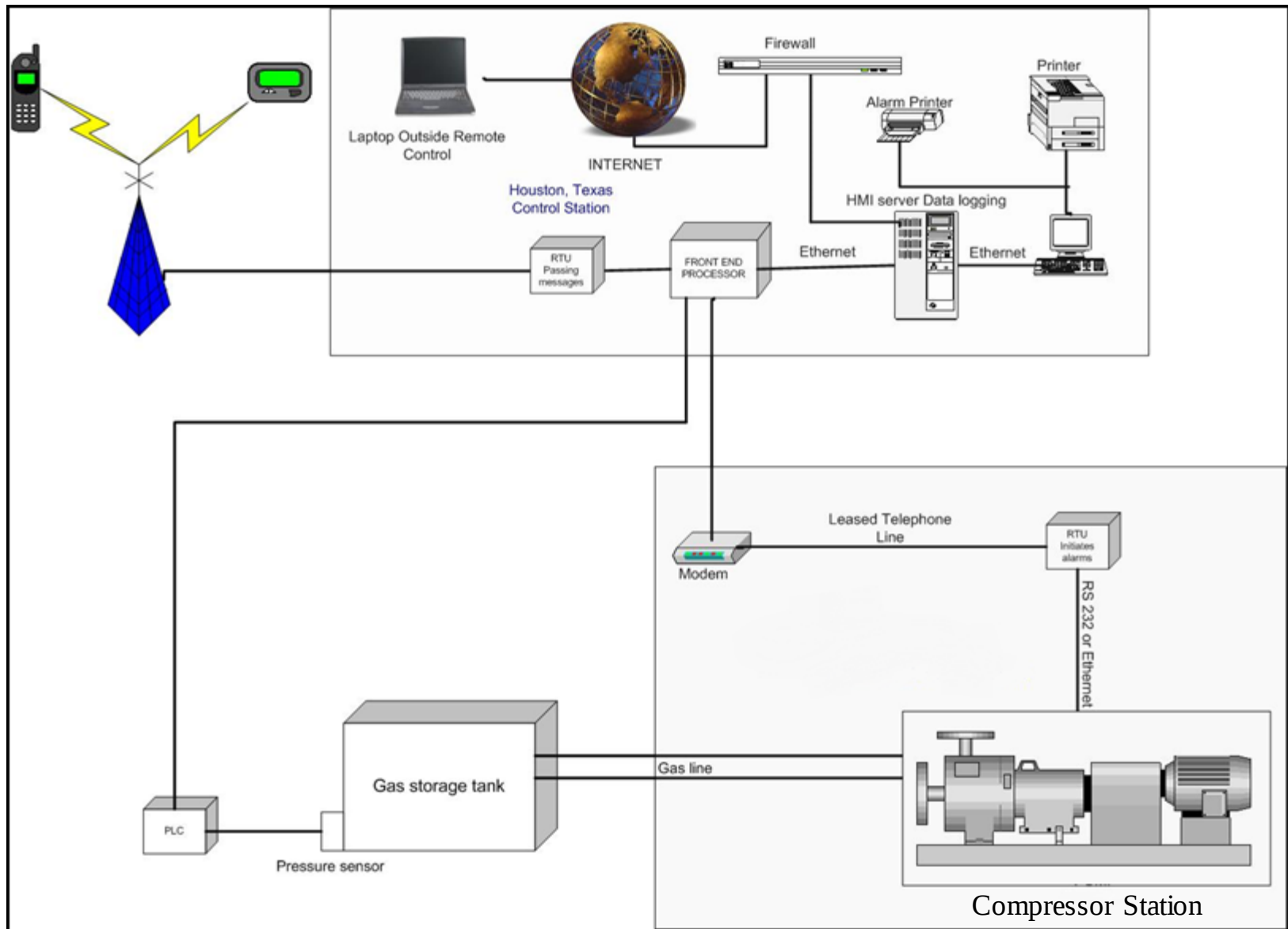
SCADA System Application Area:

- ❑ **OIL & GAS Production, Treatment, Gathering, Storage, Movement, Transportation, Pipelines and Distribution Networks**
- ❑ **OIL Tank Farms, Trucks Loading/Unloading facilities**
- ❑ **GAS Compressor & OIL Pumping Stations**
- ❑ **UTILITIES and Municipalities managing Water, Gas, Electric Power, Heating distribution Networks**
- ❑ **Drinkable WATER Purification & Transportation facilities, WASTEWATER Treatment plants, WATER Quality Monitoring**
- ❑ **INFORMATION Systems for Customers service, administration, General & Industrial Accounting, Inventory & Purchasing management in Utilities, Distribution Companies, Industry**
- ❑ **Electric POWER Industry: generation, transmission, EMS & DMS**

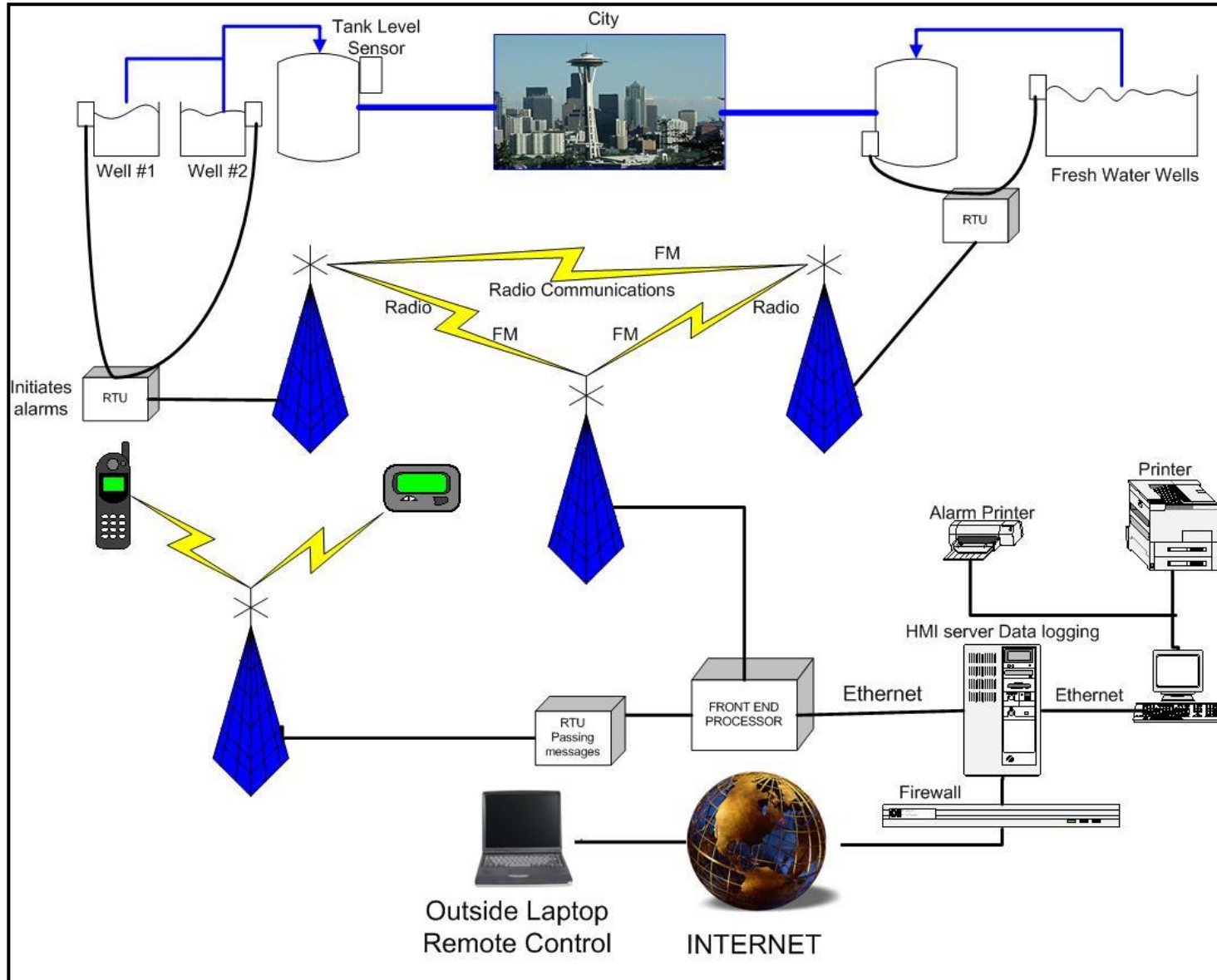
Oil & Gas Applications



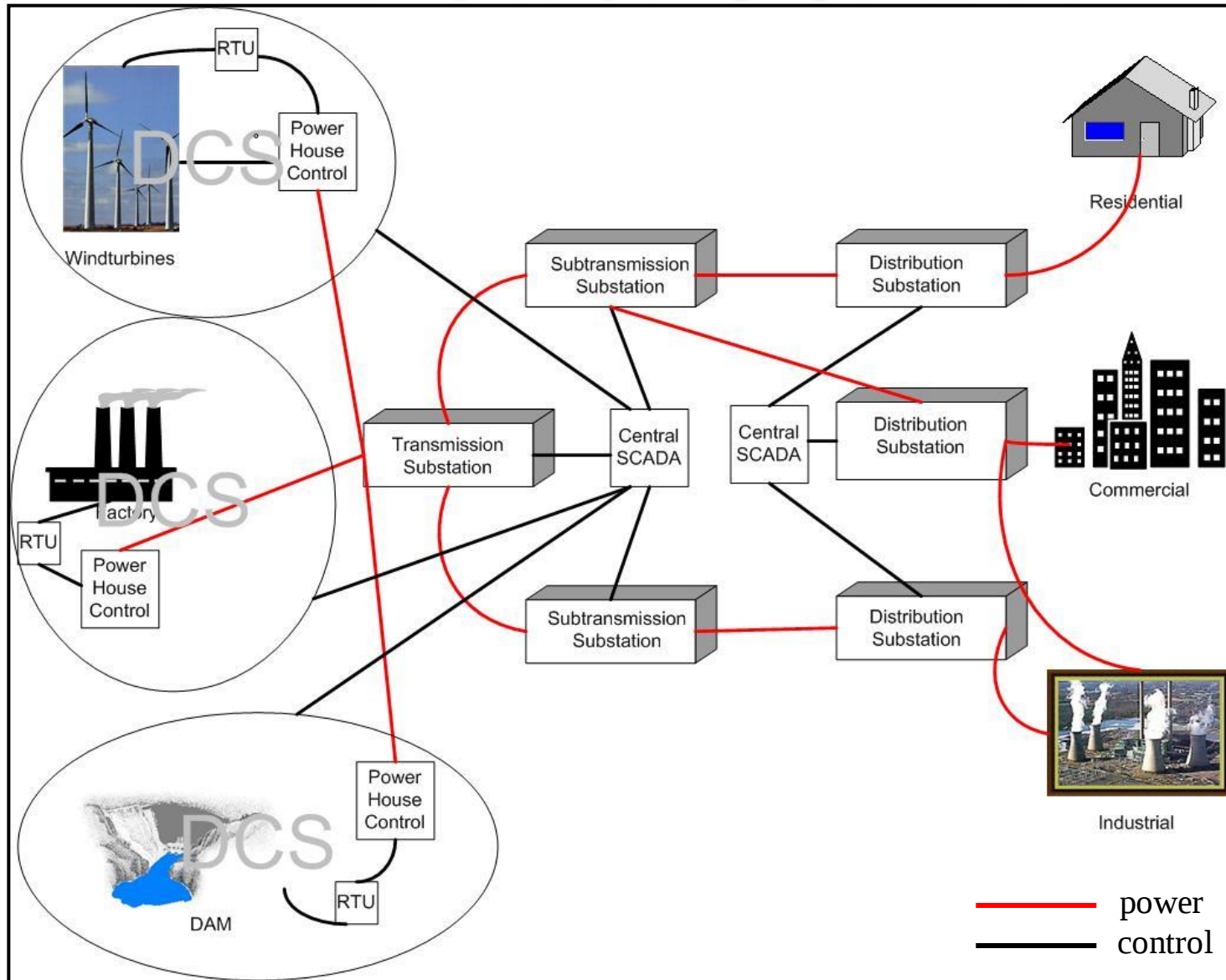
Gas SCADA



Water SCADA



Power SCADA





Automation Solutions

❑ SCADA system manufacturers

- Modular SCADA, UK
- MOSCAD, Motorola
- Rockwell Automation
- ABCO
- ABB
- Lantronix



SCADA Hardware

□ SCADA Hardware manufacturers

- Rockwell Allen Bradley
- General Electric (GE)
- Emerson
- Siemens
- Schneider Electric



SCADA Software

□ SCADA Software manufacturers

- Fix Intellution
- Iconics
- Wonderware (InTouch)
- Citect (CitectSCADA)
- National Instruments (Lookout SCADA)
- Cimplicity (GE Fanuc)
- Siemens WinCC



Summary

- ❑ SCADA is a *two-way system* : remote monitoring & controlling
- ❑ Applicable to widely distributed processes
- ❑ Two way communication system is required
- ❑ Basic Elements of SCADA :
 - *Master Terminal Unit (MTU)*
 - *Remote Terminal Unit (RTU)*
 - *Communications Equipment*