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WSN Applications

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WSN and its Application

Basic Application of WSN

- Basically, wireless sensor networks are used for the measurement or sensing of one or more variables **over an area.**

- A common architecture of the WSN-based system used for measurement/ sensing is shown in the next slide.

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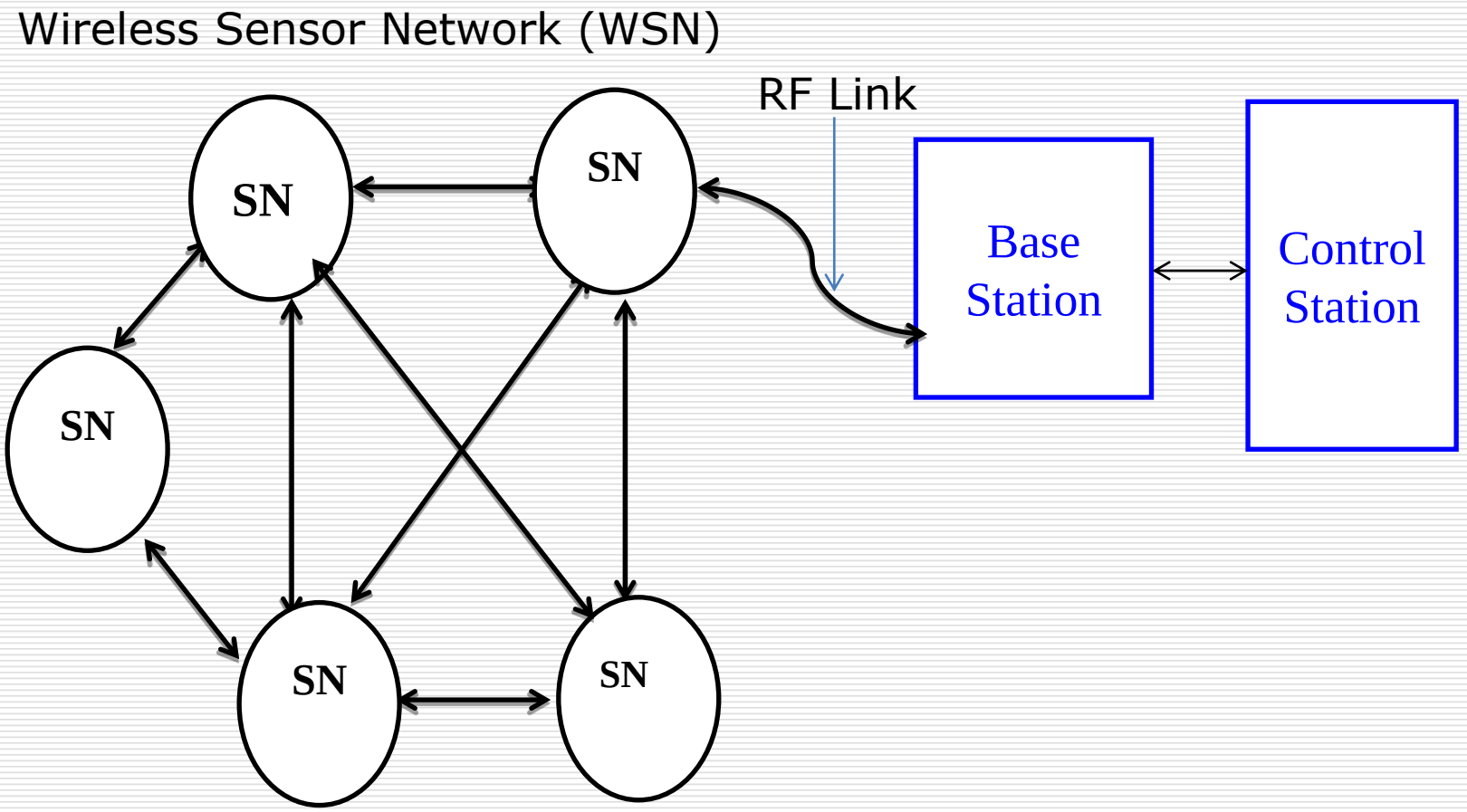
Architecture of WSN-Based Measurement/Sensing System



WSN-Based Measurement/Sensing System

- Each node in WSN is a wireless sensor node (WS node), labelled as SN in the figure.
- WSN uses a network protocol like Zigbee
- Base station has 3 roles to play:
  1. Network coordinator for the WSN
  2. Data collector for collecting data from nodes
  3. Gateway between WSN and control station.
- Communication between base-station and control-station will depend on the distance between them and the network available at the site. For example, it can be a USB, Bluetooth, direct radio link, WiFi network, Ethernet LAN or even the Internet.

Further Applications of WSN

- The basic measurement or sensing application can be extended for the following purposes:
  1. Spatial profiling of one or more variables **over an area**
  2. Temporal profiling of one or more variables at several points **in an area**
  3. Monitoring of one or more variables **over an area**
  4. Surveillance of **an area**

- Applications of WSN are still emerging as the technology is new and fast developing.

1.1 WSN-Based Structural-Health Monitoring

WSN-Based Structural Health Monitoring (1)

- Structural health monitoring (SHM) consists in making certain measurements periodically over a time and analyzing the measurement data continuously in real-time to monitor the health of a big concrete or steel structure.
- Types of structures monitored:
  - Large and wide structures, such as bridges, fly-overs, power station buildings, tunnels, etc.
  - Tall structures, such as tall buildings (sky-scrapers), chimneys of thermal power plants, transmission towers, TV towers, etc.
  - Specially, old structures of the above types.
- Purpose of SHM could be:
  - To evaluate degradation in the condition of the structure due to use and environmental effects, or
  - To assess the residual useful life of the structure, or
  - To identify the type and extent of damage to the structure due to an earth-quake, wind-storm, snow-storm etc.

WSN-Based Structural Health Monitoring (2)

- Monitoring has to be accurate and in real-time.
- SHM process consists of the following steps:
  1. Selection of Variables and Sensors
  2. WSN-Based System Installation
  3. Data Acquisition
  4. Data Collection and Transfer
  5. Data Processing
  6. Decision making

SHM Process

1. **Selection of Variables and Sensors:** Select the variables (health parameters) to be measured, sensors to be used, and number and locations of sensors.
2. **WSN-Based System Installation:** Set up a WSN-based system shown in slide#5.
3. **Data Acquisition**: Acquire data through sensors (embedded in or connected to WS nodes).
4. **Data Collection and Transfer**: Collect data from these nodes into Base Station and transfer the same to Control Station.
5. **Data Processing**: Carried out in Control Station (personal computer). Involves (a) Data normalization, (b) Data cleansing, (c) Data analysis for feature extraction (extraction of health features)
6. **Decision making:** As per the objective of the SHM.

Sensors and Instruments for SHM

- Sensors employed (either embedded in, or connected externally to, wireless sensor nodes):
  1. Accelerometers (for vibration measurements)
  2. Strain gauges
  3. Displacement transducers
  4. Anemometers (for wind speed and direction)
  5. Pressure sensors (for wind pressure measurement)
  6. Temperature sensors
  7. Humidity sensors

- Off-line instruments used:
  1. Level measuring station (for level measurements)
  2. Tilt measuring instrument
  3. Impact hammer (for measuring compressive strength of concrete)
  4. Ultrasonic crack detector (for concrete structures)
  5. Eddy-current crack detector (for steel structures)

1.2 WSN-Based Equipment-Health Monitoring

WSN-Based Equipment Health Monitoring (1)

- Equipment health monitoring (EHM) or machine condition monitoring (MCM) consists in making certain measurements periodically over a time and analyzing the measurement data continuously in real-time to monitor the health of large industrial equipment, specially large rotating machines.
- Purpose/Objective:
  - To evaluate degradation in the condition of the industrial equipment, or
  - To evaluate its condition for subjecting it to preventive maintenance, or
  - To assess its residual life, or
  - To identify the type and extent of damage to the equipment due to misuse, accident, or a disaster like earthquake, flood, fire, explosion, etc.

WSN-Based Equipment Health Monitoring (2)

- Monitoring has to be accurate and in real-time.
- EHM or MCM process consists of the following steps:
  1. Selection of Variables and Sensors
  2. WSN-Based System Installation
  3. Data Acquisition
  4. Data Collection and Transfer
  5. Data Processing
  6. Decision making

EHM or MCM Process

1. **Selection of Variables and Sensors:** Select the variables (health parameters) to be measured, sensors to be used, and number and locations of sensors. (Only a few sensors are needed per machine. Hence, the technique is generally used for a group of machines.)
2. **WSN-Based System Installation:** Set up a WSN-based system shown in slide#5.
3. **Data Acquisition**: Acquire data through sensors (embedded in or connected to WS nodes).
4. **Data Collection and Transfer**: Collect data from these nodes into Base Station and transfer the same to Control Station.
5. **Data Processing:** Carried out in Control Station (personal computer). Involves (a) Data normalization, (b) Data cleansing, (c) Data analysis for feature extraction (extraction of equipment health features)
6. **Decision Making:** As per the objective of the EHM/MCM.

Sensors and Instruments for EHM/MCM

- Sensors employed (either embedded in, or connected externally to, wireless sensor nodes):
  1. Vibration sensors (2-axis or 3-axis)
  2. Sound-level sensors
  3. Pressure sensors (for oil pressure measurement)
  4. Temperature sensors
  5. Voltage sensors
  6. Current sensors

- Off-line instruments used:
  1. Tilt measuring instrument
  2. Vibration analyzer

1.3 WSN-Based Environment Monitoring

WSN-Based Environment Monitoring (1)

- Environment monitoring (EM) consists in measuring environmental parameters of interest periodically and analyzing the measurement data continuously in real-time to monitor the changes in the **natural environment of a certain area.**

- Purpose/Objective:
  - To assess environmental conditions and trends of variation of specific environmental parameters, or
  - To assess the quality of the environment in a certain area, or
  - To assess harmful effects of certain human activities on the natural environment in a certain area.

WSN-Based Environment Monitoring (2)

Types of Environment Monitoring, for which WSN-based solution is applicable:

(a) **Air-pollution monitoring:**

- Use WSN-based system shown in slide#5
- Monitoring process similar to that used for structural health monitoring.
- Sensors used in WS Node:
  - GPS sensor to find location of the WS node
  - Gas sensors for pollutant gases (carbon dioxide and carbon monoxide)

(b) **Sound-pollution monitoring:**

- Use WSN-based system shown in slide#5
- Monitoring process similar to that used for structural health monitoring.
- Sensors used in WS Node:
  - GPS sensor to find location of the WS node
  - Sound sensors (microphones).

WSN-Based Environment Monitoring (3)

Types of Environment Monitoring, for which WSN-based solution is not applicable:

(a) **Soil-pollution monitoring:**
WSN-based solution is not applicable because monitoring of soil requires collection of soil samples and testing them in laboratory.

(b) **Water-pollution monitoring:**
WSN-based solution is not applicable because monitoring of water bodies (like lakes and rivers) requires collection of water samples and testing them in laboratory.

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Sensor and Actuator Network (SAN)

Sensor and Actuator Network (SAN)

- A SAN contains both sensor and actuator nodes in the network.
- These nodes can be wireless or wired, and accordingly, they can communicate on either a wireless network or a wired network, respectively.

- **Sensor Node:** It uses one or more sensors for measuring or sensing certain variables.
- **Actuator Node:** It uses one or more actuators for delivering control signals to control certain variables.

Sensor and Actuator Nodes

- **Sensor Node** has at least three basic capabilities achieved through appropriate hardware components and software:
  1. One or more sensors, which may be embedded inside the node or connected from outside.
  2. A data processor (microprocessor or micro-controller) for (a) processing the data acquired through sensors and (b) network communications.
  3. Transmitter and receiver for communication.

- **Actuator Node** has at least three basic capabilities achieved through appropriate hardware components and software:
  1. One or more actuators or control devices
  2. A data processor (microprocessor or micro-controller) for (a) processing the received data and (b) network communications.
  3. Transmitter and receiver for communication.

Applications of SAN

- SANs are generally applied for the following purposes:
  1. Monitoring and control of one or more variables in an area
  2. Monitoring and protection of an area
  3. Industrial automation

- Applications of SANs are still emerging as the technology is new and fast developing.

Types of SAN

- A SAN can be either a homogeneous network or a heterogeneous network.
- A homogeneous SAN, in turn, can be either a wireless SAN (WSAN) or a wired SAN (referred to just as SAN).

- Thus, SANs can be of the following three types:
  1. **WSAN** : Homogeneous wireless sensor and actuator network
  2. **Wired SAN** : Homogeneous wired sensor and actuator network
  3. **HSAN** : Heterogeneous sensor and actuator network comprising a wireless sensor network (WSN) and a wired actuator network.

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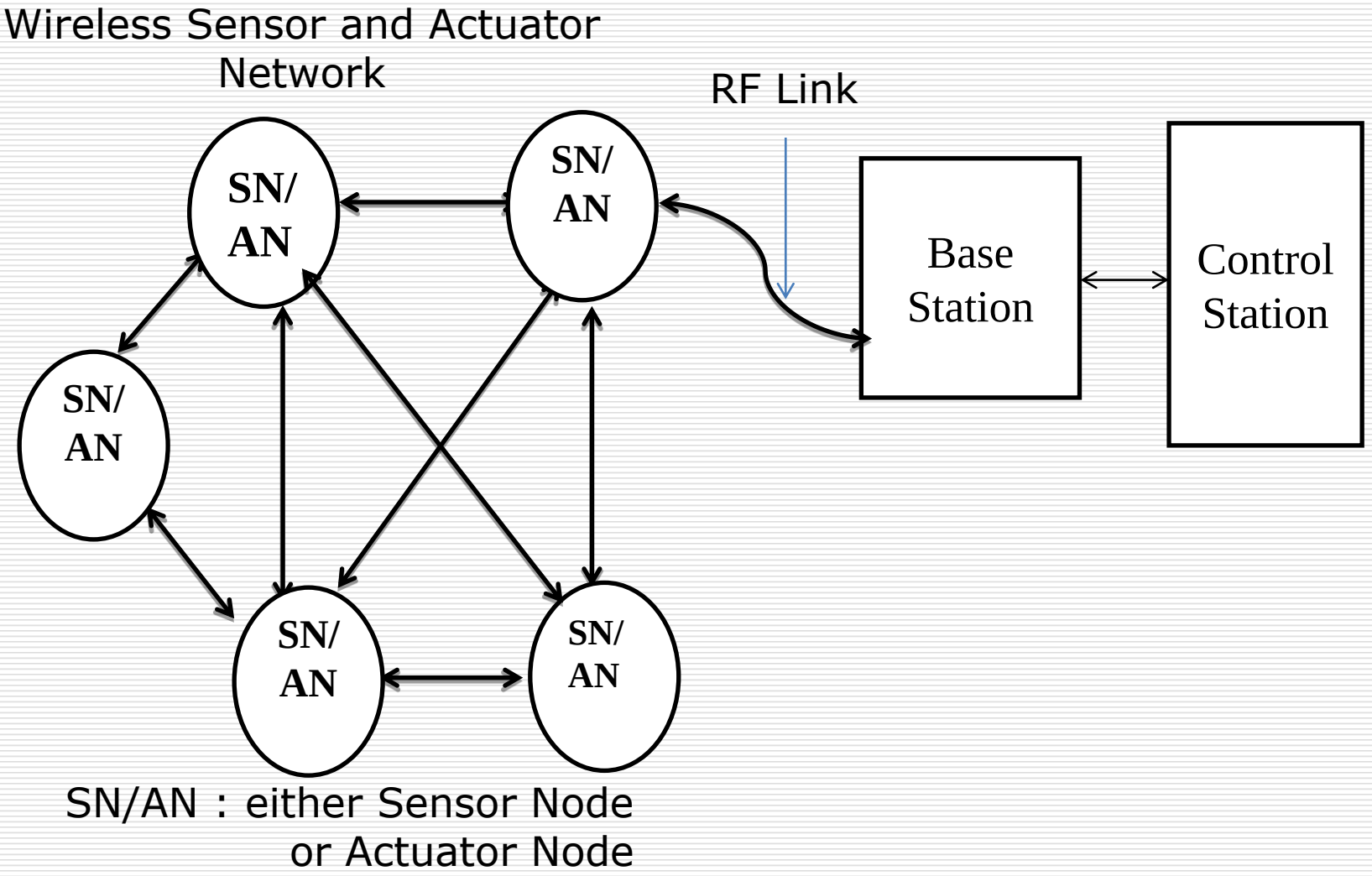
Wireless SAN and its Application

Architecture of WSAN-Based Monitoring & Control System



WSAN-Based Monitoring & Control System

- WSAN is a single wireless LAN of sensor and actuator nodes and can be considered an extension of WSN.
- Each node in the network can be either a sensor node (SN) or an actuator node (AN), as shown in figure
- WSAN uses a network protocol like Zigbee, which is very common for WSNs.
- Base station has 4 roles to play:
  1. Network coordinator for the WSAN
  2. Data collection from SNs
  3. Data delivery to ANs
  4. Gateway between WSAN and control-station.
- **Advantages:** WSAN offers all the advantages of WSN as far as sensors are concerned.
- **Drawback:** WSAN has serious drawback for actuators, which almost always need large operating power and are rarely battery driven.

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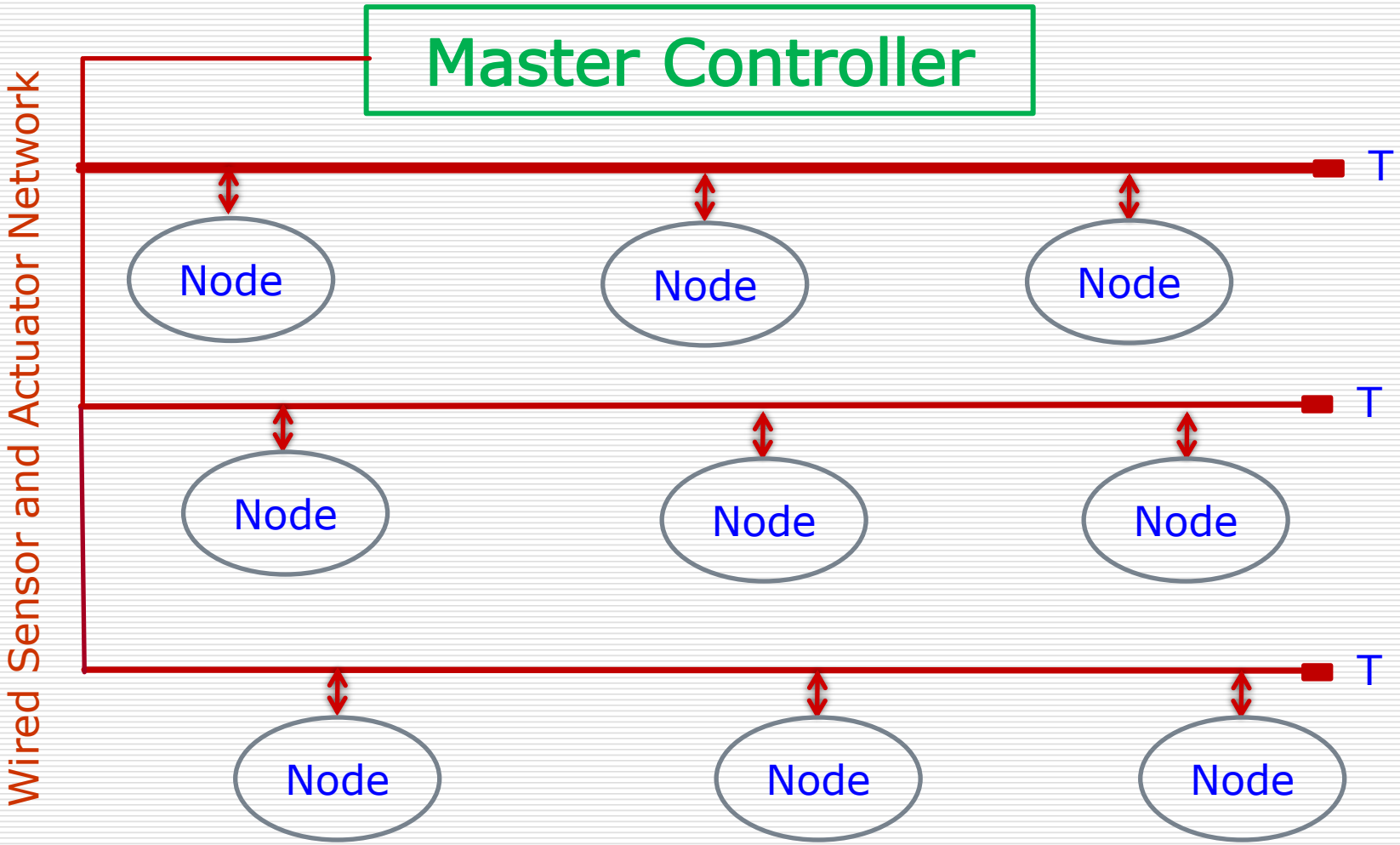
Wired SAN and its Application

Architecture of SAN-Based Monitoring and Control System



Each Node is either a 'Measuring Instrument' or a 'Control Unit'

SAN-Based Monitoring and Control System

- Wired SAN is a single wired LAN of sensors and actuators.
- Each node of the network in the diagram can be:
  - either a 'measuring instrument' incorporating a data processor and a suitable communication port,
  - or a 'control unit' (ranging from an on-off switch to a PID controller) incorporating a data processor and a suitable communication port.
- SAN topology is generally a tree, or sometimes a bus.
- SAN uses a network protocol like RS485/Modbus or Foundation Fieldbus (FF).
- MAC protocol is generally 'master-slave protocol', in which the 'master controller' acts as the master and all other nodes as slaves.

Advantages and Drawbacks of SAN-Based Monitoring and Control System

- **Advantage:** SAN has the advantage for the control units which need large operating power and need to be wired for that reason.

- **Drawback:** It cannot be used where instruments or control units are located at inaccessible or difficult-to-access places, or they are mobile.

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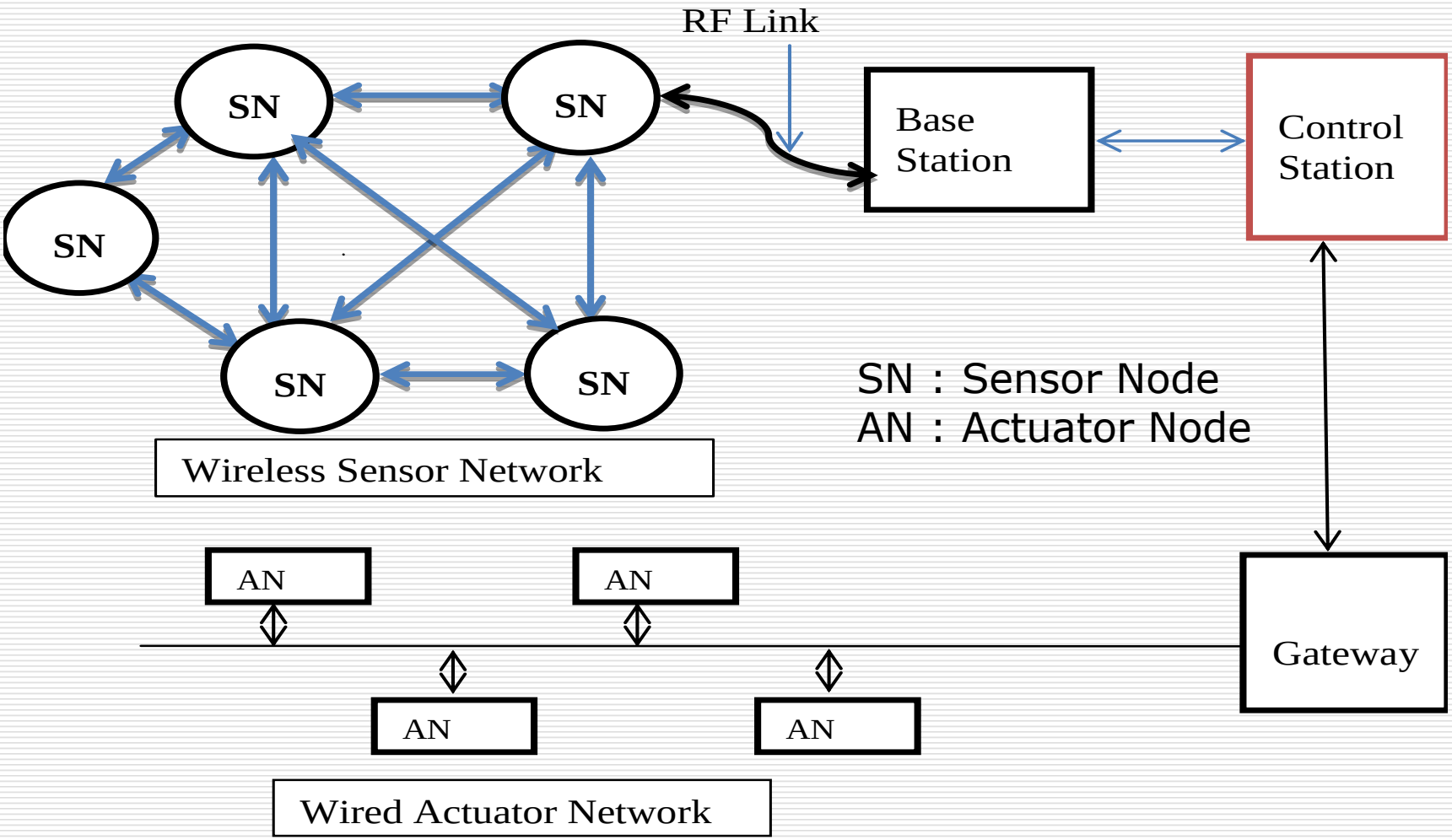
Hybrid SAN and its Application

Architecture of HSAN-Based Monitoring and Control System



HSAN-Based Monitoring and Control System

- HSAN is a combination of a wireless sensor network (WSN) and a wired actuator network.
- The WSN uses a network protocol like Zigbee
- Base station has 3 roles to play:
  1. Network coordinator for the WSN
  2. Data collector for collecting data from WS nodes
  3. Gateway between WSN and control station.
- The wired actuator network uses a protocol like RS485/Modbus or Foundation Fieldbus (FF).
- Gateway handles communication between the wired actuator network on one side and the control station on the other side.
- HSAN combines the advantages of WSN for sensors and those of wired actuator networks for actuators.

5.1 HSAN-Based Monitoring and Control of Greenhouse

HSAN-Based Monitoring & Control of Greenhouse (1)

- A **greenhouse** is a specially designed closed farm-structure built to provide a favourable climate for improving crop production and crop protection.
- An **intelligent greenhouse (IGH)** can collect the information related to the various climatic parameters inside the greenhouse, which affect the production of the crops inside and can control the greenhouse climate (called as micro-climate) automatically to optimum level based on the collected information.
- Selected climatic parameters are measured with the help of suitable **sensors** and controlled with the help of **actuators** and **control systems.**

HSAN-Based Monitoring & Control of Greenhouse (2)

- HSAN-based system shown in slide#35 can be used for monitoring and controlling micro-climatic parameters inside a greenhouse, thereby making it an IGH.
- HSAN comprises a wireless sensor network (WSN) and a wired actuator network.
- The best **network protocol for the WSN** is Zigbee.
- **Base station** has 3 roles to play:
  1. Network coordinator for the WSN
  2. Data collector for collecting data from WS nodes
  3. Gateway between WSN and control station.
- The wired actuator network uses a protocol like RS485/Modbus or Foundation Fieldbus (FF).
- **Gateway** handles communication between the wired actuator network on one side and the control station on the other side.

Micro-climatic Parameters Monitored and Controlled

Essential micro-climatic parameters to be monitored and controlled in the greenhouse:

1. **Air temperature**: Every crop needs a certain temperature for its optimal growth.
2. **Humidity**: The best relative humidity range for disease-free growth of plants is 50% to 70%.
3. **Photosynthetic Active Radiation (PAR):** About 10 to 12 hours of good light is required for optimal growth. The need for light increases to approximately 16 hours when the plants are producing flowers or fruits.
4. **Soil Moisture**: Soil moisture needs to be maintained within a certain range for each plant species.
5. **Soil Temperature:** Soil temperature also plays a major role in plant growth and should be maintained within the correct range for each plant species.

Control Systems

Control systems for essential parameters:

1. **Air heaters:** To control air temperature during winters.
2. **Air Coolers:** To control air temperature during summers.
3. **Wet Pads and Blowers**: For control of humidity.
4. **Artificial Lights:** For extending the exposure of plants to light.
5. **Drip Irrigation:** To control soil moisture while saving water.
6. **Soil Heaters:** To control soil temperature.

Additional Parameters Monitored and Controlled

Additional parameters to be monitored and controlled:

a) **Carbon Dioxide Concentration**: During the photosynthesis process, the plant converts the CO2, water and light into glucose and oxygen. During the summer, the greenhouse gets the CO2 it needs from the natural air itself when ventilation and roof window are open. In winters growers can use burners to increase the CO2 level if required.

b) **Micronutrient Level in Soil**: Soil micronutrients include Nitrogen (N), Phosphorus (P) and Potassium (K). These micronutrients are very essential for the growth of plants. The excessive use of these macronutrients will result in contamination of the surface of the earth and ground-water. So, the application of fertilizers should be optimized.

Monitoring & Control Process

1. **Data Acquisition**: Outputs of sensors are acquired in the sensor nodes of WSN as data.
2. **Data Collection and Transfer**: Collect data from the sensor nodes into Base Station and transfer the same to Control Station.
3. **Data Processing**: The collected data is processed in Control Station (personal computer). It involves (a) Data normalization, (b) Data cleansing, and (c) Data analysis to obtain running average values of various parameters in the greenhouse.
4. **Generate control commands** in Control Station for various control systems (such as switch on or off heaters, increase or decrease dripping rate of water, raise or lower temperature setting of air cooler).
5. **Send control commands** to the actuators.
6. **Actuators act** on respective control systems.

6

Emerging Applications of WSN

Emerging Applications of WSN

i. Precision Agriculture
ii. Smart Traffic Control
iii. Security and Surveillance
iv. Asset and Warehouse Management
v. Disaster Mitigation
vi. Habitat Monitoring
vii. Medicine & Health Care

Precision Agriculture

- Objective:

  Maximum yield with minimum damage to ecology

- Activities:
  - Soil mapping (mapping of soil moisture and composition) and environment mapping (mapping of spatial and temporal variations of ambient temperature and relative humidity) to help taking decision on selection of crop patterns
  - Real time data acquisition on temperature, relative humidity and soil moisture to control irrigation, delivery of fertilizer and pest control etc.
- Sensors:
  - Air temperature and humidity
  - Soil moisture and composition

Smart Traffic Control

- Purpose:
  - Collection of real-time traffic information for traffic management
  - Optimization of routes to reduce congestion
  - Accident prevention by avoiding collision
- Approach:
  - Vehicle-to-vehicle communication
  - Communication between vehicle and road side infrastructure
- Sensors:
  - Sensors on vehicles for tyre pressure, speed, ambient temperature, pollution, etc.
  - Sensors on road-side for vehicle counting, speed, pollution, etc.

Security and Surveillance

- Security monitoring and surveillance of
  a) Buildings
  b) Airports
  c) Subways
  d) Power installations (plants & switchyards)
  e) Gas & oil installations
  f) Other large industrial installations

- Sensors:
  - ***Ranging from*** low-cost motion sensors, acoustic sensors & PIR sensors
  - ***to*** expensive imaging systems.

Asset Management

- Purpose:
  - For managing assets of an industry
  - For real-time inventory control
  - To monitor location, movement and condition of movable assets (like trucks and lorries) to improve their utilization
- Approach:
  - Real time information of assets / goods / stores is collected into a central computer from offices or from field
- Sensors:

  Tracking sensors ranging from Passive RF Identification (RFID) tags (RFID readers: stationary & movable) to GPS-equipped locators

Disaster Mitigation

1. Wild-Fire
   - For detection & alarm
   - Sensors produce a "temperature–map" collectively
   - Temperature map is used to decide fire fighting strategy

2. Accidents in Chemical Plants
   - For detection and alarm
   - Sensors used: Gas, Smoke, Temperature, Pressure, Liquid level

3. Earthquakes
   - To sense the safety of a building before entering it after an earthquake
   - To sense the presence of victims inside a building after an earthquake.

Habitat Monitoring

- Monitoring the movement of wild animals with the objective of minimizing disturbance to them by human beings.
- Monitoring the movement of migratory birds with the objective of creating favourable conditions for their migration.
- Biodiversity mapping: Mapping of animals, birds and plants

Medicine & Health Care

- Patient tracking system
- Doctor tracking system
- Post-operative and intensive care
- Surveillance of elderly patients (and other similar patients)
- Automatic drug administration