## Wireless Sensor Networks (WSN)

- a networking paradigm that makes use of spatially distributed sensors for gathering information concerning the immediate environment of the sensors and collecting the information centrally.

- the sensors are not standalone devices but a combination of sensors, processors, and radio units referred to as sensor nodes sensing the environment and communicating the sensed data wirelessly to a remote location, which may or may not be connected to a backbone network.

## Domains of implementation

**Wireless Multimedia Sensor Networks (WMSN):**

- Has ability to retrieve videos, audios, images, or all three in addition to regular scalar sensor readings. The sensing range and coverage area of a camera based WMSN are defined by the field of view (FOV) of the constituent cameras.
- Because of their superlative capabilities, WMSNs are popularly sought after in critical domains such as surveillance and road traffic monitoring.
- However, due to the use of multimedia sensors, the power and processing requirements of this class of WSNs are very high as compared to the other classes of WSNs. Additionally, WMSNs typically demand high network bandwidths for convenient operation.

**Underwater Sensor Networks (UWSN):**

- work in underwater environments.
- Compared to terrestrial or aerial environments, wireless underwater communications are severely restricted in terms of data rate, range, and bandwidth due to the high underwater attenuation of electromagnetic signals. The reliable use of light based underwater communication is also limited in terms of range and noise. The most accepted global means of underwater communication is by acoustic waves.
- However, the long propagation delays and uneven data rate makes it necessary to develop newer topologies and architectures, which can work under the conditions of severe limitations of the physical layer.

## Domains of implementation

**Wireless Underground Sensor Networks (WUSN):**

- designed to be deployed entirely underground.
- The underground environment poses challenges of attenuation due to the rocks and minerals in the soil.
- Another significant problem associated with this class is the need for digging up of the nodes to replenish their energy sources.
- Typical usage scenarios of this class of WSNs are underground mines and monitoring of underground plumbing systems. WUSNs need denser deployment architectures owing to the limited range of wireless communication in underground environments.

**Wireless Mobile Sensor Networks (MSN):**

- This class of WSNs is characterized by its mobility and low power requirements.
- The sensor nodes are mobile, which requires them to rapidly connect to networks, disconnect from them, and then again connect to new networks until the nodes are mobile.
- Typical examples of MSNs include smartphone networks, wearable, vehicular networks, and others.

-**find out few challenges**

## Features/Functionalities of CPS: (3C)

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**1. Computation**

Computation refers to the data processing and decision-making capabilities of CPS using embedded systems, microcontrollers, or edge/cloud computing.

- IoT devices collect raw data from sensors.
- The system processes this data locally (on the device/edge) or remotely (on the cloud).
- The processed results are used to make intelligent decisions.

**Example:**

- A DHT11 sensor measures temperature and humidity.
- Raspberry Pi computes whether the room is too hot or humid.
- Based on thresholds, the system decides to turn on a fan or air conditioner.

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**2. Communication**

Communication refers to the exchange of information between CPS components, IoT devices, servers, and users.

- IoT devices send data to other devices, gateways, or cloud platforms.
- Communication happens using wired (UART, SPI, I2C) or wireless (Wi-Fi, Bluetooth, ZigBee, LoRa, MQTT, HTTP) technologies.

**Example:**

- The Raspberry Pi collects DHT11 sensor data.
- It uploads the temperature and humidity values to a cloud server like AWS, Firebase, or Thingspeak.
- A mobile app or dashboard displays real-time data to the user.

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**3. Control**

Control refers to automated actions taken based on the computed data and communicated results.

- After analyzing data, CPS controls actuators or other systems to achieve a desired outcome.
- This can be done locally (edge control) or remotely (cloud-based control).

**Example:**

- If the DHT11 sensor detects temperature > 35°C,<br>→ Raspberry Pi sends a signal to turn on the cooling fan.
- Similarly, an ultrasonic sensor can detect object distance and trigger an alarm when someone comes close.

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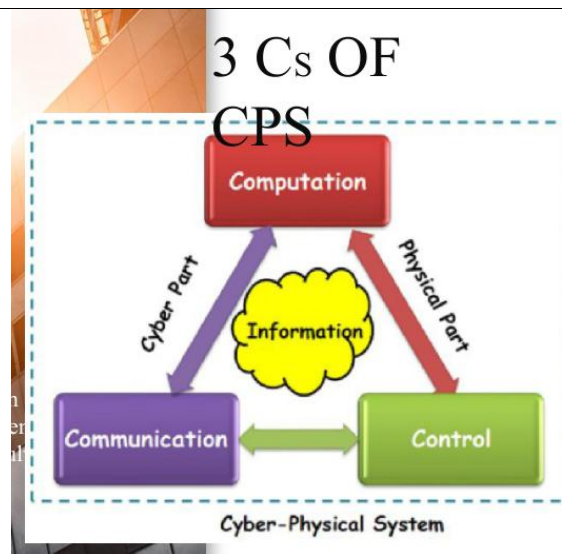


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## Architectural Components of CPS

- **Connection:** The sensed data from the base of the architecture should be accurate and reliable enough to actuate effectual feedback for the whole system. The sensed data from various sensor units should be collected in a hassle free and organized manner. The best possible solution is the use of tether-free communication systems, which should be able to support plug-and-play features of these sensing units
- **Conversion:** The collected data should be converted to a standard unified format. Post data standardization, usable information must be extracted from the sensed data. Data from various sensor types and sources need to be correlated to generate practical information from vastly multi-dimensional data. This data can be used to predict changes to the monitored environments, machinery malfunctions, and failures.

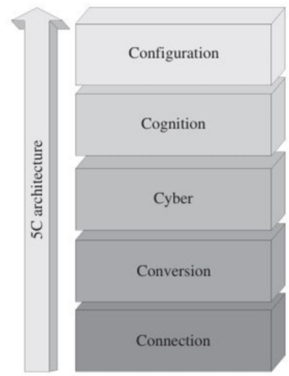


**Figure 3.11** The 5C architecture for CPS

- **Cyber:** This acts as the central nodal point of data collection and the holistic analysis of the system under control of the CPS. Data from various machine networks, environments, systems, and processes arrive at this point. Detailed and advanced analytics on the obtained data is performed to gather statistical trends. These trends can be used to predict the future behavior of machine systems and processes. The prediction can be based on digital twins of the actual systems, comparative performance of a machine with other machines, and temporal and regression results of machine health and performance.
- **Cognition:** This level is mainly responsible for the amalgamation of the collective health of the running systems and processes. The information is presented in the form of human-readable visualizations and trends. This helps in prioritizing actions and control of processes and systems under the purview of the CPS.
- **Configuration:** This stage is responsible for generating feedback for adjusting the environment being controlled. The feedback systems need to be highly adaptive, self-configuring, and resilient for effective control of the system as a whole

Architectural components also known as 5C..!!!!!