Course Name:
IoT & Applications (18EI2T09)

Class-1

Module-2: **IoT Strategies-** Networking, Communication, Adaptive & Event Driven Processes, Virtual Sensors, Security, Privacy & Trust, Low power communication, Energy harvesting, IoT related standardization;

IoT Protocols: MQTT, CoAP, AMQP, JMS, DDS, REST, XMPP.

Topics:

- Networking technologies
  - 5G and its features
- Communication technology
- Virtual Sensors
- Processes: Adaptive and Event Driven Processes

• Networking Technology

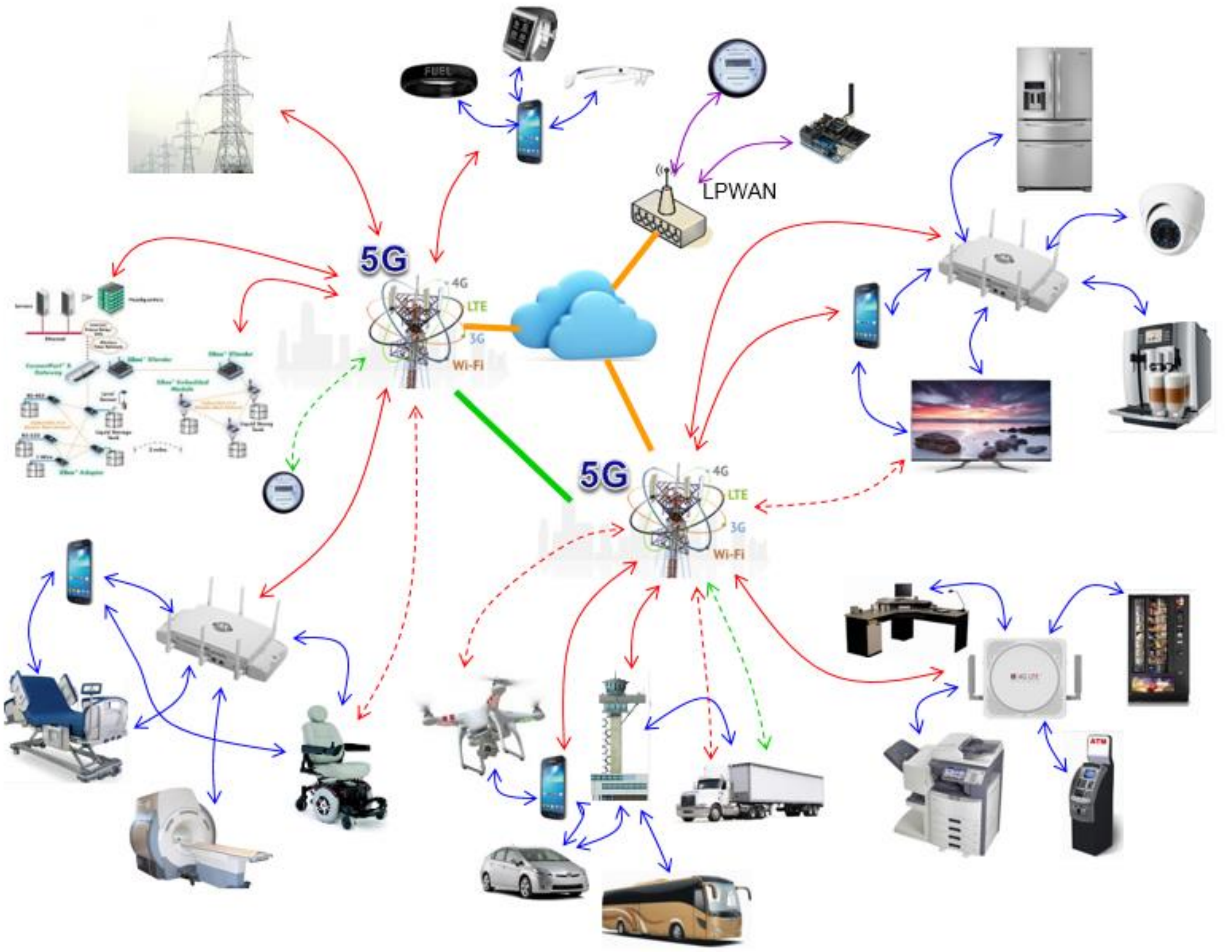
- Mobile traffic today is driven by **predictable** activities such as making calls, receiving email, surfing the web, and watching videos.
- Over the next 5 to 10 years, billions of IoT devices with **less predictable traffic patterns will join the network, including vehicles, machine-to-machine (M2M) modules, video surveillance that requires all the time bandwidth, or different types of sensors** that send out tiny bits of data each day.

How 5G will help future IoT Implementations?

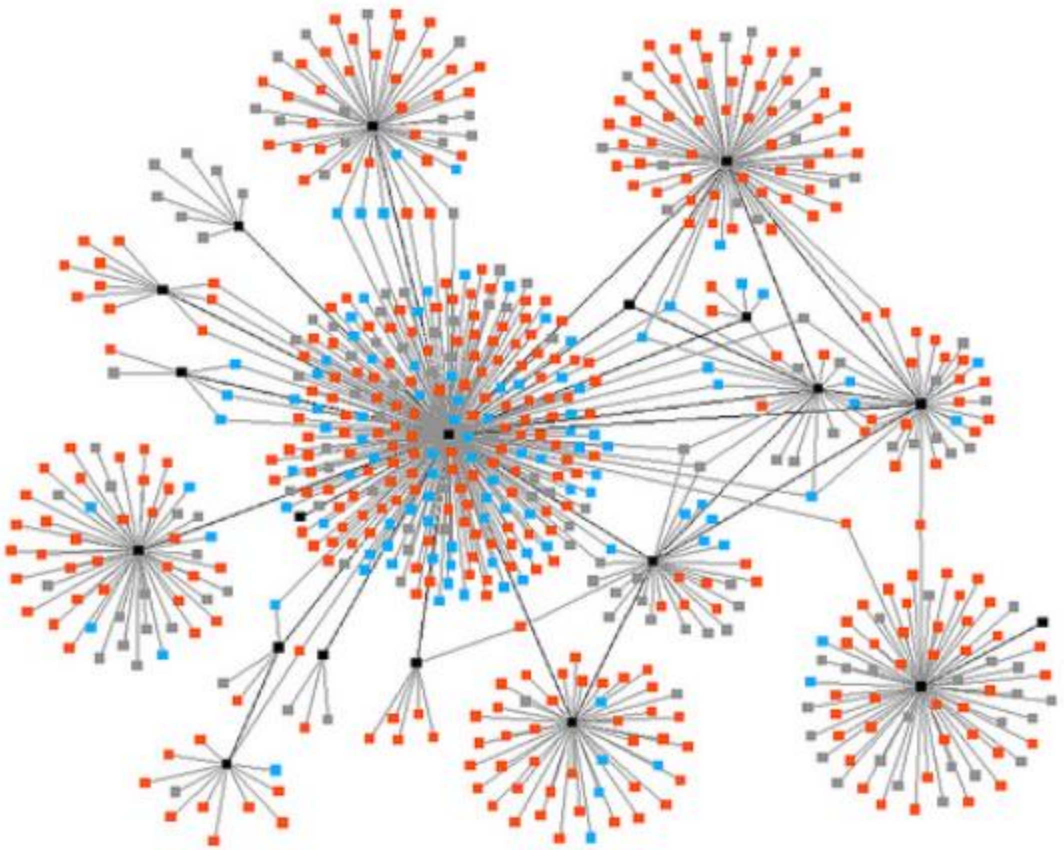
1. The **rise of cloud computing requires** new network strategies for **fifth evolution of mobile the 5G**, which represents clearly a convergence of network access technologies.
2. The architecture of such network has to integrate the needs for IoT applications and to offer seamless integration. To make the IoT and M2M communication possible **there is a need for fast, high-capacity networks**.
3. 5G networks will deliver 1,000 to 5,000 times more capacity than 3G and 4G networks today and will be made up of cells that support peak rates of between 10 and 100Gbps.

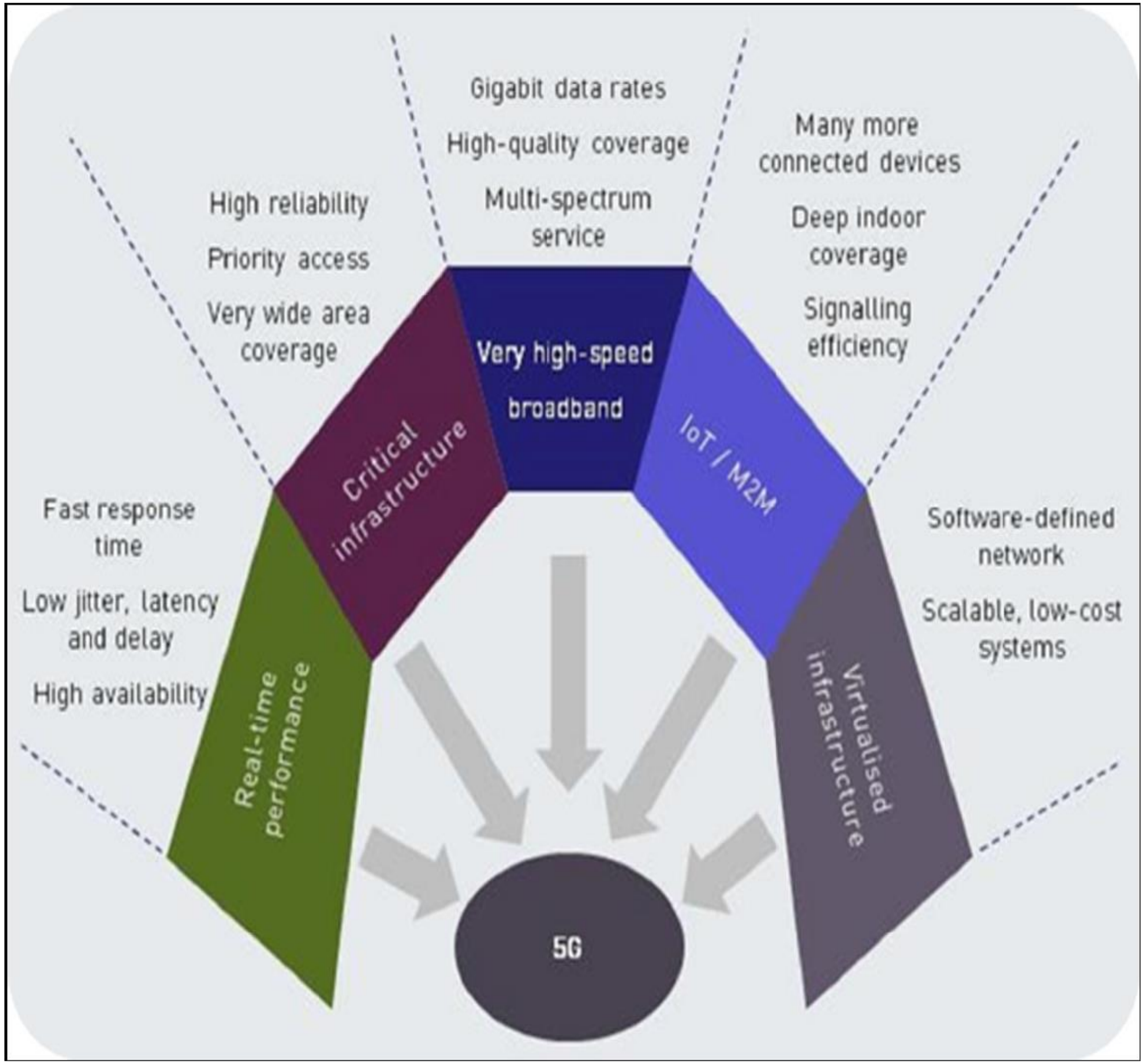
How 5G will help future IoT Implementations?

4. They need to be ultra-low latency, meaning **it will take data 1–10 milliseconds** to get from one designated point to another, compared to 40–60 milliseconds today.
5. **Another goal is to separate communications infrastructure and allow mobile users to move seamlessly between 5G, 4G, and WiFi**, which will be fully integrated with the cellular network.
6. Networks will also increasingly become programmable, **allowing operators to make changes to the network virtually, without touching the physical infrastructure**.


5G
4G
LTE
3G
Wi-Fi
LPWAN
5G
4G
LTE
3G
Wi-Fi

Features of 5G Communication





Features of 5G Communication

5G communication technology offers several advanced features that significantly enhance wireless connectivity. Key features include:

- **Ultra-Fast Speeds** – 5G provides data rates up to 10 Gbps, significantly faster than 4G LTE.
- **Low Latency** – 5G reduces latency to as low as 1 ms, enabling real-time applications like remote surgery and autonomous vehicles.
- **Massive Device Connectivity** – Supports up to 1 million devices per square kilometer, ideal for IoT ecosystems.
- **Higher Bandwidth** – Utilizes a broader spectrum, including mmWave (24–100 GHz), providing higher data throughput.
- **Network Slicing** – Allows multiple virtual networks within a single physical network, optimizing resources for different applications.

Features of 5G Communication - Cont…

- **Improved Energy Efficiency** – Reduces power consumption per bit, enhancing battery life for connected devices.
- **Enhanced Mobility** – Supports speeds up to 500 km/h, ensuring seamless connectivity in high-speed environments.
- **Better Spectrum Efficiency** – Uses advanced techniques like Massive MIMO and beamforming to maximize spectral use.
- **Strong Security & Reliability** – Implements improved encryption, authentication, and network resilience for secure communications.
- **Edge Computing Integration** – Reduces latency by processing data closer to the user, improving application performance.

- **Network self-organization**

(What are the major characteristics of self-organizing network?)

  - Autonomous negotiation of interference management
  - Cognitive spectrum usage
  - Optimization of network structure and traffic
  - Load distribution in the network
  - Self-healing of networks

- **Communication Technologies (some examples)**
  - **Bit-level communication and continuous data streams**
  - **Sporadic connections and connections being always on**
  - **Standard services and emergency modes**
  - **Open communication and fully secured communication**
  - **Spanning applications from local to global**
  - **Single devices and globally distributed sets of devices**

Network Technology

- **Complexity of the networks of the future**
  - A key research topic will be to understand the complexity of these future networks and the expected growth of complexity due to the growth of Internet of Things.
  - The research results of this topic will give guidelines and timelines for defining the **requirements for network functions, for network management, for network growth and network composition and variability**.
  - Wireless networks cannot grow without such side effects as **interference**.

Contd.

- **Growth of wireless networks**
  - Wireless networks especially will grow largely **by adding vast amounts of small Internet of Things devices with minimum hardware, software and intelligence**, limiting their resilience to any imperfections in all their functions.
  - **Based on the research of the growing network complexity**, caused by the Internet of Things, **predictions of traffic and load models will have to guide further research on unfolding the predicted complexity to real networks**, their standards and on-going implementations.
- **Mobile networks**
  - Applications such as **body area networks** may develop into an autonomous world of small, mobile networks being attached to their bearers and being connected to the Internet by using a common point of contact.
  - The mobile phone of the future could provide this function.

Contd.

- **Expanding current networks to future networks**
  - Generalizing the examples given above, the trend may be to expand current end **user network nodes into networks of their own or even a hierarchy of networks.**
  - In this way networks will grow on their current access side by unfolding these outermost nodes into even smaller, attached networks, spanning the Internet of Things in the future.
- **Overlay networks**
  - Even if network construction principles should best be unified for the worldwide Internet of Things and the networks bearing it, there will not be one unified network, but several.
  - In some locations even multiple networks overlay one another physically and logically.
  - The Internet and the Internet of Things will have access to large parts of these networks.

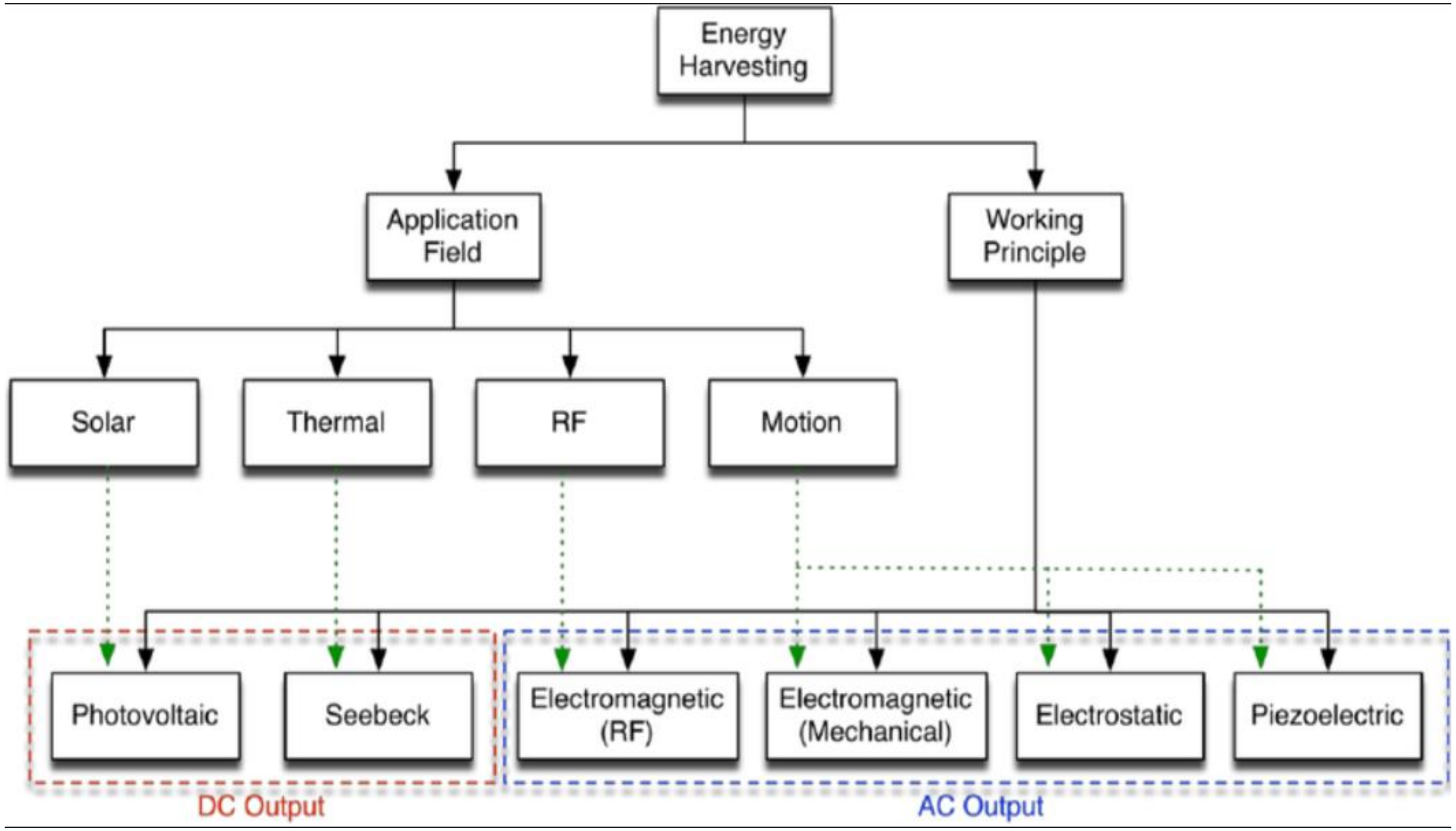
Contd.

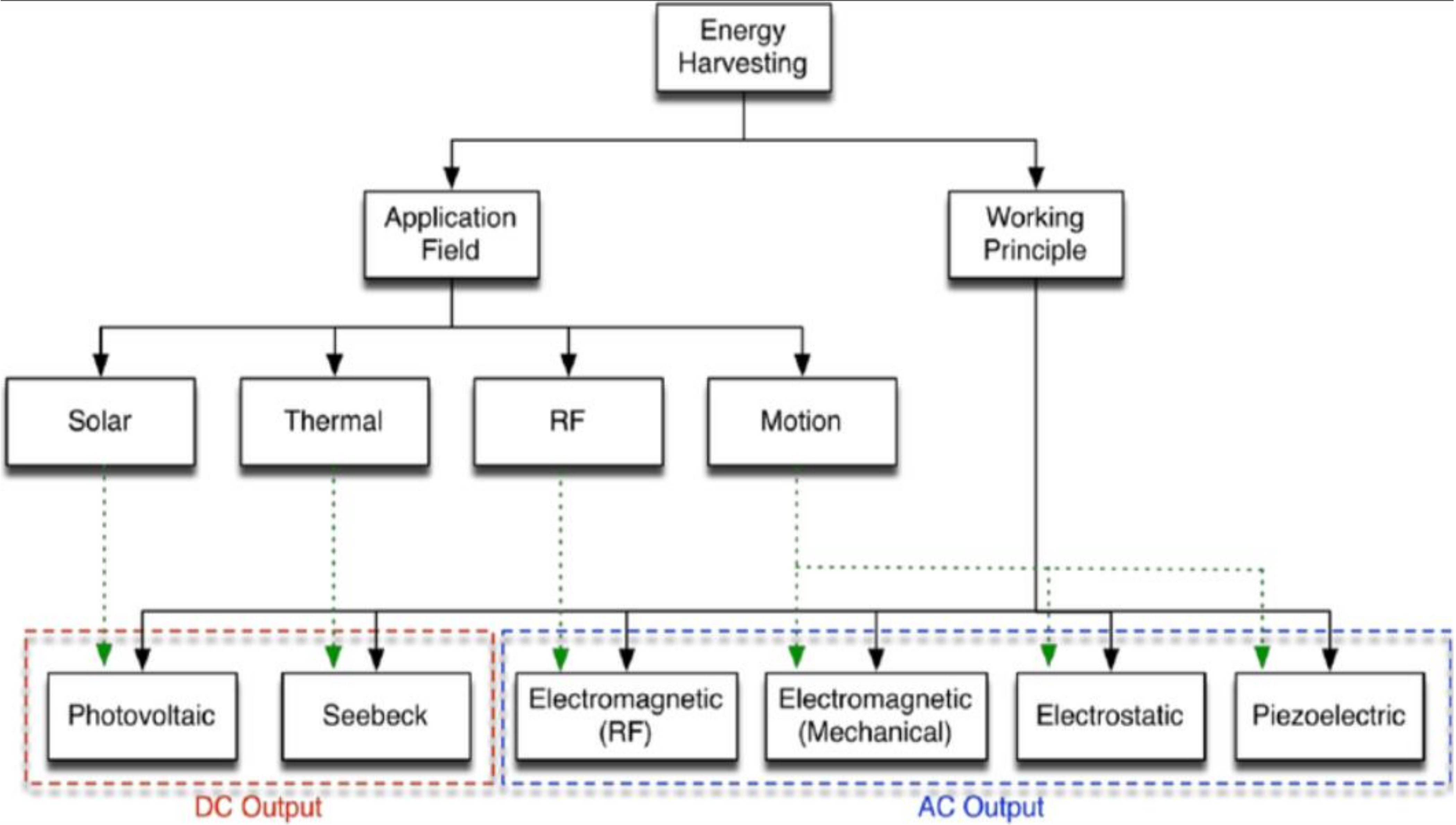
- **Network self-organization**
  - Self-organization principles will be applied to **configuration by context sensing, especially concerning autonomous negotiation of interference management and possibly cognitive spectrum usage, by optimization of network structure and traffic and load distribution in the network, and in self-healing of networks**.
  - All will be done in heterogeneous environments, without interaction by users or operators.
- **IPv6, IoT and Scalability**
  - The current transition of the global Internet to **IPv6** will provide a **virtually unlimited number of public IP addresses** able to provide bidirectional and symmetric (true M2M) access to Billions of smart things.
  - It will show the way to new models of IoT interconnection and integration.

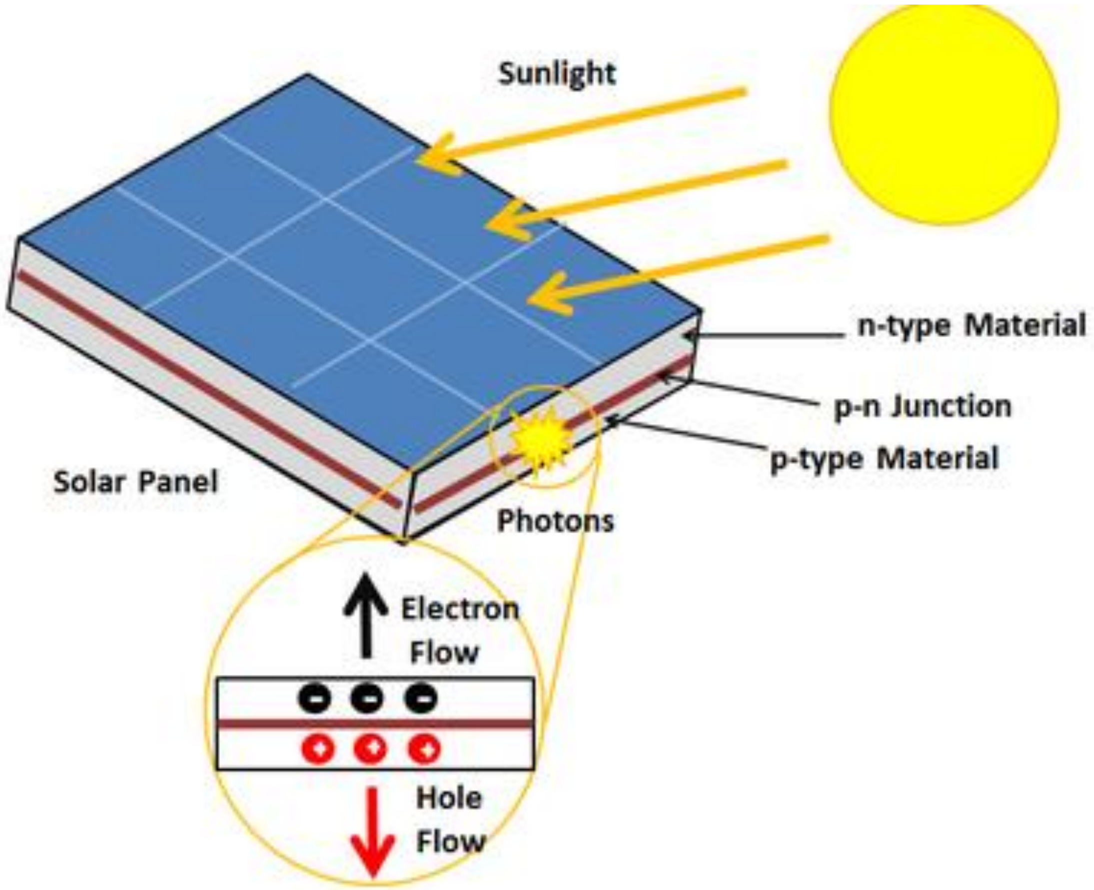
Contd.

- **Green networking technology**
  - Given the enormous expected growth of network usage and the number of user nodes in the future, driven by the Internet of Things, there is a real need to **minimize** the resources for implementing all **network elements and the energy being used** for their operation.
  - In recent years shows that networks can achieve an **energy efficiency increase of a factor of 1,000** compared to current technologies

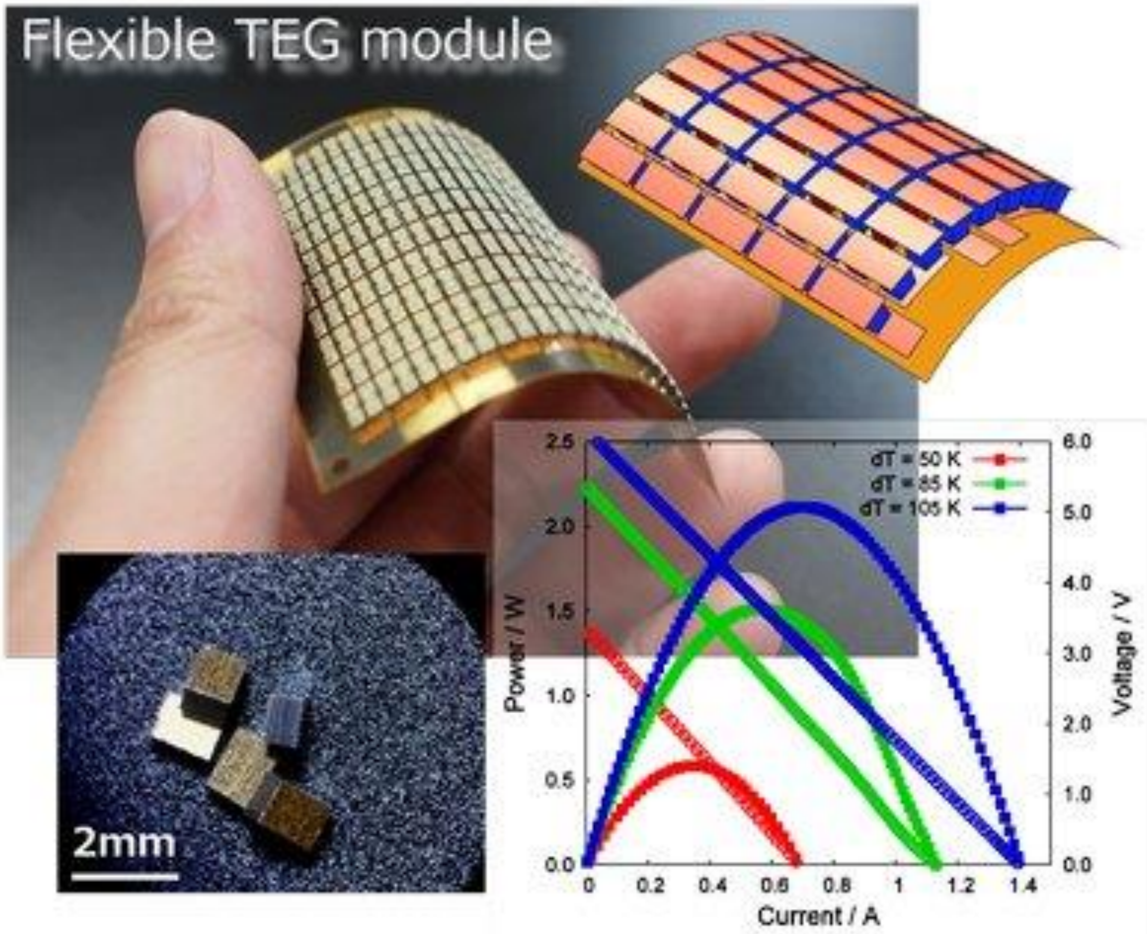
- Energy limitations of IoT devices
  - Can be solved using **energy harvesting technologies** and developing low power IoT devices
  - Example: some LoRaWAN devices consume 34mA during peak transmission



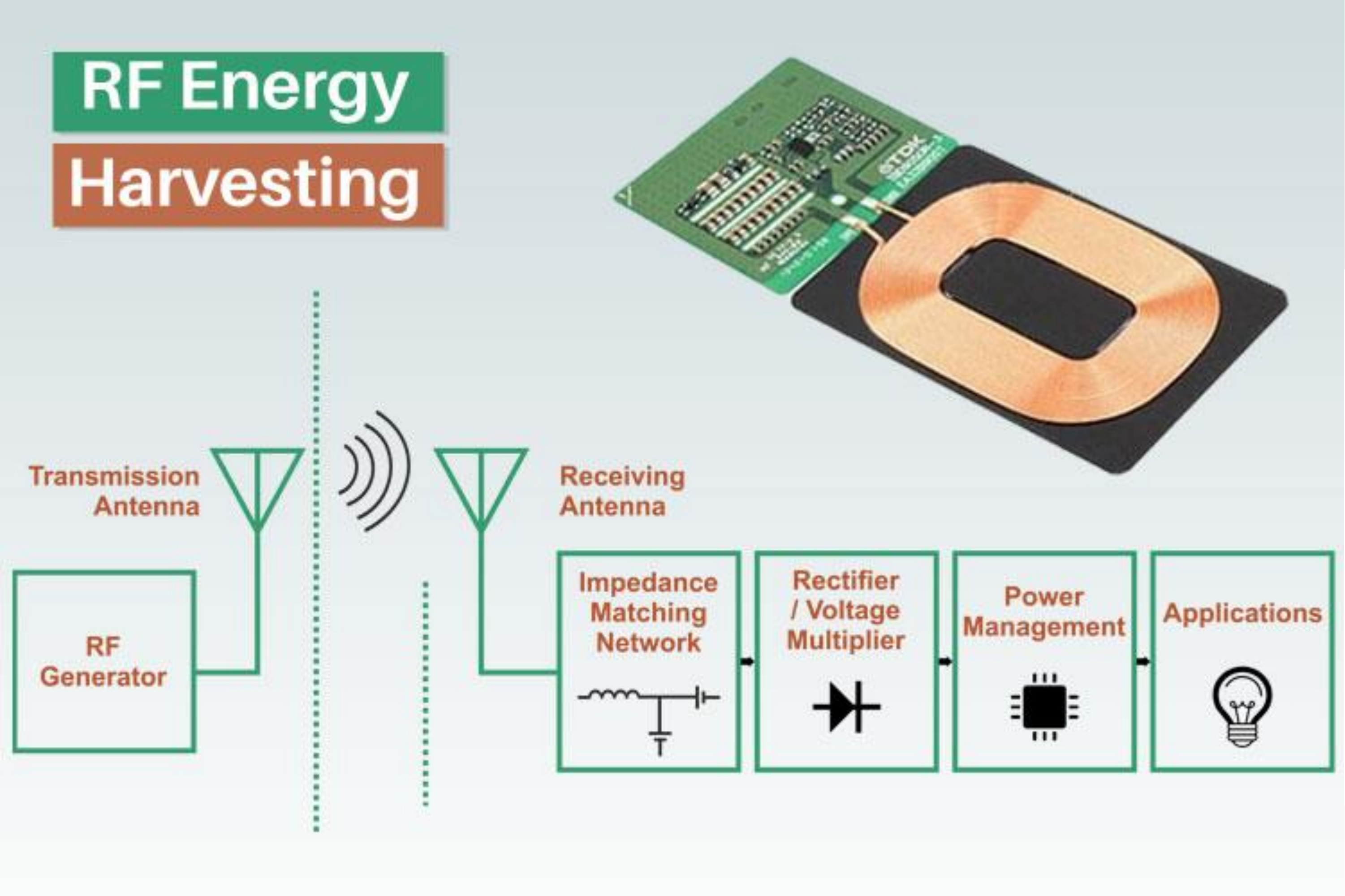

Energy Harvesting
Application Field
Working Principle
Solar
Thermal
RF
Motion
Photovoltaic
Seebeck
Electromagnetic (RF)
Electromagnetic (Mechanical)
Electrostatic
Piezoelectric
DC Output
AC Output



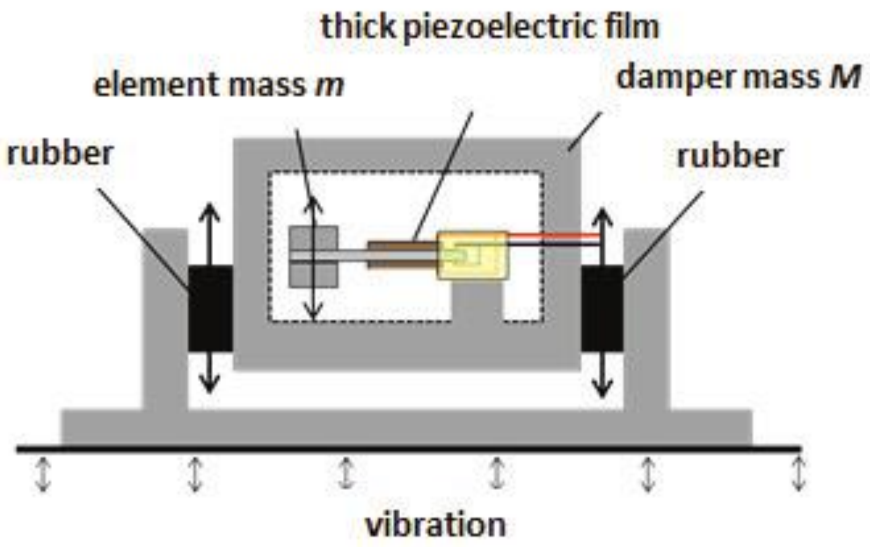
Photoelectric generator



Thermoelectric generator



RF Harvesting



Piezoelectric generator

Communication Technology

- **Unfolding the potential of communication technologies**
  - The research aimed at communication technology to be undertaken in the coming decade will have to develop and unfold all potential communication profiles of Internet of Things devices, from
    - **bit-level communication to continuous data streams,**
    - **from sporadic connections to connections being always on,**
    - **from standard services to emergency modes,**
    - **from open communication to fully secured communication,**
    - **spanning applications from local to global,**
    - **based on single devices to globally-distributed sets of devices.**
- **Correctness of construction**
  - Correctness of construction of the whole system is a systematic process that starts from the **small systems running on the devices up to network and distributed applications.**
  - Methods to prove the correctness of structures and of transformations of structures will be required, **including protocols of communication between all levels of communication stacks** used in the Internet of Things and the Future Internet.
  - These methods will be essential for the Internet of Things devices and systems, as the smallest devices will be implemented in hardware and many types will not be programmable.

Contd.

- **An unified theoretical framework for communication**
  - Communication between processes running within an operating system on a single or multicore processor, communication between processes running in a distributed computer system, and the **communication between devices and structures in the Internet of Things and the Future Internet using wired and wireless channels shall be merged into a unified minimum theoretical framework covering and including formalized communication within protocols.**
  - In this way **minimum overhead, optimum use of communication channels and best handling of communication errors should be achievable**.
- **Energy-limited Internet of Things devices and their communication**
  - Many types of Internet of Things devices will be connected to the energy grid all the time; on the other hand a significant subset of Internet of Things devices will have to rely on their own limited energy resources or energy harvesting throughout their lifetime.
  - Given this spread of possible implementations and the expected importance of minimum-energy Internet of Things devices and applications, an important topic of research will have to be the search for minimum energy, minimum computation, slim and lightweight solutions through all layers of Internet of Things communication and applications.

Virtual Sensors

A virtual sensor can be considered as a product of spatial, temporal and/or thematic transformation of raw or other virtual sensor producing data with necessary provenance information attached to this transformation.

Virtual sensors and actuators are a programming abstraction simplifying the development of decentralized WSN applications.

Models for interacting with wireless sensors such as Internet of Things and sensor cloud aim to overcome restricted resources and efficiency.

New sensor clouds need to enable different networks, cover a large geographical area, connect together and be used simultaneously by multiple users on demand.

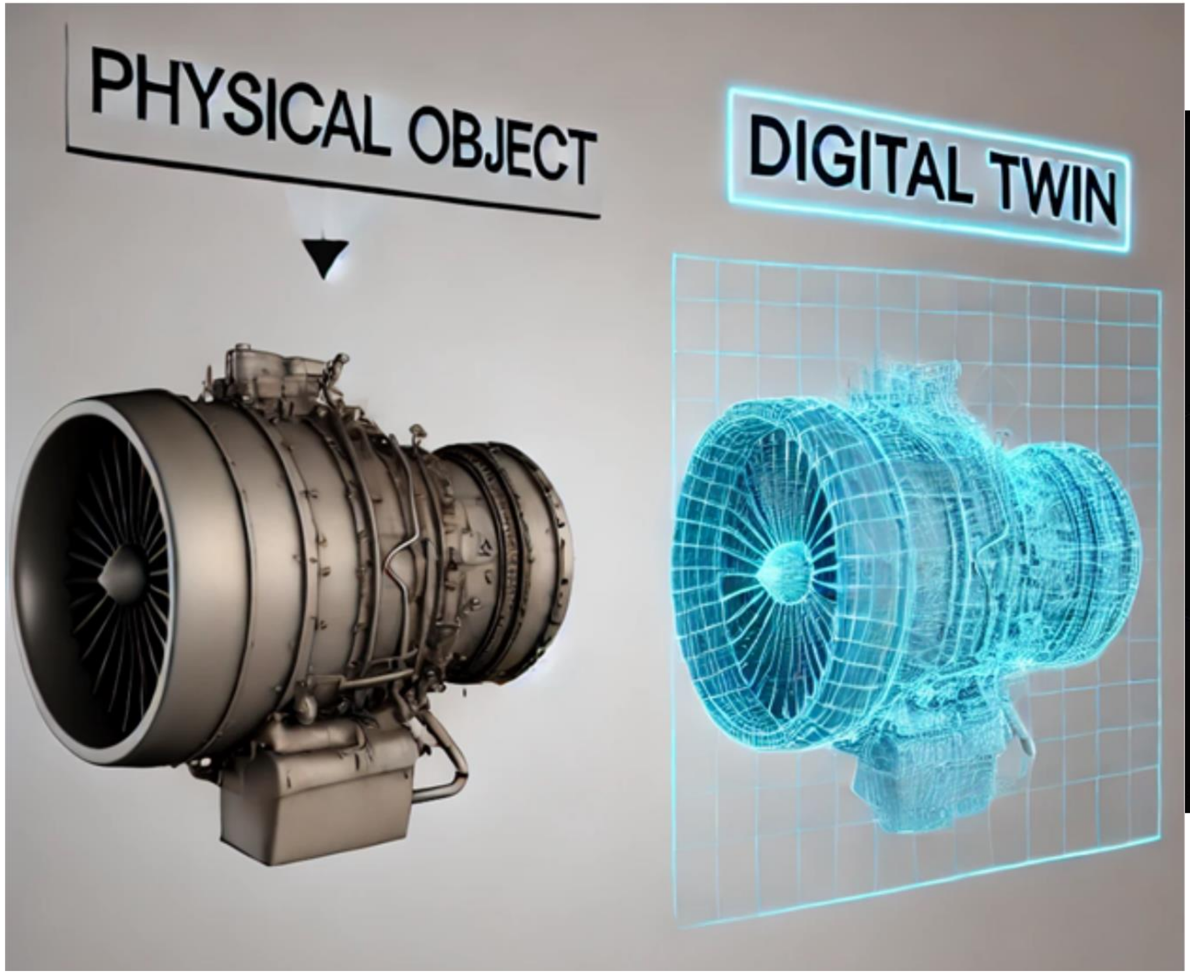
Virtual Sensors

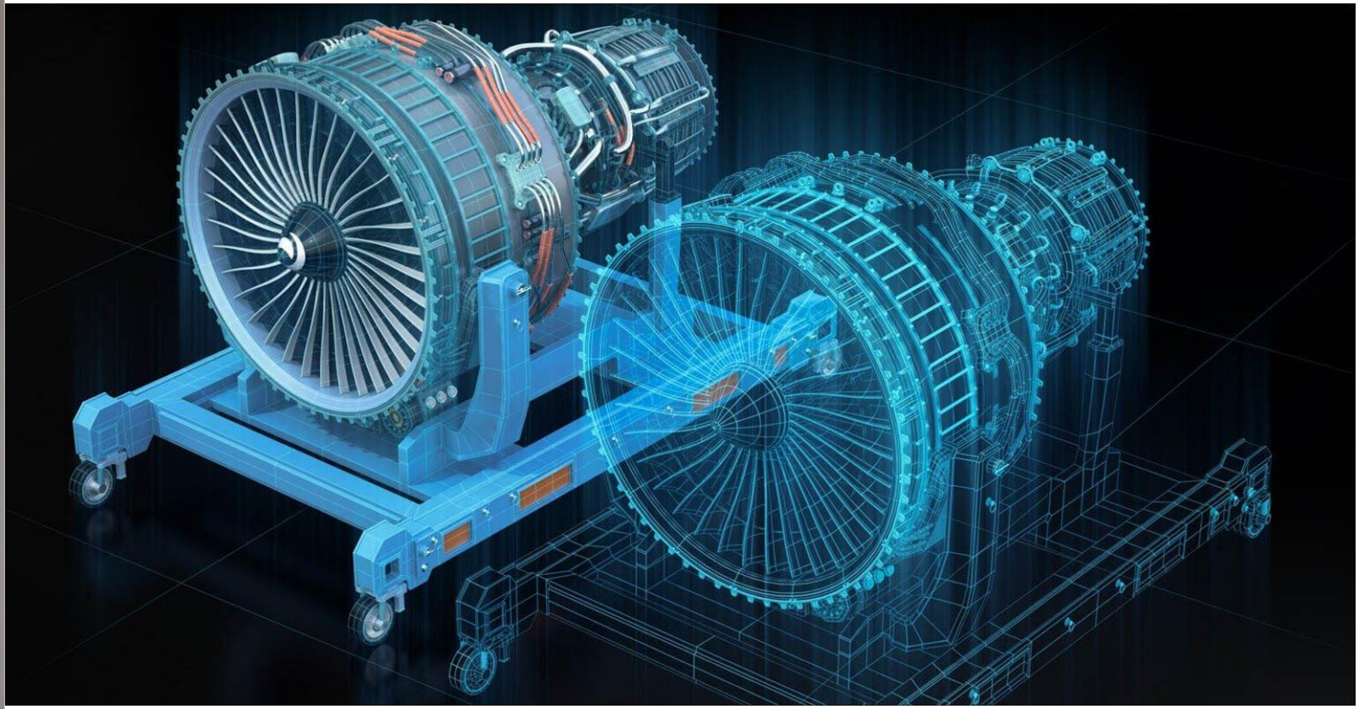
Virtual sensors, as the core of the sensor cloud architecture, assist in creating a multiuser environment on top of resource constrained physical wireless sensors and can help in supporting multiple applications.

- A virtual sensor is used to estimate the properties of product otherwise conditions of the process with the help of mathematical models which use readings of an extra physical sensor to compute the expected condition or property.
- Digital Twin of any object.

Virtual Sensors

- **Digital Twin of any object.**





Virtual Sensors

Definition:

A Virtual Sensor is a software-based system that estimates or predicts values of physical variables using mathematical models, machine learning algorithms, or data fusion from multiple physical sensors. Unlike physical sensors, virtual sensors do not directly measure the environment but infer data based on other available information.

Key Characteristics of Virtual Sensors:

- **Software-based:** Uses computational models instead of direct physical measurements.
- **Data Fusion:** Integrates data from multiple sources.
- **Cost-Effective:** Reduces the need for expensive physical sensors.
- **Improved Reliability:** Can compensate for sensor faults or missing data.

Virtual Sensors

Virtual sensors use mathematical models, machine learning, or statistical methods to estimate a desired parameter.

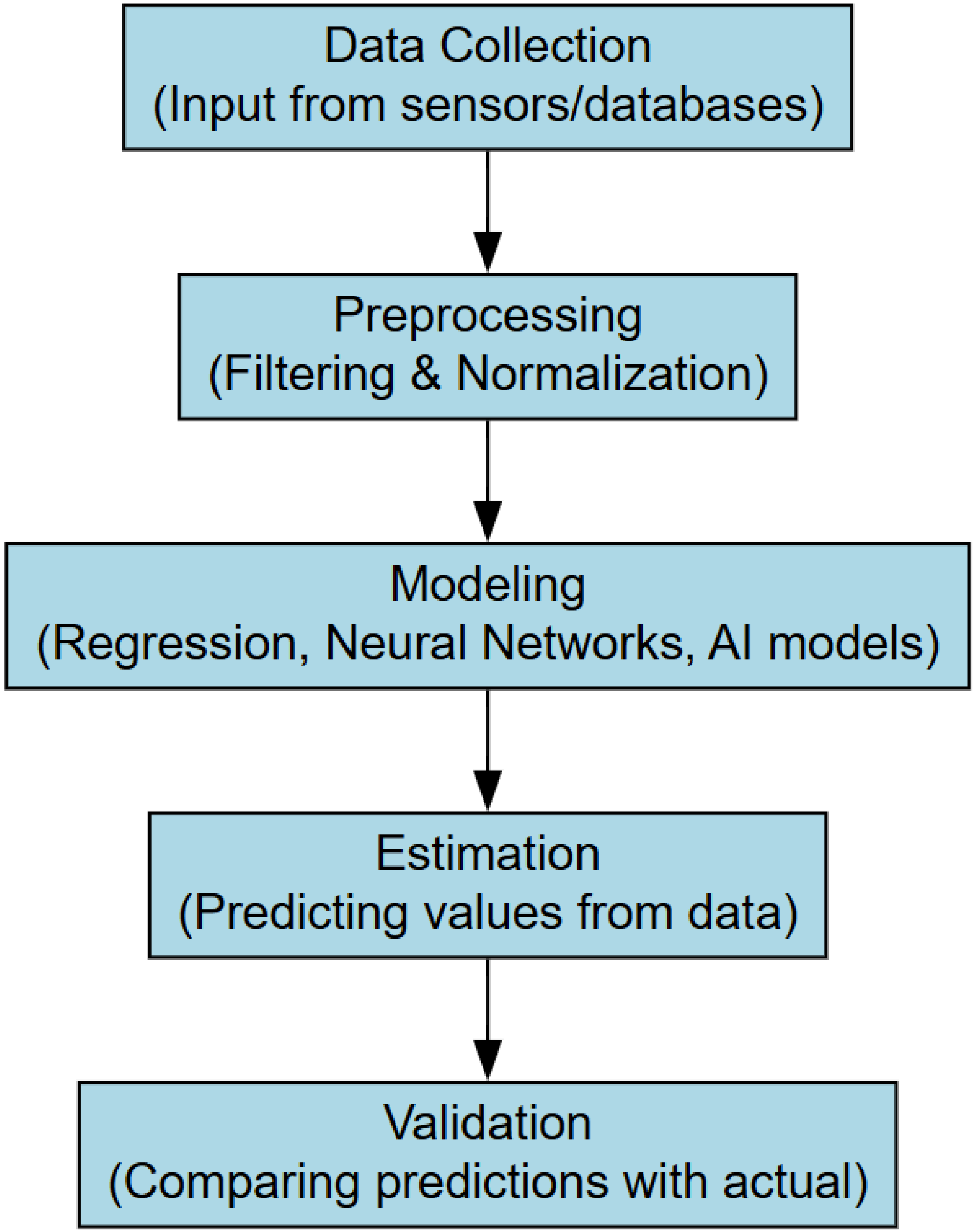
The common steps involved are:

1. **Data Collection:** Input from physical sensors or databases.
2. **Preprocessing:** Filtering and normalizing the data.
3. **Modeling:** Using techniques like regression, neural networks, Kalman filtering, or AI-based models.
4. **Estimation:** Predicting the required values based on available data.
5. **Validation:** Comparing predictions with actual measurements for accuracy.

Virtual Sensors

The common steps involved are:

1. **Data Collection**
2. **Preprocessing**
3. **Modeling**
4. **Estimation**
5. **Validation**



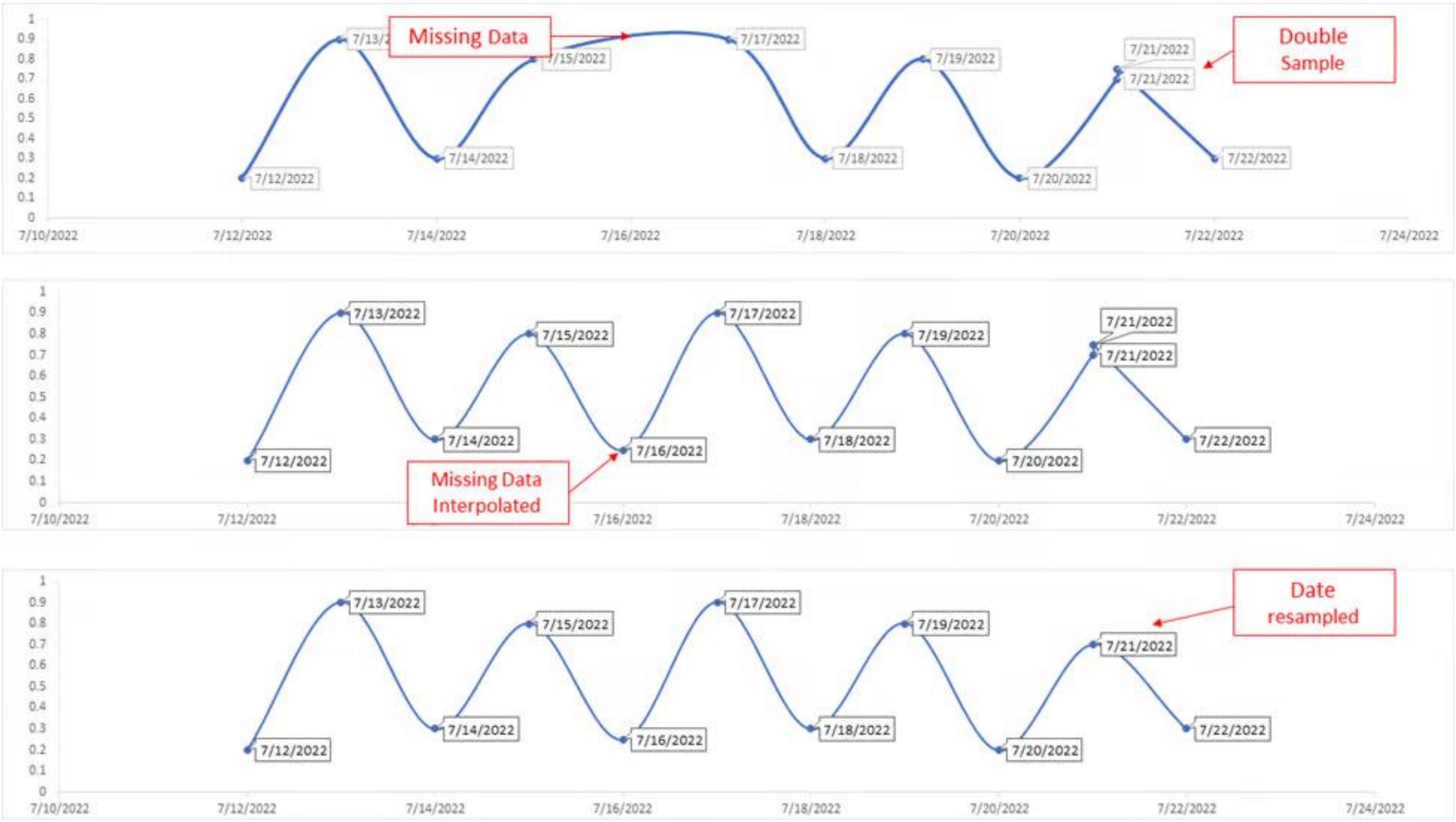
The data acquired by a set of sensors can be collected, processed according to an application-provided aggregation function, and then perceived as the reading of a single virtual sensor.

Dually, a virtual actuator provides a single-entry point for distributing commands to a set of real actuator nodes.

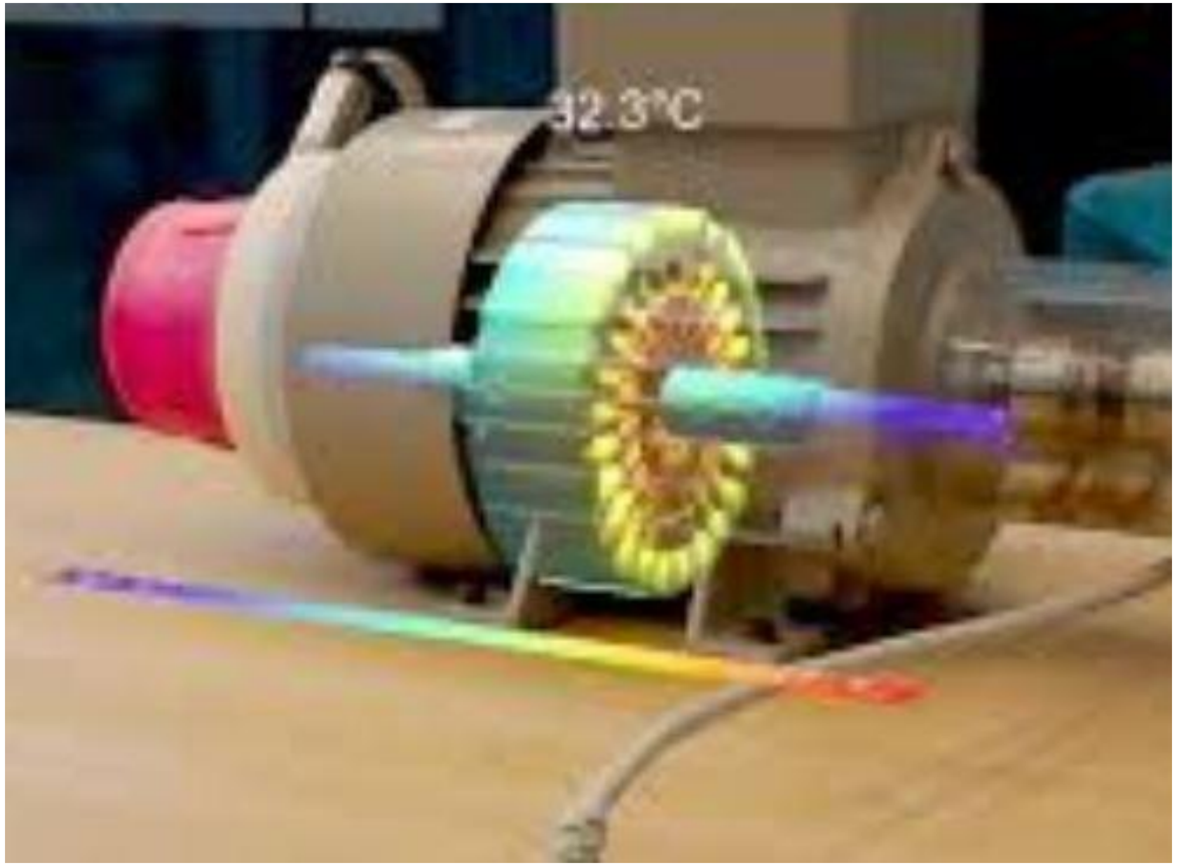
- **Android gives 4-principal virtual sensors like**
    - **TYPE_GRAVITY**
    - **TYPE_ORIENTATION**
    - **TYPE_LINEAR_ACCELERATION**
    - **TYPE_ROTATION_VECTOR**

We follow that statement with this definition:

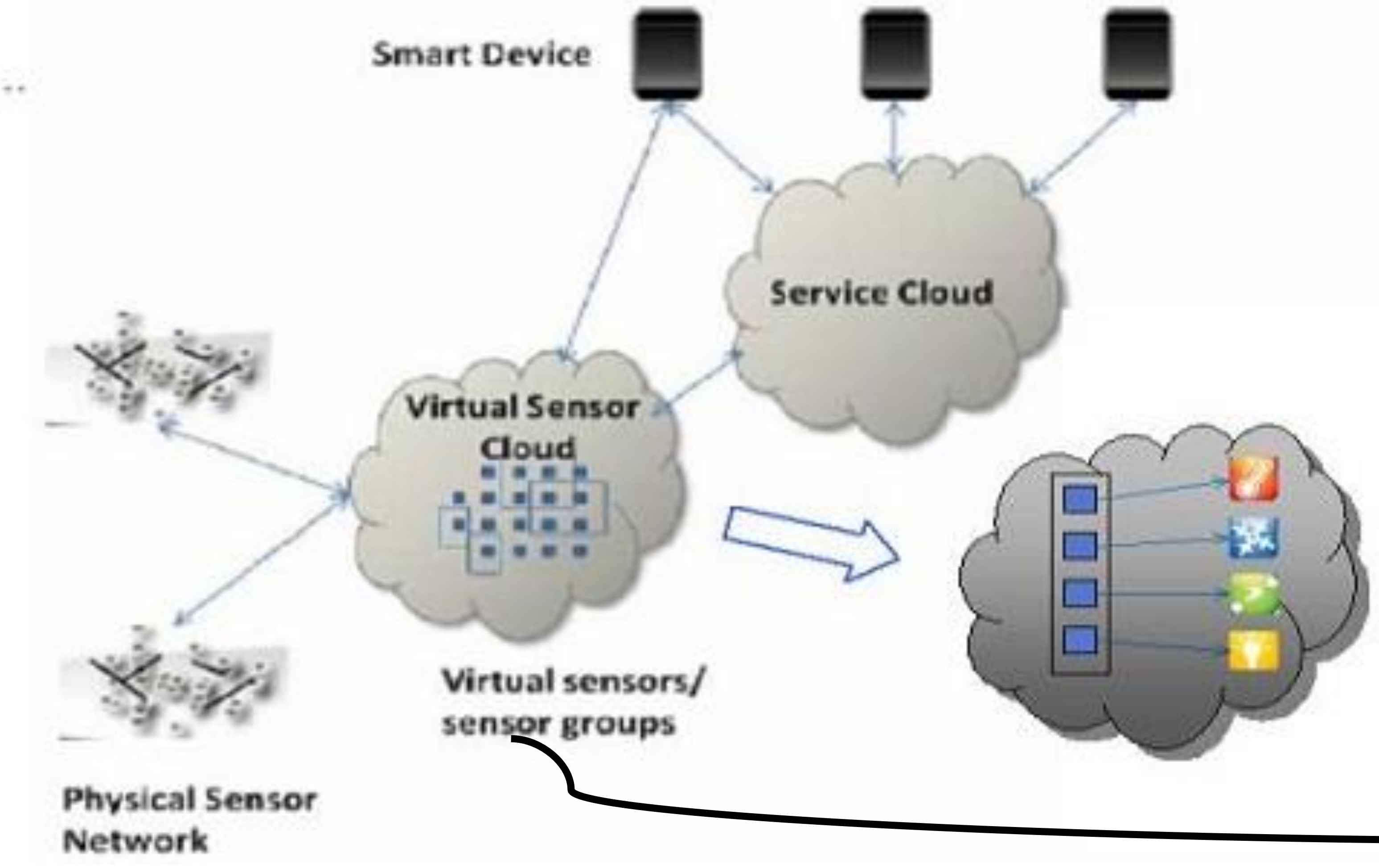
- **A virtual sensor behaves just like a real sensor, emitting time-series data from a specified geographic region with newly defined thematic concepts or observations which the real sensors may not have.**

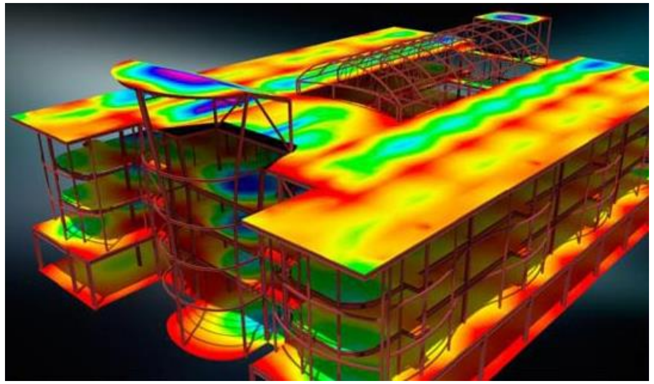


- **A virtual sensor may not have any real sensor's physical properties** such as manufacturer or battery power information, but does have other properties, such as: who created it; what methods are used, and what original sensors it is based on.



Case study discussion: An architecture





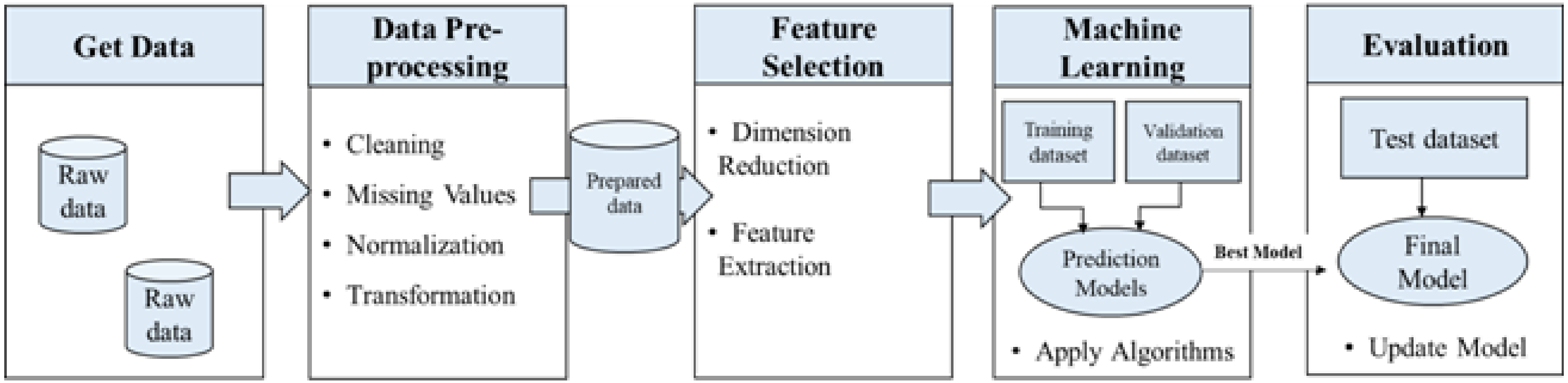
Predictive model of civil structures
Digital Twin

Virtual Sensors

Example 1: Estimating Air Quality

A virtual sensor for **Air Quality Index (AQI)** can estimate pollution levels in an area using data from:

- Temperature & Humidity Sensors
- Traffic Data
- Weather Conditions
- Satellite Data



Virtual Sensors

Example 2: Virtual Tire Pressure Sensor in Automobiles

Instead of using a direct pressure sensor, a car's virtual tire pressure monitoring system estimates tire pressure based on:

- Wheel speed sensors
- Vehicle acceleration
- Ambient temperature
- Vehicle load conditions

Virtual Sensors

Example 3: Predicting Fuel Efficiency in Vehicles

A virtual sensor can estimate fuel efficiency using:

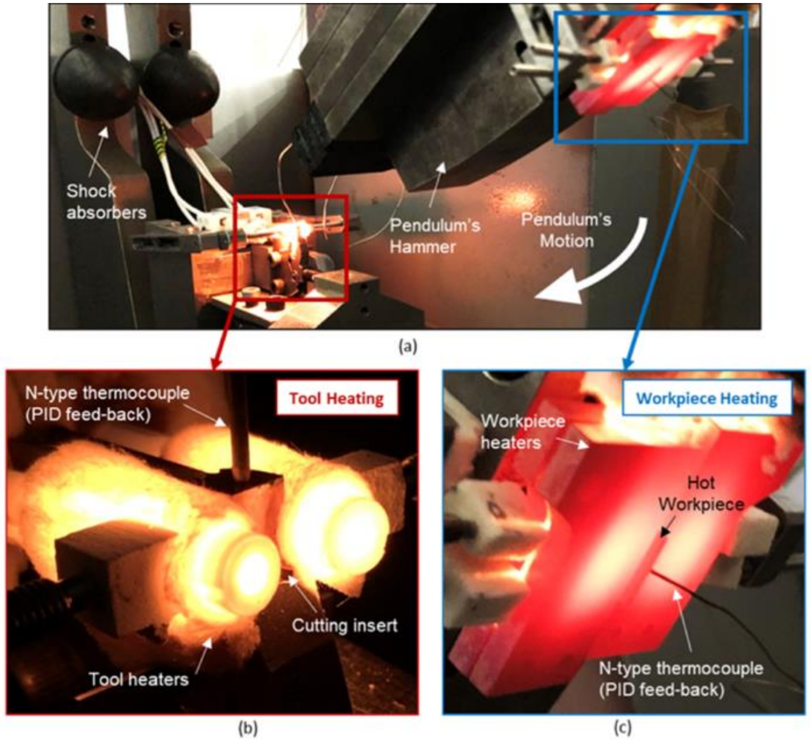
- Engine speed
- Fuel injection rate
- Throttle position
- Ambient temperature

Virtual Sensors

Example 4: Temperature Estimation in Industrial Processes

Many industrial furnaces and reactors use virtual sensors to estimate internal temperatures based on:

- External surface temperature measurements
- Heating power applied
- Material properties

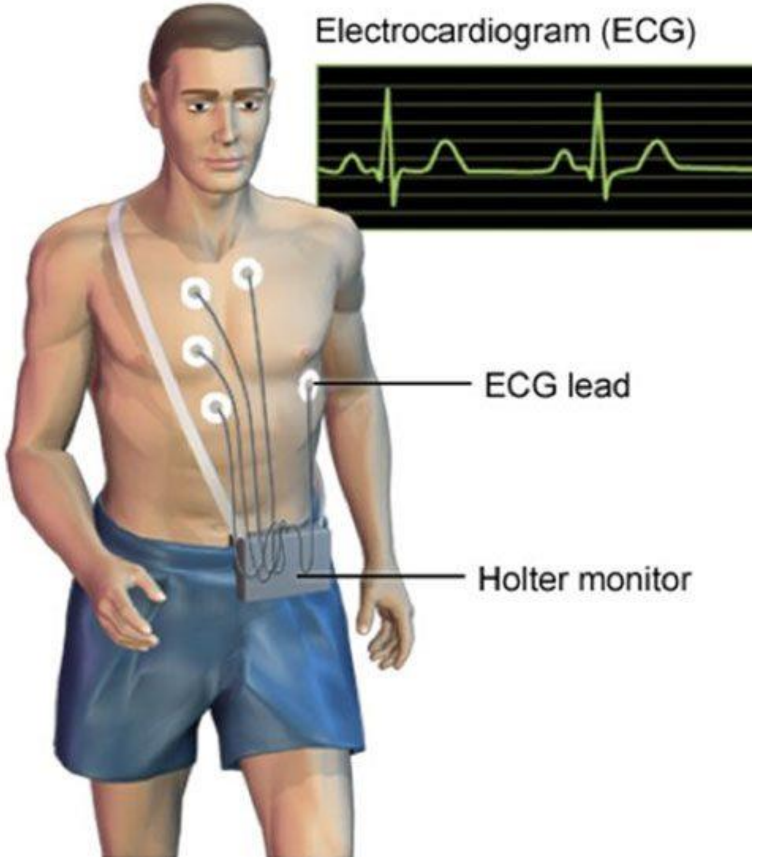


Virtual Sensors

Example 5: Virtual Sensor in Healthcare – Heart Rate Monitoring

Instead of a direct heart rate monitor, smartwatches estimate heart rate using:

- Accelerometer data (motion sensing)
- Optical sensors
- AI-based models to correct noisy signals



Virtual Sensors

Applications of Virtual Sensors

- **Automotive:** Tire pressure monitoring, fuel efficiency estimation.
- **Healthcare:** Heart rate estimation, glucose level prediction.
- **Industrial Automation:** Predictive maintenance, temperature monitoring.
- **Smart Agriculture:** Soil moisture estimation, crop health prediction.
- **Aerospace:** Aircraft engine health monitoring, fuel optimization.

Adaptive and Event Driven Processes

Introduction

- The deployment of IoT technologies will significantly impact and change the way enterprises do business as well as interactions between different parts of the society, affecting many processes.
- To acquire the potential benefits that have been postulated for the IoT, several challenges regarding the modelling and execution of such processes need to be solved in order to see wider and in particular commercial deployments of IoT.
- The special characteristics of IoT services and processes have to be taken into account.

Contd.

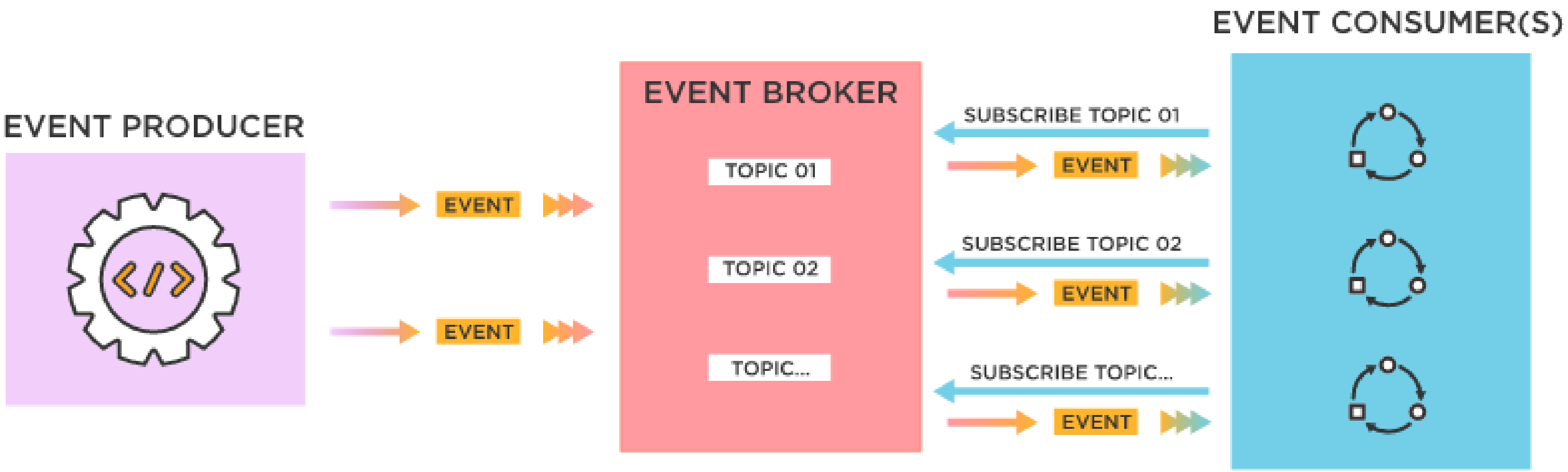
- Research on adaptive and event-driven processes could consider the extension and exploitation of **EDA (Event Driven Architectures) for activity monitoring and complex event processing (CEP) in IoT systems.**
- EDA could be combined with business process execution languages in order to trigger specific steps or parts of a business process.

• Adaptive and Event Driven Processes

One of the main benefits of IoT integration is that processes become more adaptive to what is actually happening in the real world.

Inherently, this is based on events that are either detected directly or by real-time analysis of sensor data. Such events can occur at any time in the process.

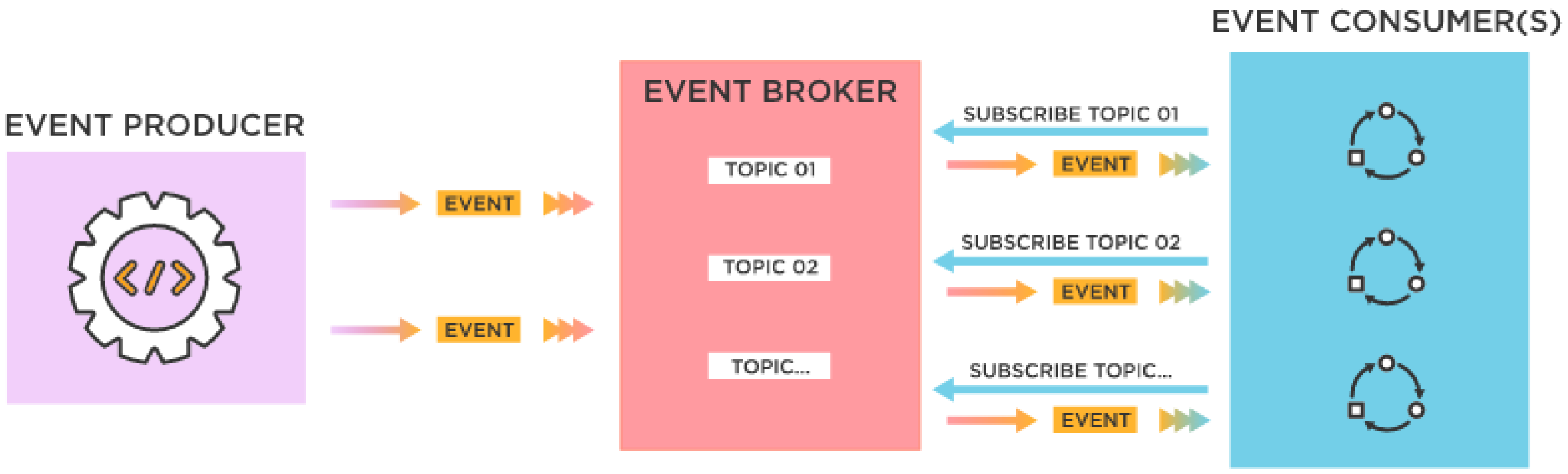
For some of the events, the occurrence probability is very low: one knows that they might occur, but not when or if at all.

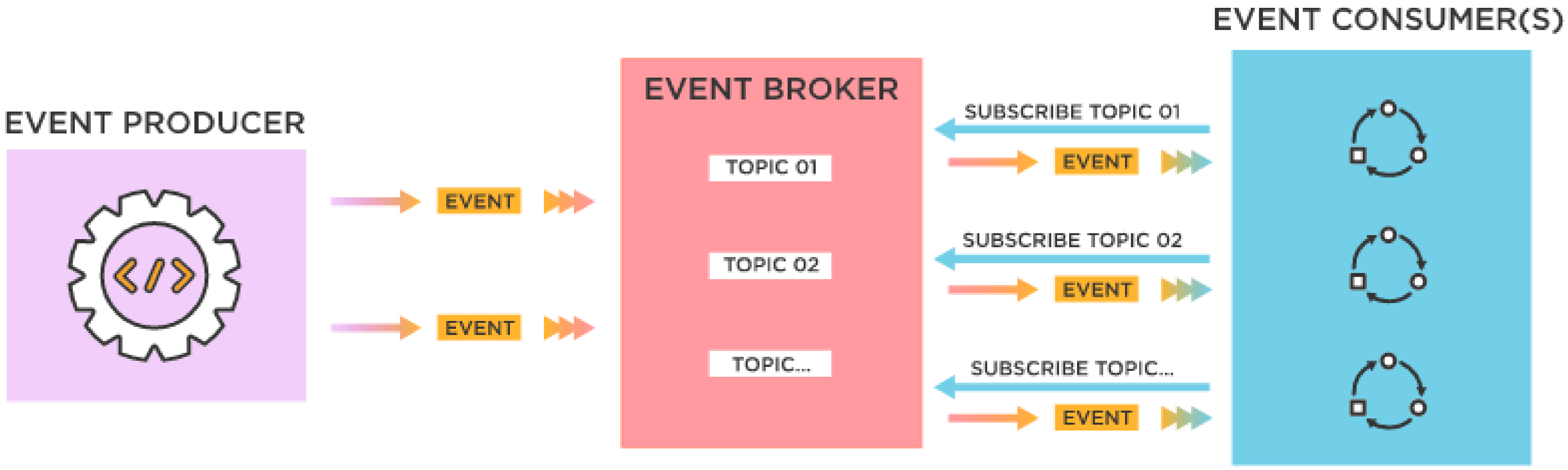


• Adaptive and Event Driven Processes

Modelling such events into a process is cumbersome, as they would have to be included into all possible activities, leading to additional complexity and making it more difficult to understand the modelled process, in particular the main flow of the process (the 80% case).

Secondly, how to react to a single event can depend on the context, i.e. the set of events that have been detected previously.




EVENT PRODUCER
EVENT
EVENT
EVENT BROKER
TOPIC 01
TOPIC 02
TOPIC...
SUBSCRIBE TOPIC 01
EVENT
SUBSCRIBE TOPIC 02
EVENT
SUBSCRIBE TOPIC...
EVENT
EVENT CONSUMER(S)

• Adaptive and Event Driven Processes

Examples:

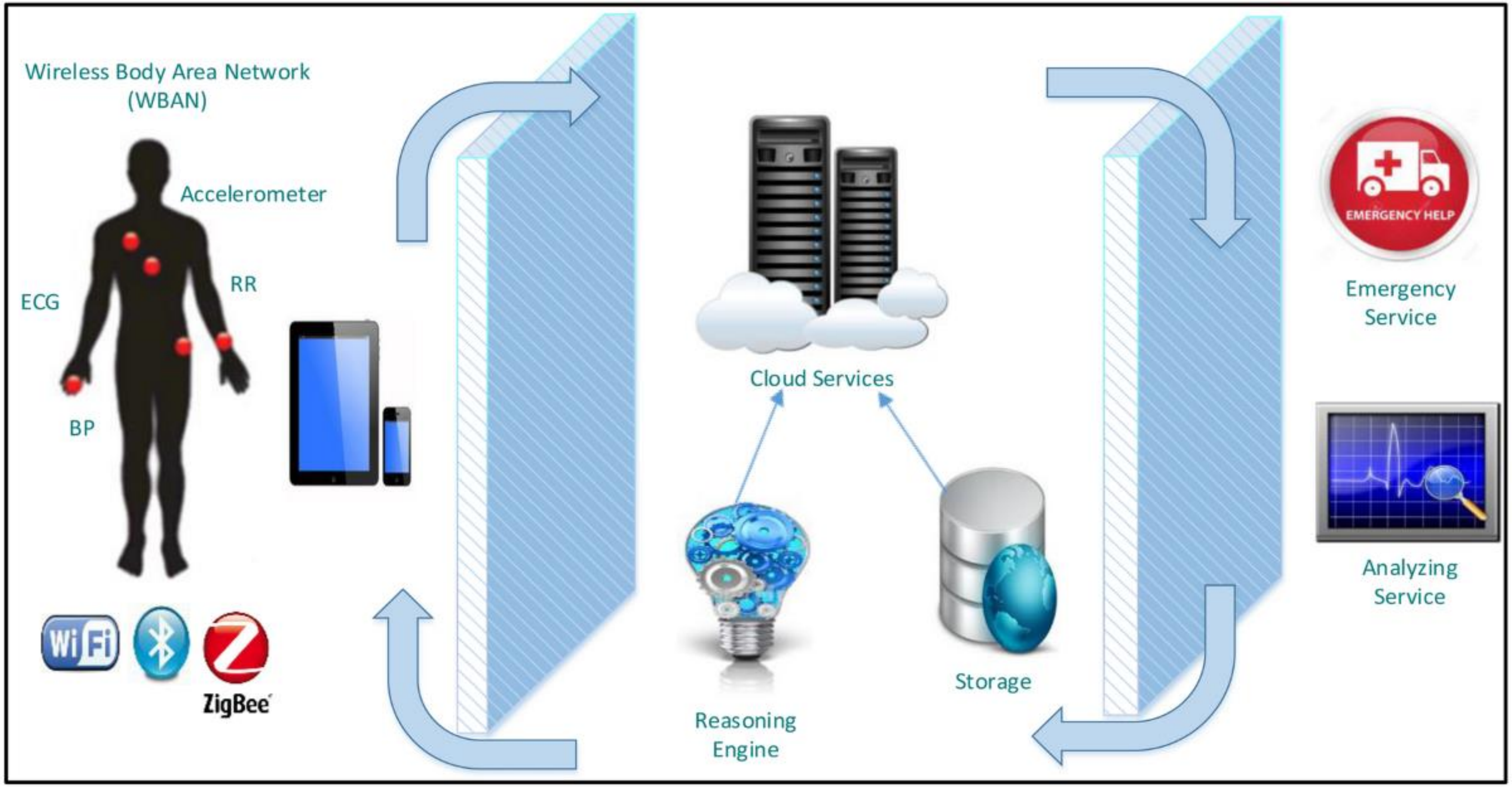
In event-driven architecture, an event will likely trigger one or more actions or processes in response to its occurrence. An example of an event might include:

- **Request to reset a password**
- **A package arrived was delivered to its destination**
- **A grocery warehouse updates its inventory**
- **An unauthorized access attempt was denied**

Each of these events is likely to trigger one or more actions or processes in response. One response might be simply to log the event for monitoring purposes. Others might be:

- **An email to reset the password is sent to the customer**
- **The sales ticket is closed**
- **An order for more lettuce (or whatever materials are running low) is placed**
- **An account is locked and security personnel are notified**

- Adaptive and Event Driven Processes Example



- Adaptive and Event Driven Processes Example