Internet of Things: An Overview

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http://www.cse.iitk.ac.in/~karkare/esd4iot

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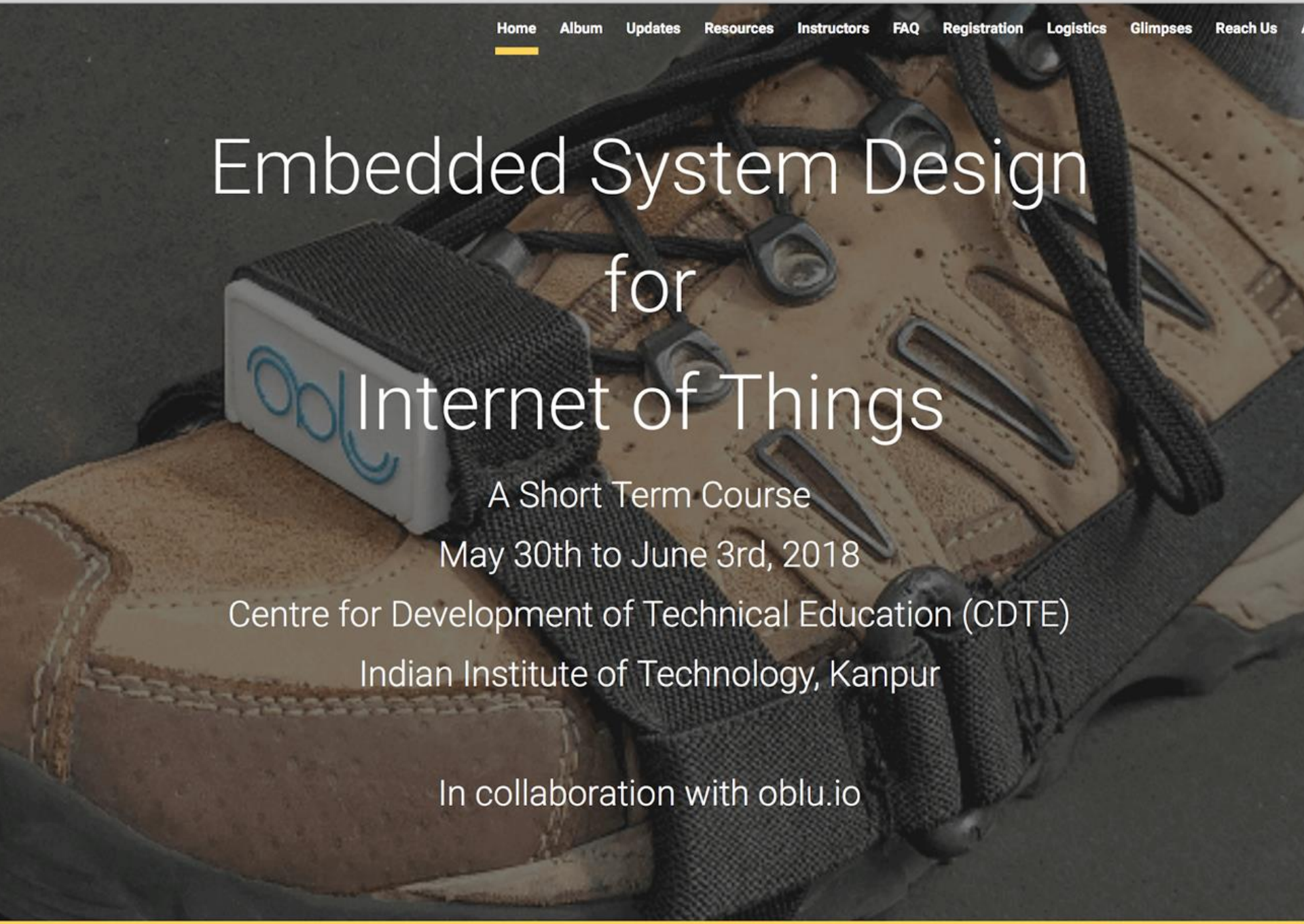


Embedded System Design for Internet of Things

A Short Term Course

May 30th to June 3rd, 2018

Centre for Development of Technical Education (CDTE)

Indian Institute of Technology, Kanpur

In collaboration with oblu.io


ESD4IoT - 2018

CS664: IoT System Design (2018 Summer Semester)

- **Instructor**: Amey Karkare (karkare@cse.iitk.ac.in, karkare@gmail.com), Amit K Gupta (amit@oblu.io)
- **Timings**: Mon, Wed, Fri 1200 -- 1300 Hours
- **Venue**: KD 102
- **TAs**:

The focus of this introductory course would be “the smart sensor node” with emphasis on design, requirement, data interfacing and capabilities. The course would cover engineering fundamentals, blended with good industrial practices, which lead to the first-time success of the design and development of sensor node. API development, cloud computing, and data analysis would also be covered in brief. Lab sessions and case studies will supplement the classroom interactions.

After completing this course, students will be in a position to understand various building blocks and working of state-of-the-art IoT systems. Students would also gain enough insights to conceive and build IoT systems on their own.

Code of Ethics

Internet

Internet

/ɪntənɛt/

noun

a global computer network providing a variety of information and communication facilities, consisting of interconnected networks using standardized communication protocols.
"the guide is also available on the Internet"

1977

Internet of Things

Internet of things

noun
noun: **Internet of things**

the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data.
"if one thing can prevent the Internet of things from transforming the way we live and work, it will be a breakdown in security"

2008-2009: Time when more “things” connected to internet than people

Cloud Computing

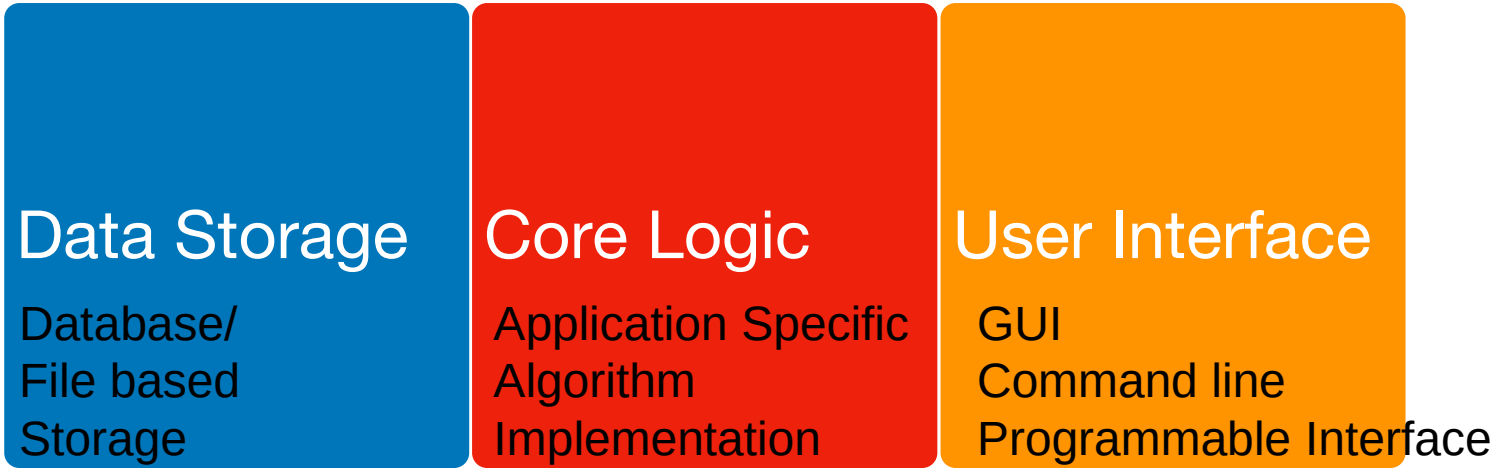
cloud computing

noun

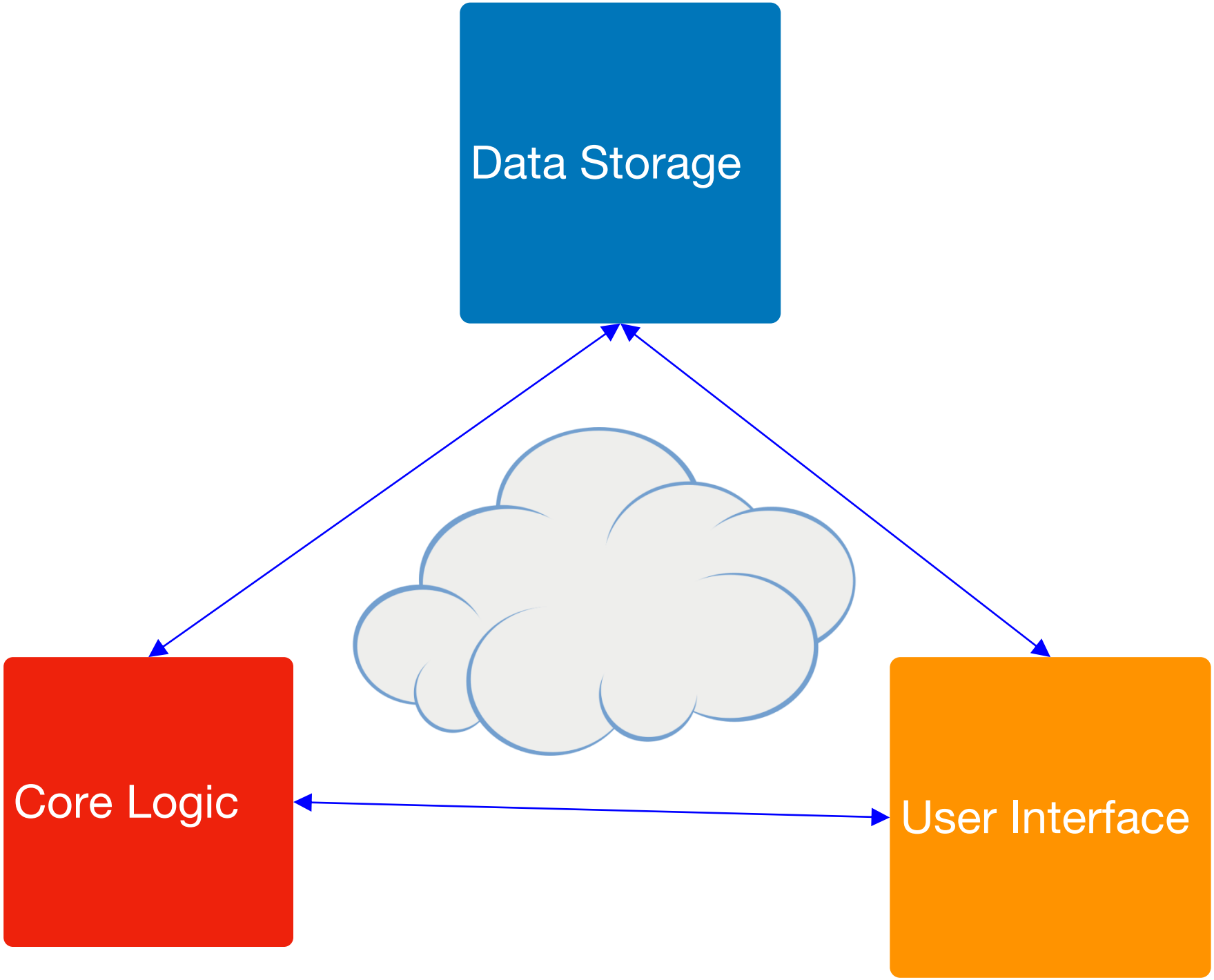
the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer.

1996: Used in Compaq internal document
2006: Made popular by Amazon EC2

Components of a typical software application



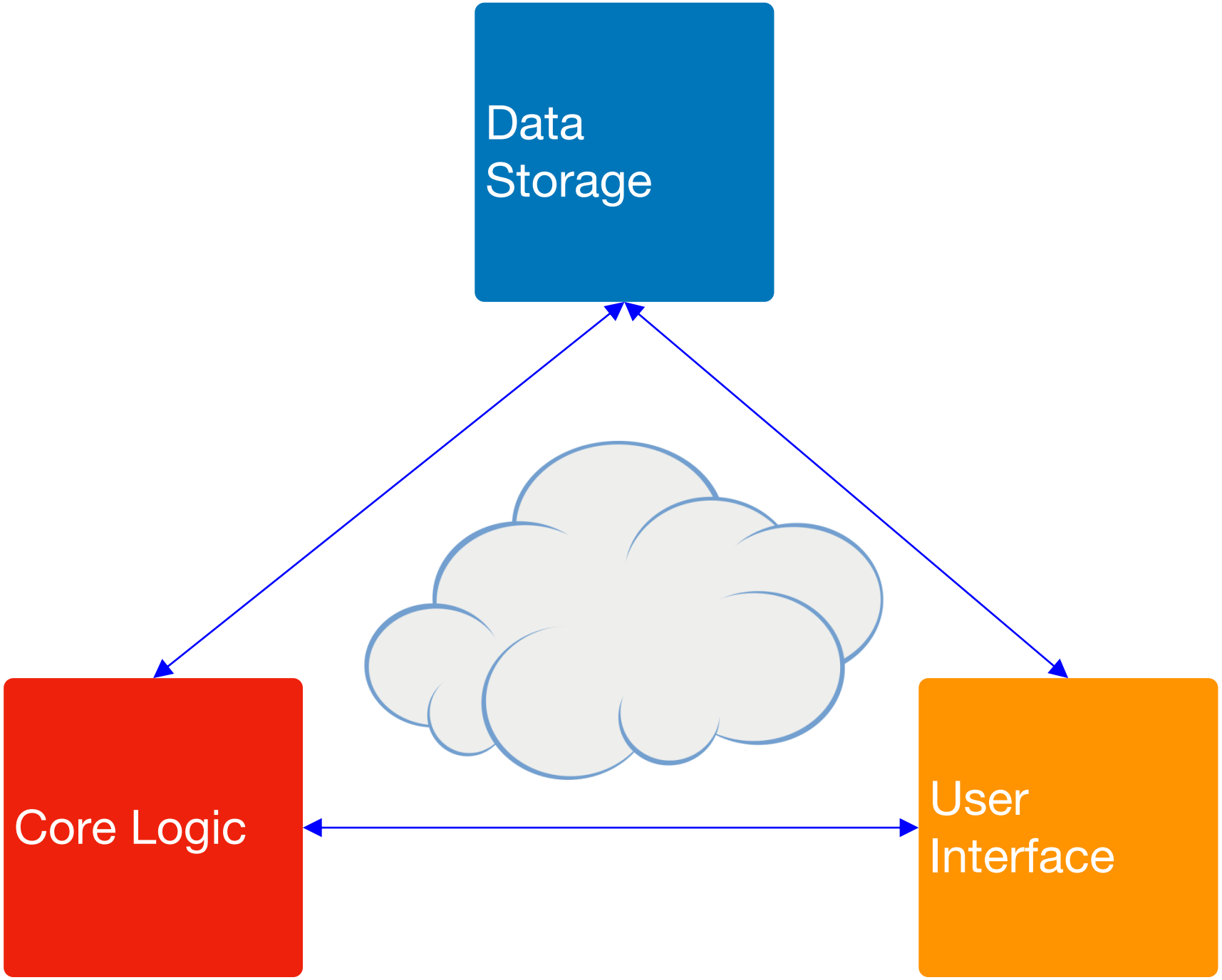
Traditionally the three components used to sit on the same computer


Data Storage
Core Logic
User Interface

Cloud Computing

- Innovation in the application of existing technology
- Cloud computing consists of
  - Development of self contained components
  - Delivering these components as services
- Similar to utilities like electricity, mobile network
  - Pay-per-use, without large infrastructural cost
- An important feature of Cloud is *elasticity*
  - provide resources to scale up OR take away resources to scale down, as per the need

IoT and Cloud


Data
Storage
Core Logic
User
Interface

Data Storage

Core Logic

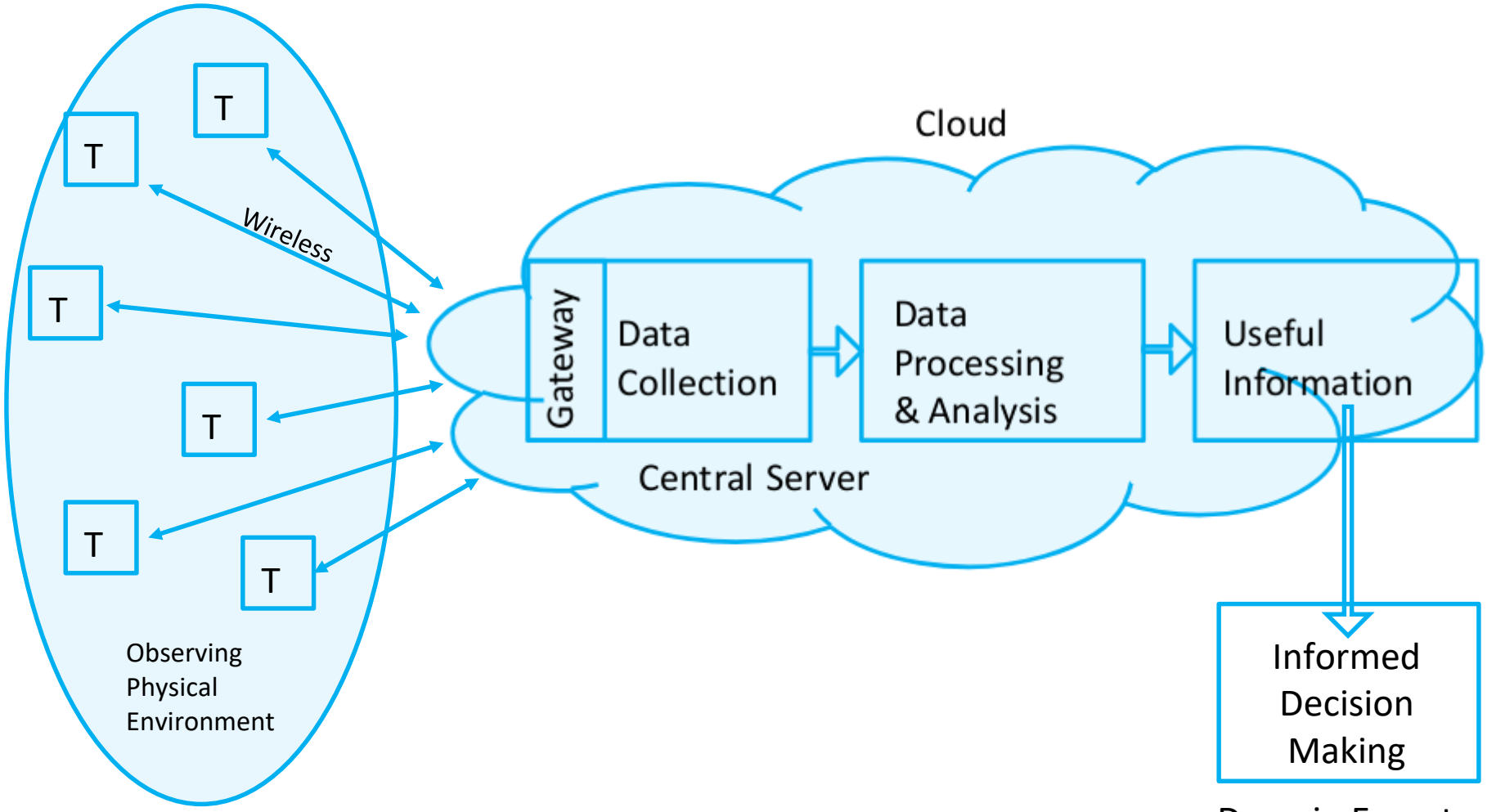
Sensors

Motion,
Temperature,
RFID readers …

Internet of Things

- **Smart Sensors Communicate**
  - talk to each other.
  - connect to the cloud through gateway/router.
- The data generated by sensors can grow huge.
  - For example, GBs or TBs of data from video surveillance.
  - “Big Data” issues - This is where scalability of clouds come in handy.
- Cloud is an *IoT Facilitator*
  - Not essential, but very useful in practice

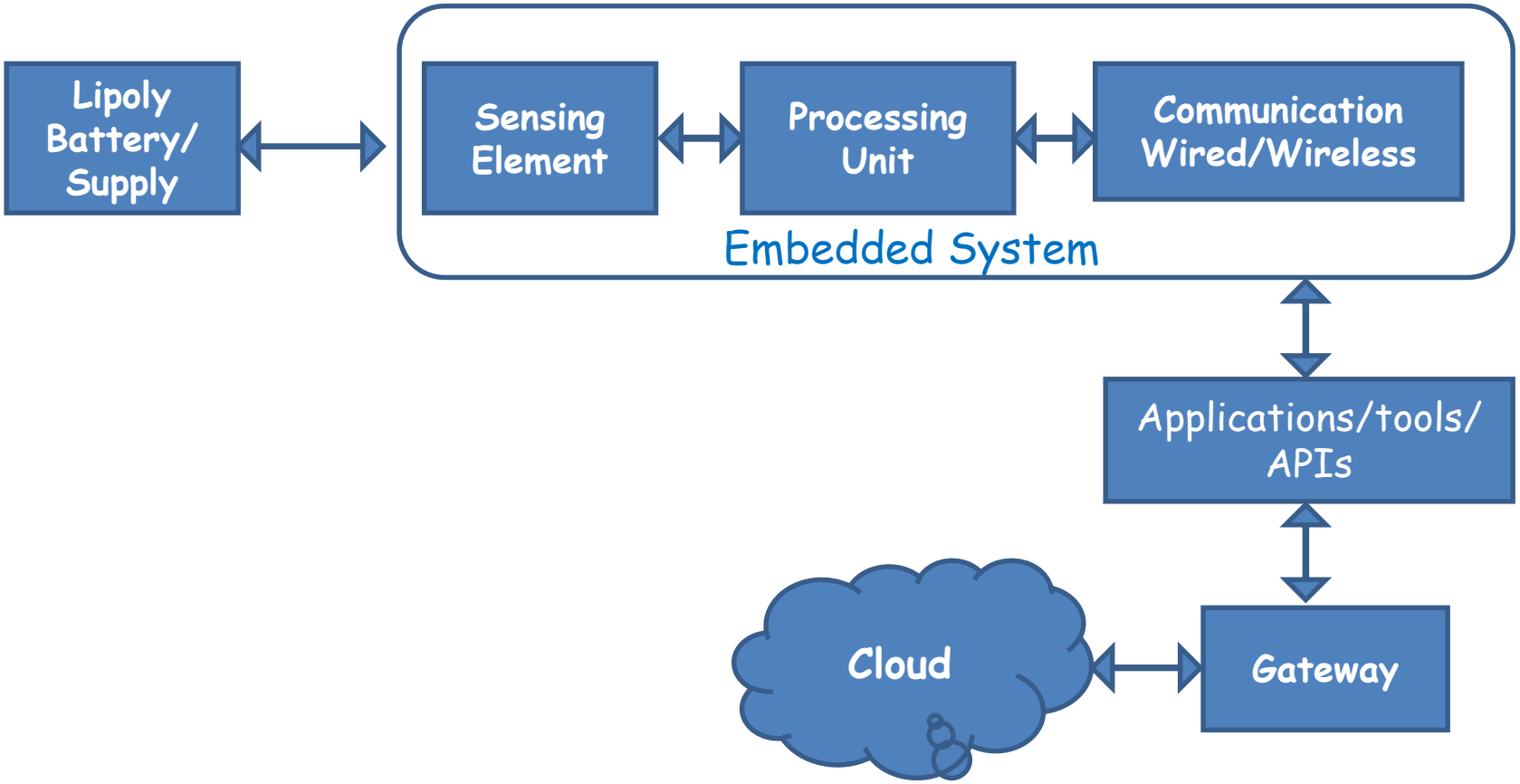
An IoT System



Machines ≡ Devices ≡ Sensors ≡ Things!

Sensors and IoT

An IoT System



Sensors

- A **sensor** typically measures or identifies a particular physical quantity.

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- Sensors convert the physical properties to electrical signals understandable by machines.

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- Sensors are ubiquitous.

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- Sensors convert the physical properties to electrical signals understandable by machines.

- Sensors are ubiquitous.

- Think about some quick examples!!

Thank you, Mother Nature!

Ears

Nose

Tongue

Eyes

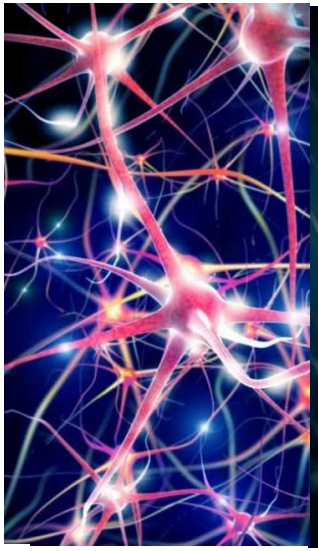
Skin

Image source: Internet

Thank you, Mother Nature!

Ears

Nose



Neural Network

Synapse

Tongue

Eyes

Skin

Image source: Internet

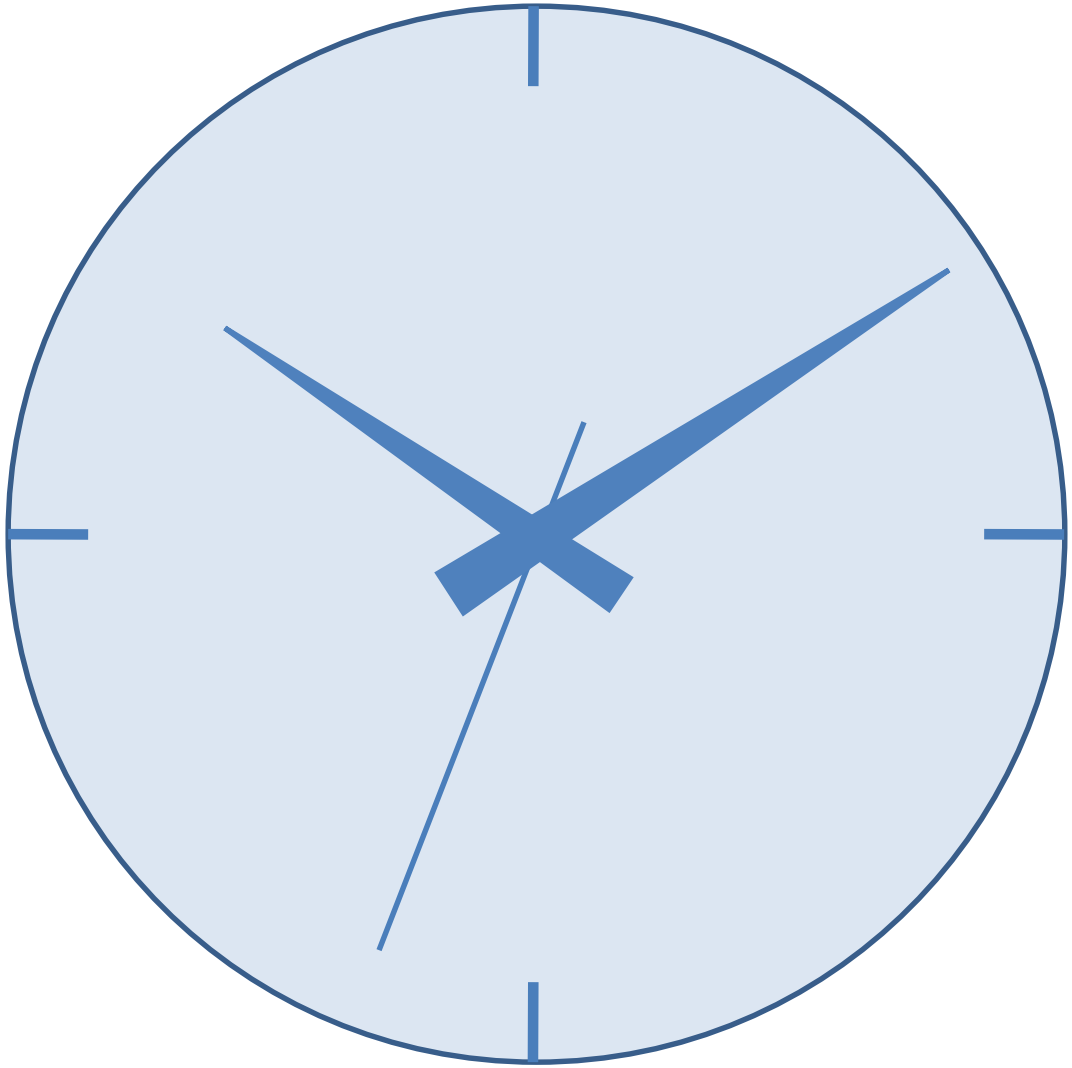
Sensors Are Everywhere!

Image source: Internet

Human made Sensors

- Temperature
- Humidity
- Photodiode (Light)
- Pressure
- Proximity
- Compass (Magnetic Field)
- Motion (Linear & Angular)
- Gas concentration
- Microphone
- Touchscreen
- Camera
- Antenna
  - Receiver / Radio
  - GPS, GSM, WiFi, BT

Is Watch a Sensor?

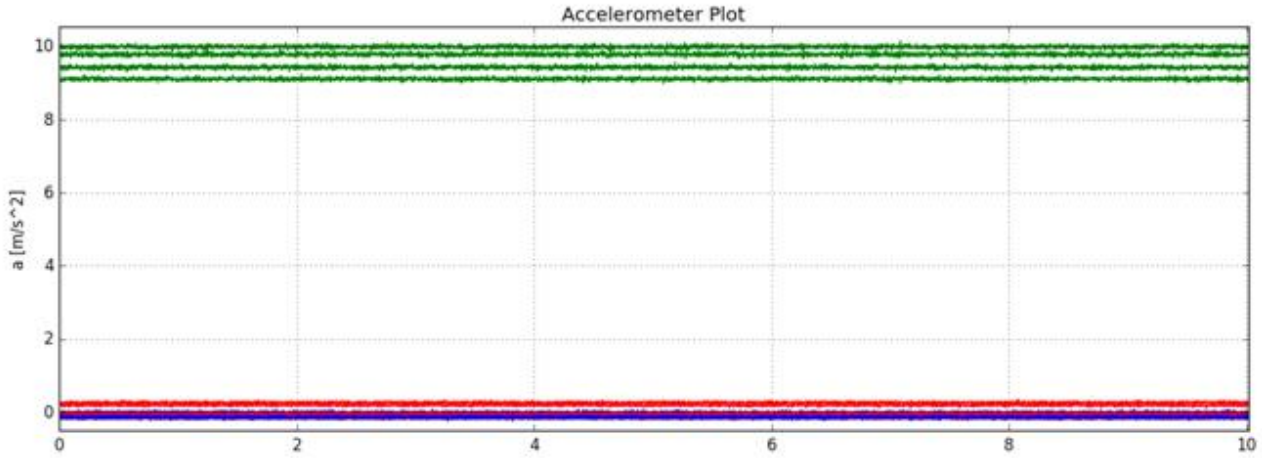


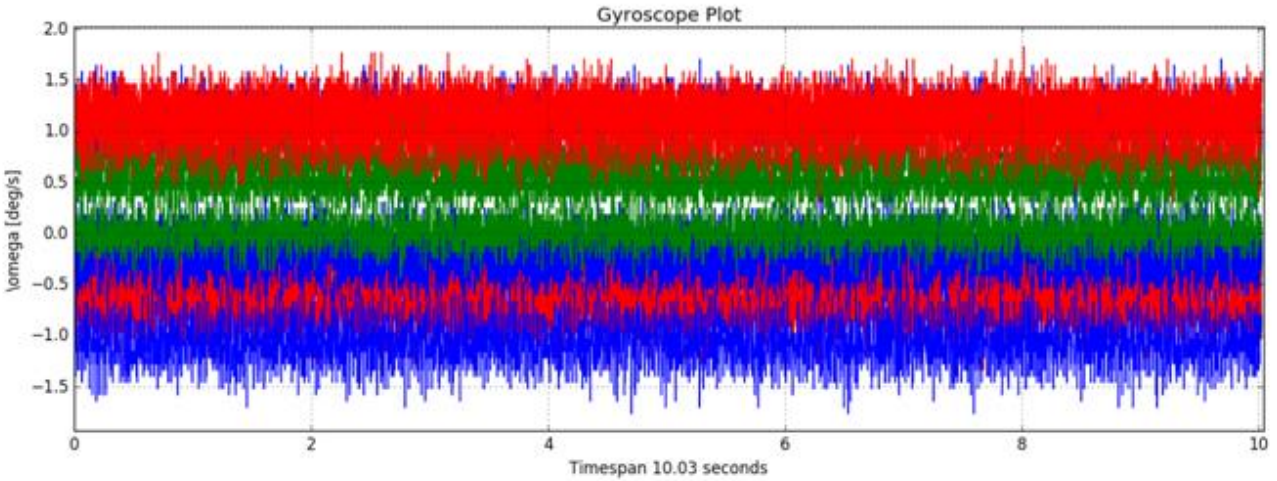
Is RFID tag a sensor?

Image source: Internet

Intrinsic Noise in Sensors

Response of a static multi-IMU system



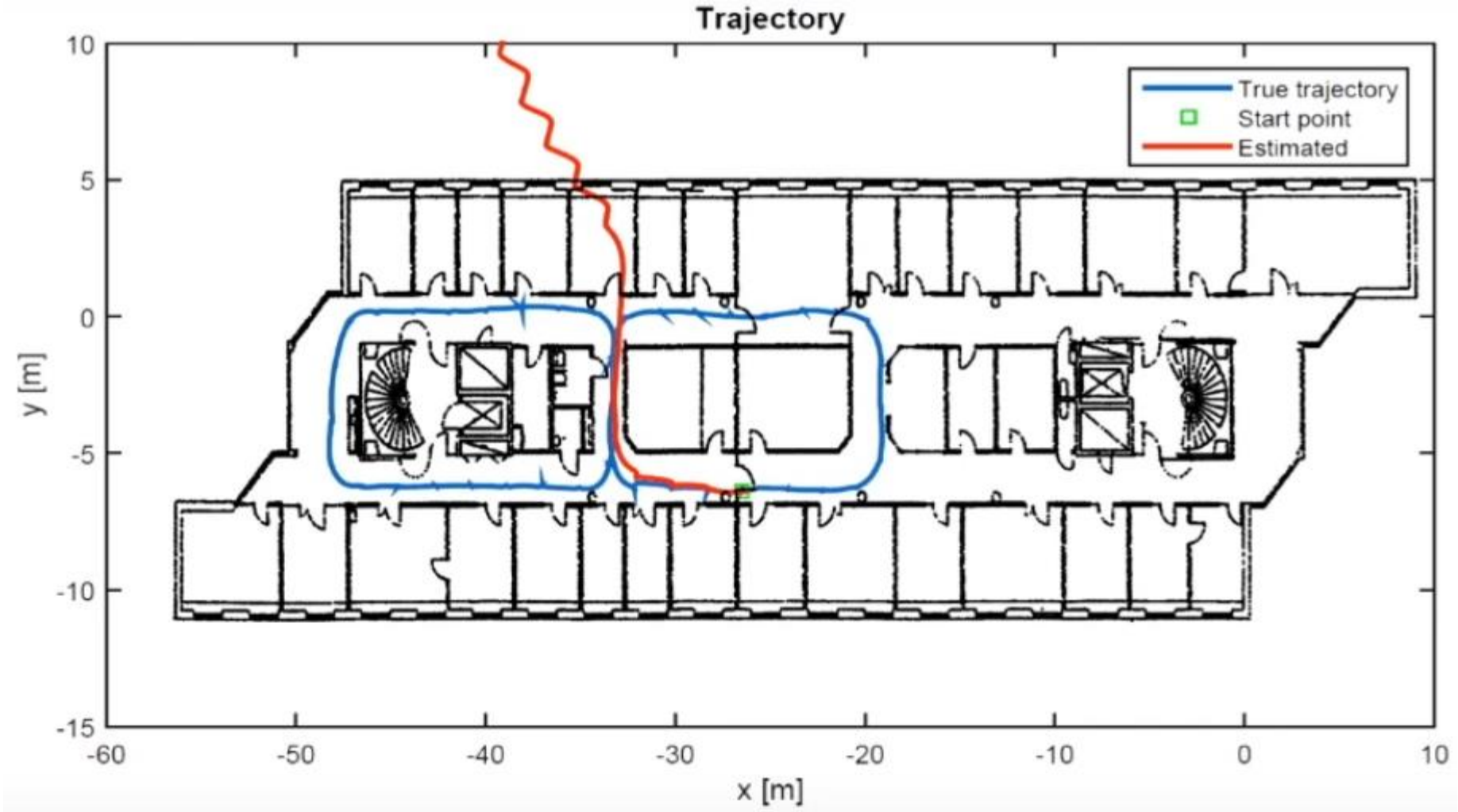


Did you observe
- Noise
- Non-aligned response

Same color data indicates same direction acceleration/rotation, but from different sensors (IMUs)

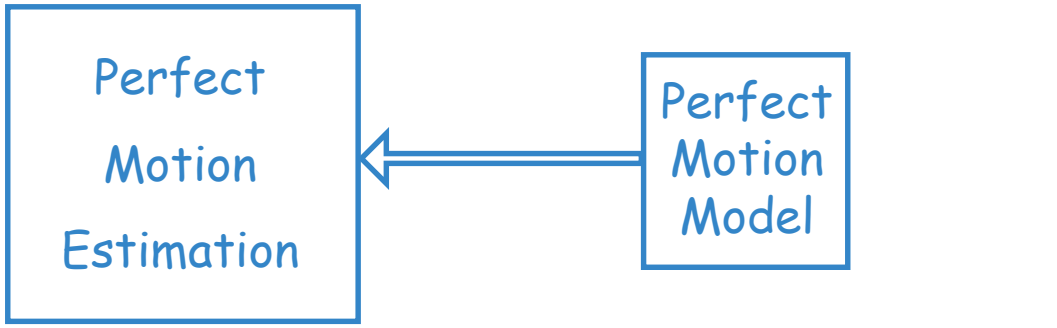
Courtesy: oblu.io

Example: Position Error Growth



Working with Low-cost Sensors

Example: Motion Sensors



(Motion sensors not required)

Working with Low-cost Sensors

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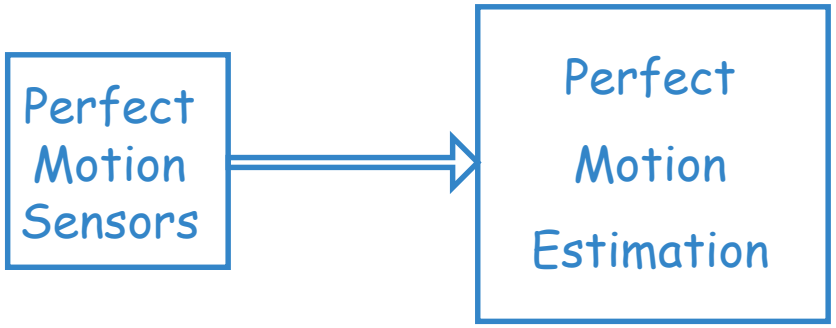

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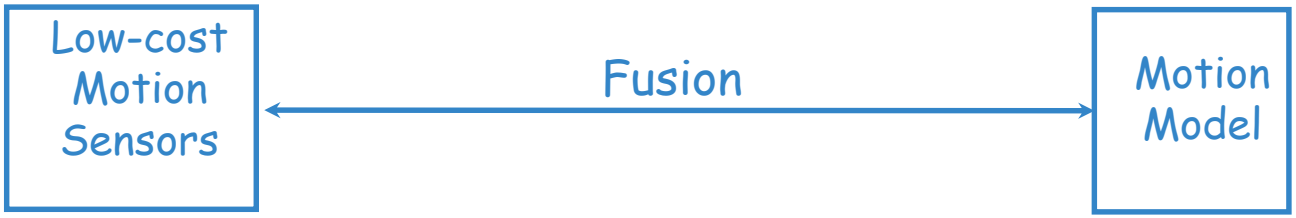

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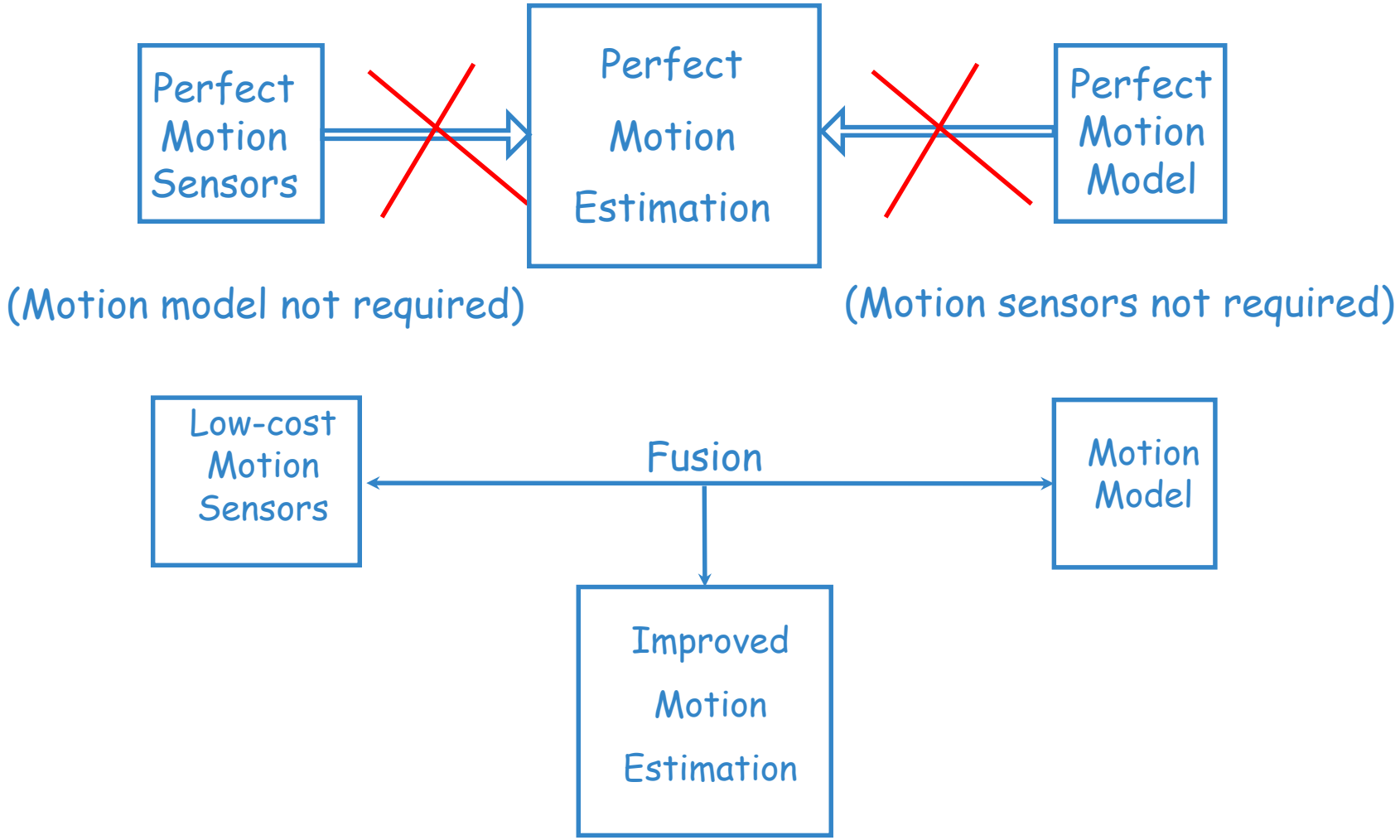

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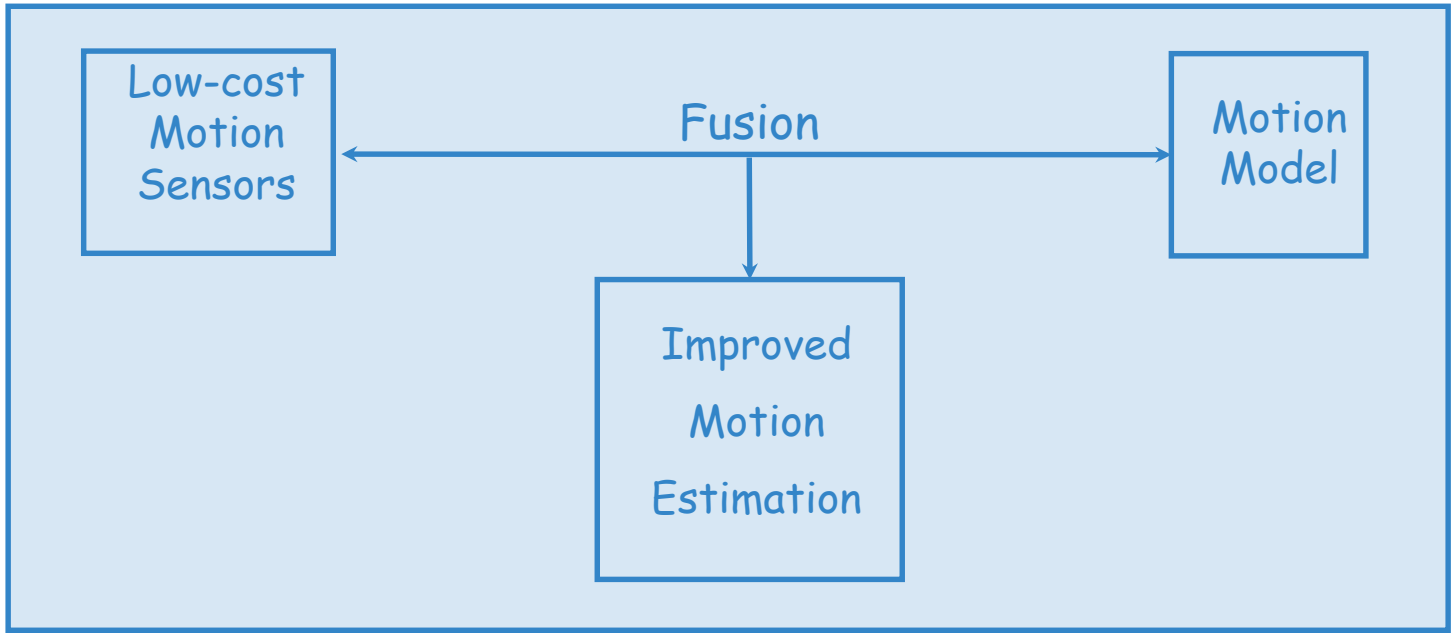

Example
Position Estimation of Stacker Reclaimer

Motion model: This huge machine moves in straight line!

Image source: Internet

Smart Sensor Nodes for IoT

Only a Sensing Element

Image source: Internet

Only a Sensing Element

Intra Cranial Pressure (ICP) Sensor for Brain Fluid Pressure Monitoring

Cylindrical shape tip; Dia ~ 2mm

Image source: Internet

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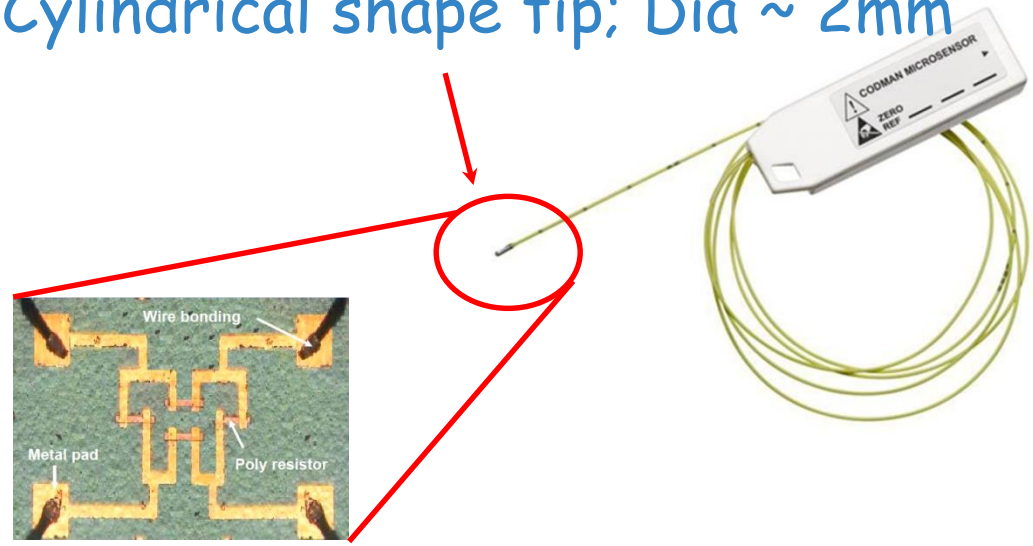

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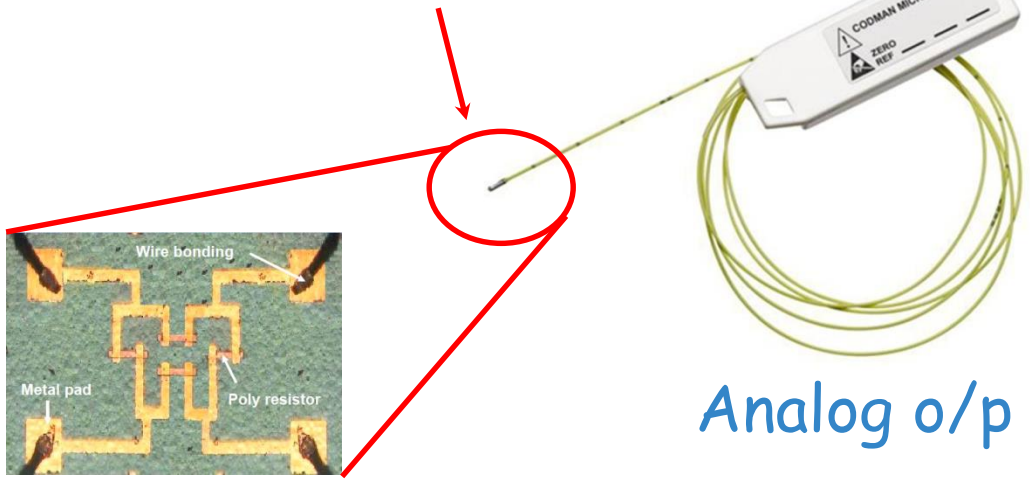


Analog o/p

Tip contains only the pressure sensing die. All other electronics outside.

Image source: Internet

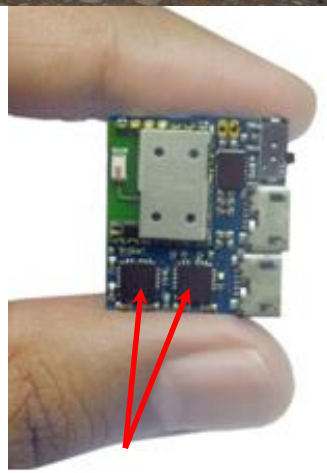
A Sophisticated Sensor Node

PDR Sensors for Indoor Pedestrian Positioning

What is inside?

- Four 9-axis IMU chipsets
- 32b floating pt μController
- Bluetooth
- USB interface
- Battery mgmt ckt
- LED indicators
- Power switch
- JTAG i/f

Digital o/p



9-axis IMUs

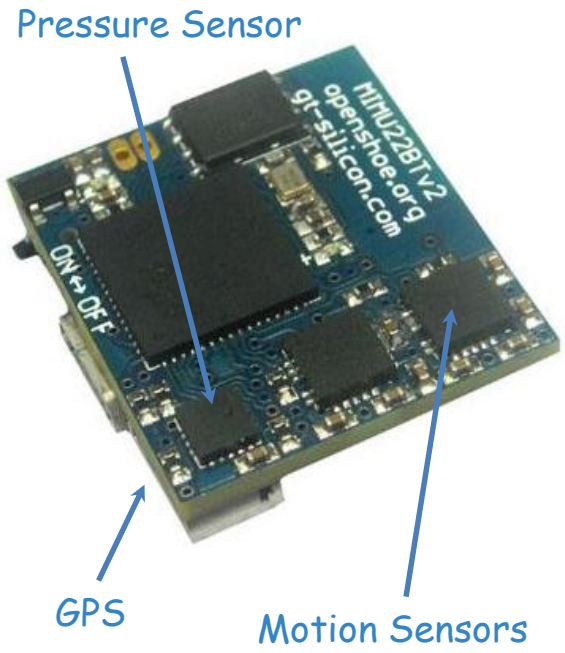
Image courtesy: InertialElements.com

Multi Sensor Systems

Courtesy: InertialElements.com

Multi Sensor Systems

Classical Multi Sensor System

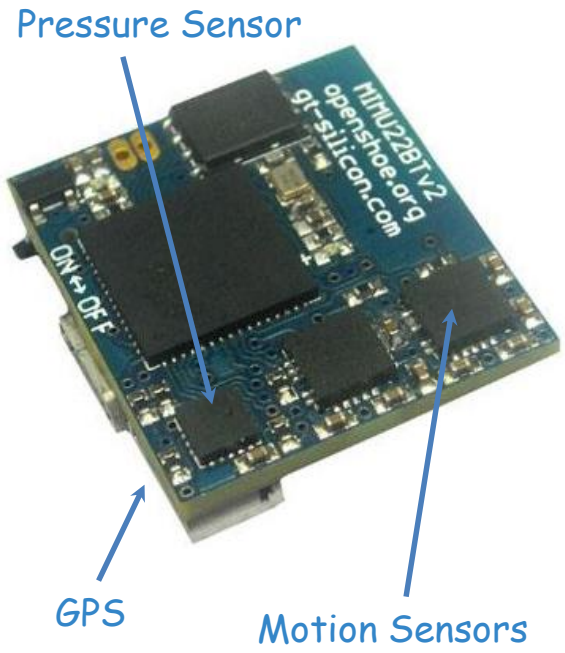


Fusing data from multiple sensors enhances performance

Courtesy: InertialElements.com

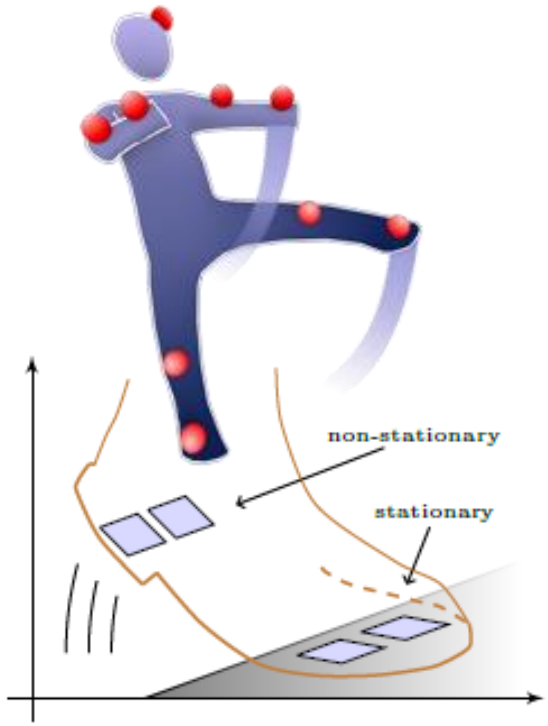
Multi Sensor Systems

Classical Multi Sensor System



Fusing data from multiple sensors enhances performance

Multi-Sensor Joint System



Multiple non-rigidly connected IMUs results in dynamic diversity

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Multi Sensor Systems

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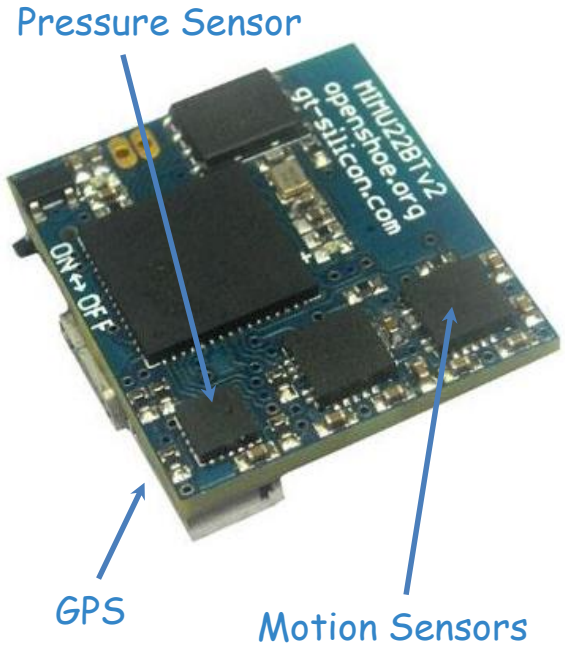

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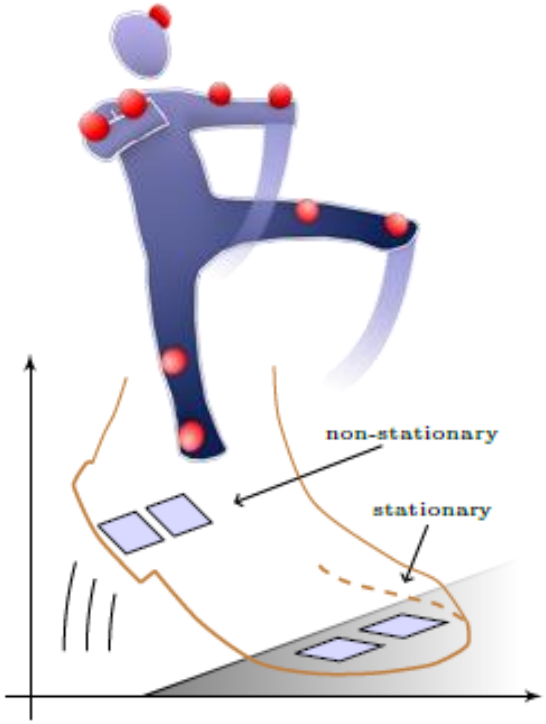
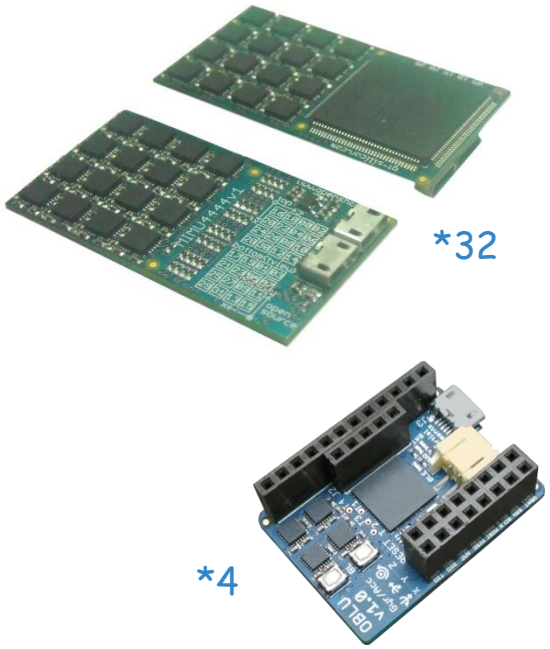


Multiple non-rigidly connected IMUs results in dynamic diversity

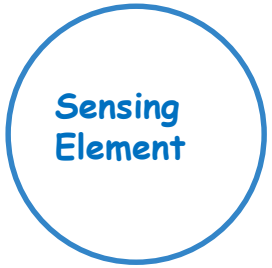
Collocated Multi-Sensor System



An array of well placed IMUs… provides new opportunities of sensing

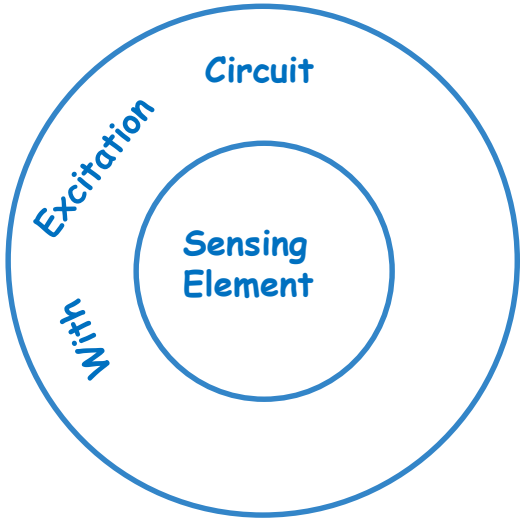
Courtesy: InertialElements.com

A Smart Sensor Node for IoT



Sensing Element
- MEMS / Chemical etc
- Responds to physical world

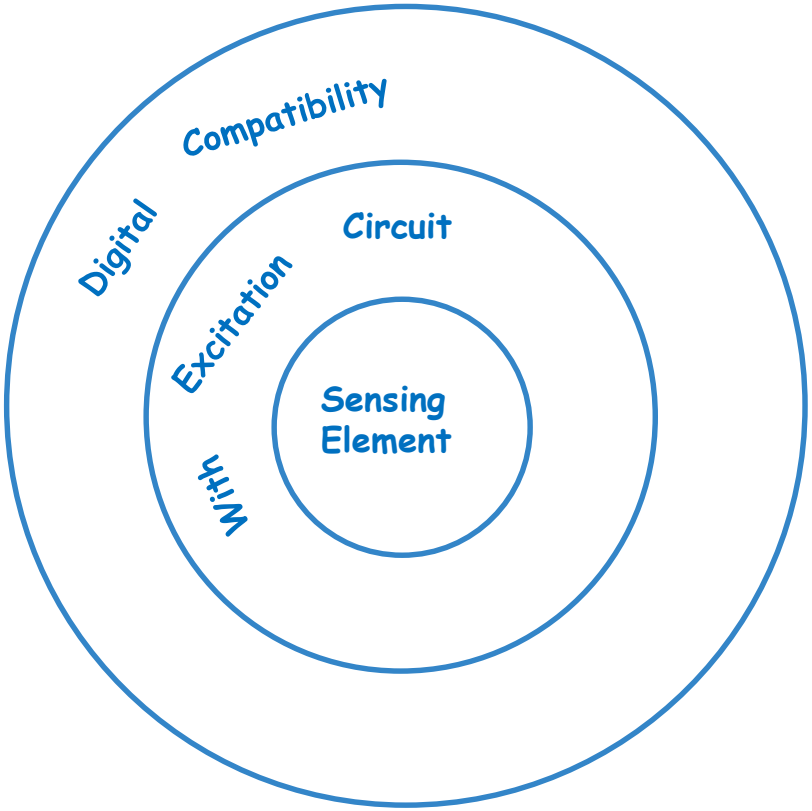
A Smart Sensor Node for IoT



Sensing Element
- MEMS / Chemical etc
- Responds to physical world

Excitation Ckt
- To excite electrically
- Amplification etc

A Smart Sensor Node for IoT



Digital Compatibility
- Analog to Digital
- Data xfer protocols

Sensing Element
- MEMS / Chemical etc
- Responds to physical world

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- To excite electrically
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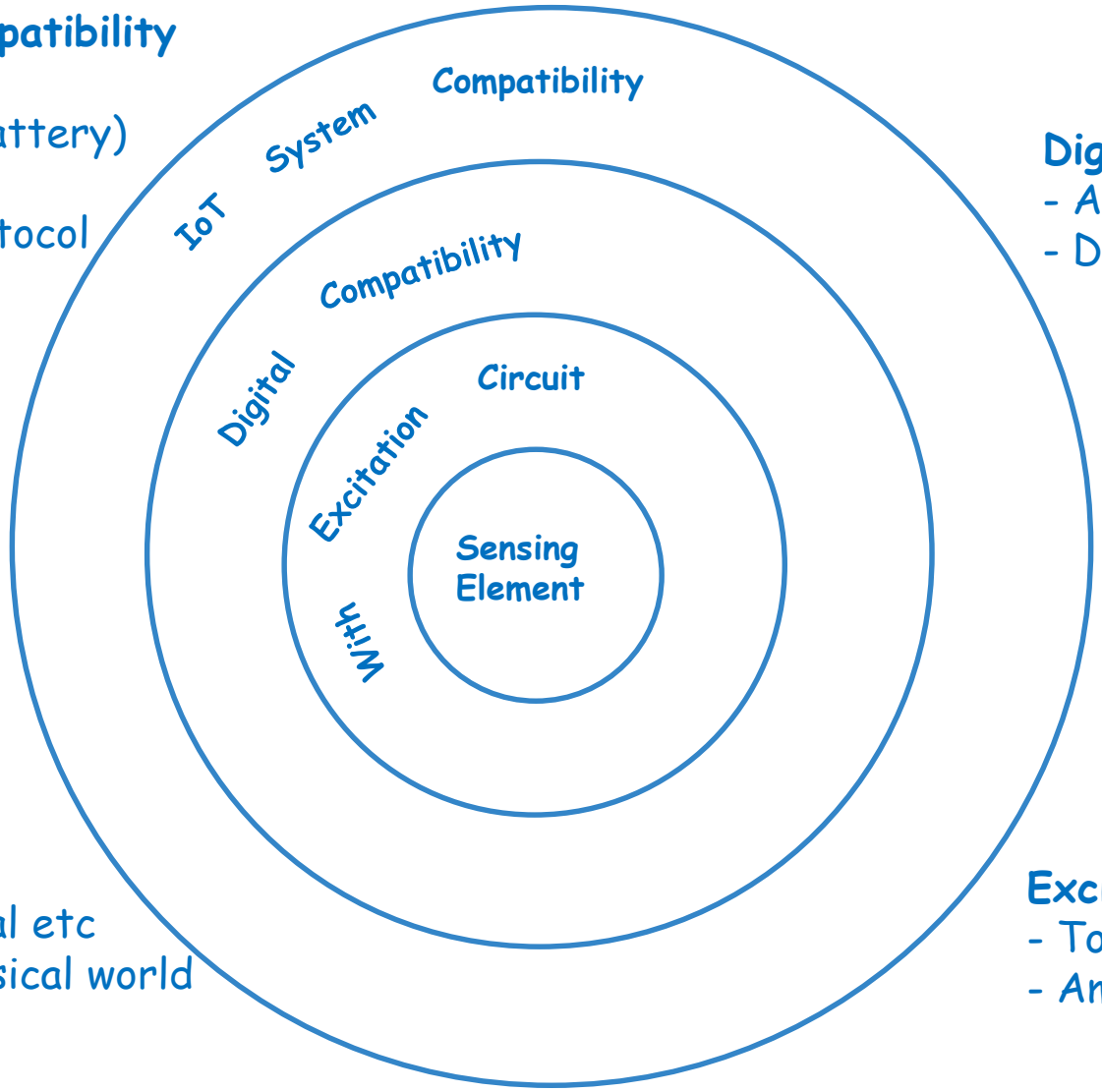
A Smart Sensor Node for IoT

IoT System Compatibility
- Computation
- Power Mgmt (Battery)
- Wireless
- Data comm. protocol



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Excitation Ckt
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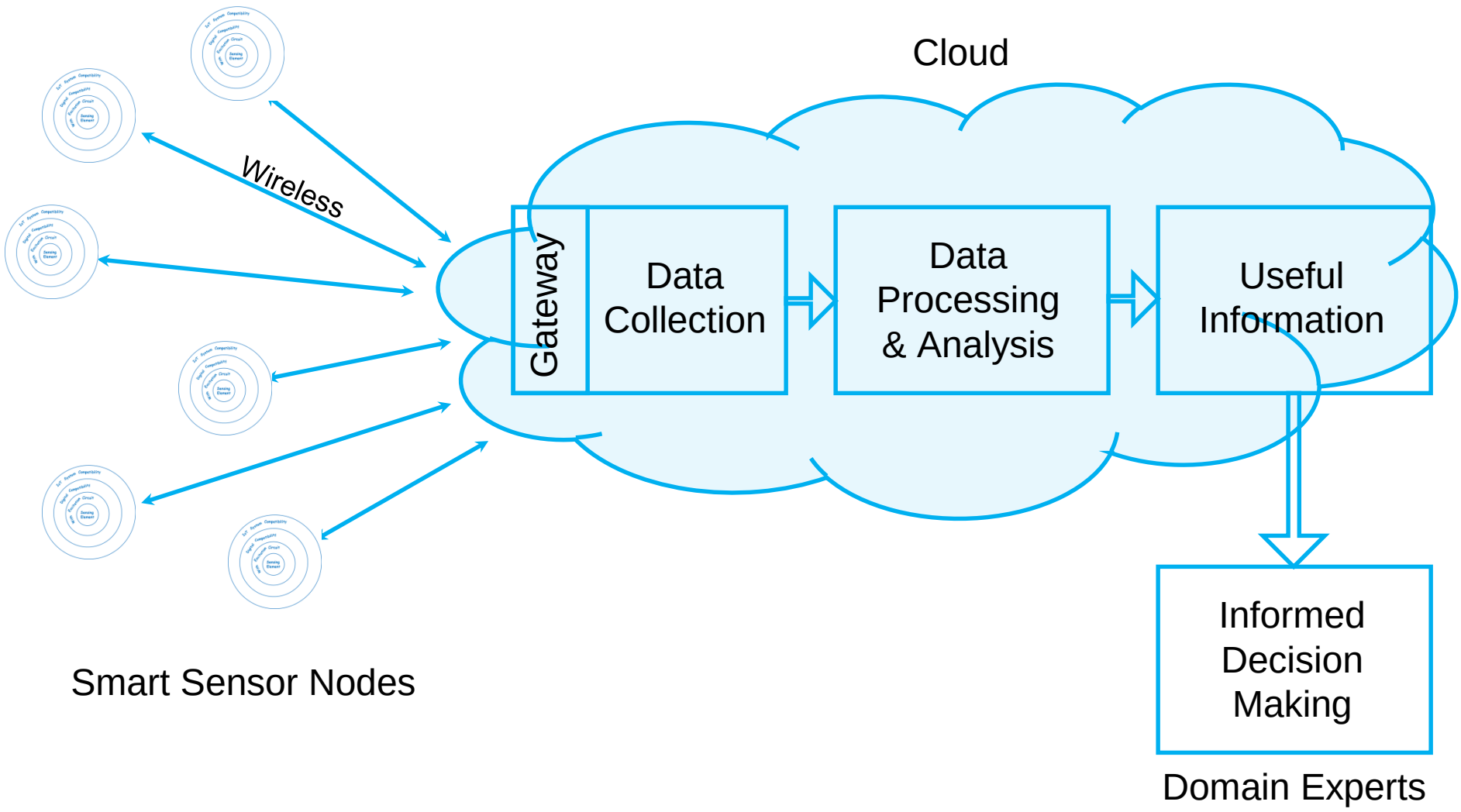
- Amplification etc

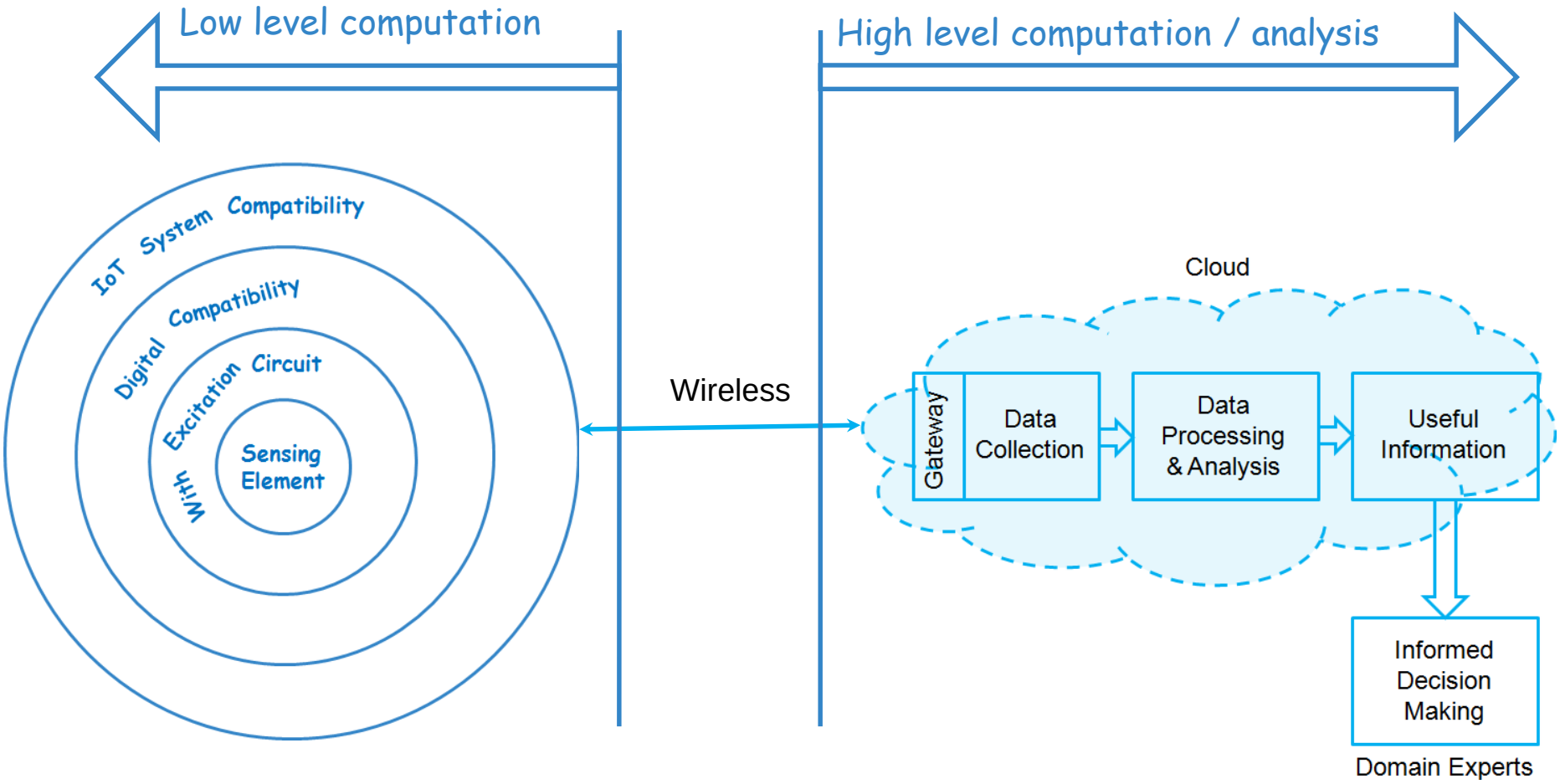
A Smart Sensor Node for IoT

- Important system design coordinates
  - Performance
  - Power
  - Area
  - Cost
- Important for IoT → S.C.A.L.E. !

IoT System with Smart Sensors



Distribution of Computation



Desirable

- Increased capabilities at the local node
- Reduced requirements on the connectivity
- Providing the back-end with high level information
- Simplified data interface

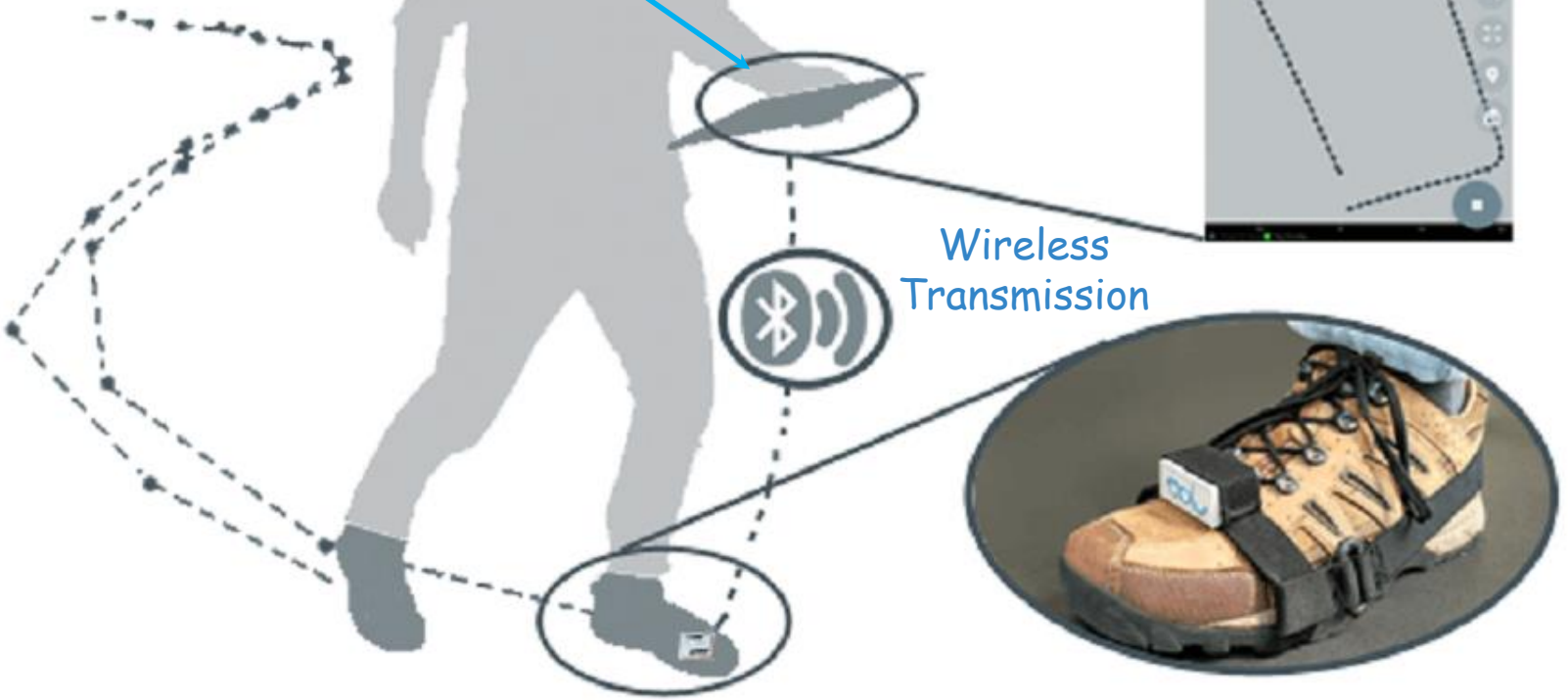
Case Study: Shoe-mounted PDR Sensor

Realtime Monitoring Application

Path construction (PDR)
on application platform

Positioning
w/o GPS !

Wireless
Transmission

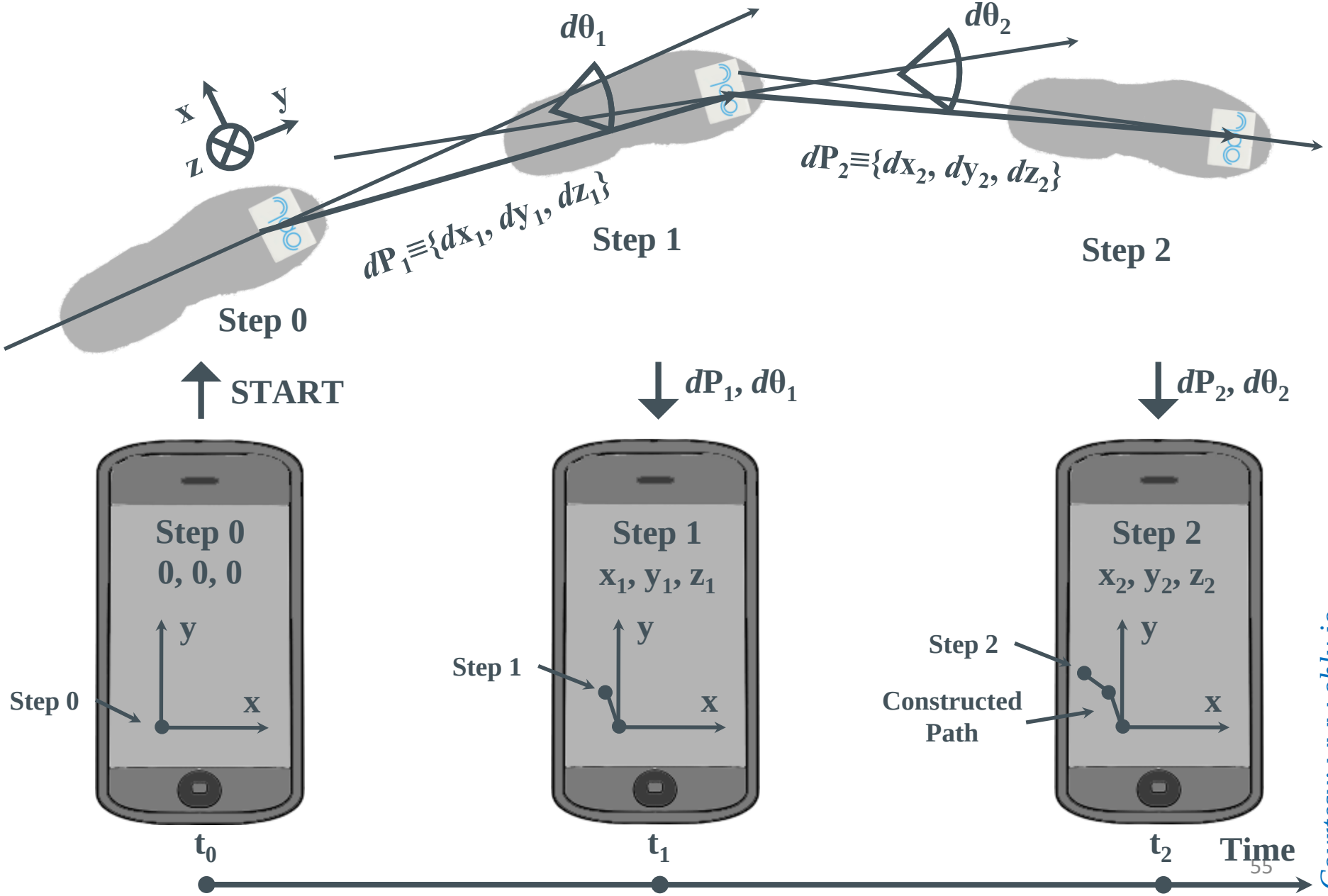


Inside the sensor: Calibration compensation, sensor fusion and navigation equation

Shoe Sensor proving high level information

Courtesy: www.oblu.io

Extremely Simplified Interface!



Courtesy: www.oblu.io

IoT System Overview

Capturing Real World

- What attributes of a system you would like to capture?
  - System's state and immediate surrounding

- How would you monitor a moving machine? Say, a robot.
  - By attaching sensor devices

What if you have to monitor humans?

- How is monitoring (sensing) of humans different from robots?

Image source: wikipedia.org

What if you have to monitor humans?

- How is monitoring (sensing) of humans different from robots?

- Human Behavior
  - Different abstraction level
  - Hard to completely capture by a machine

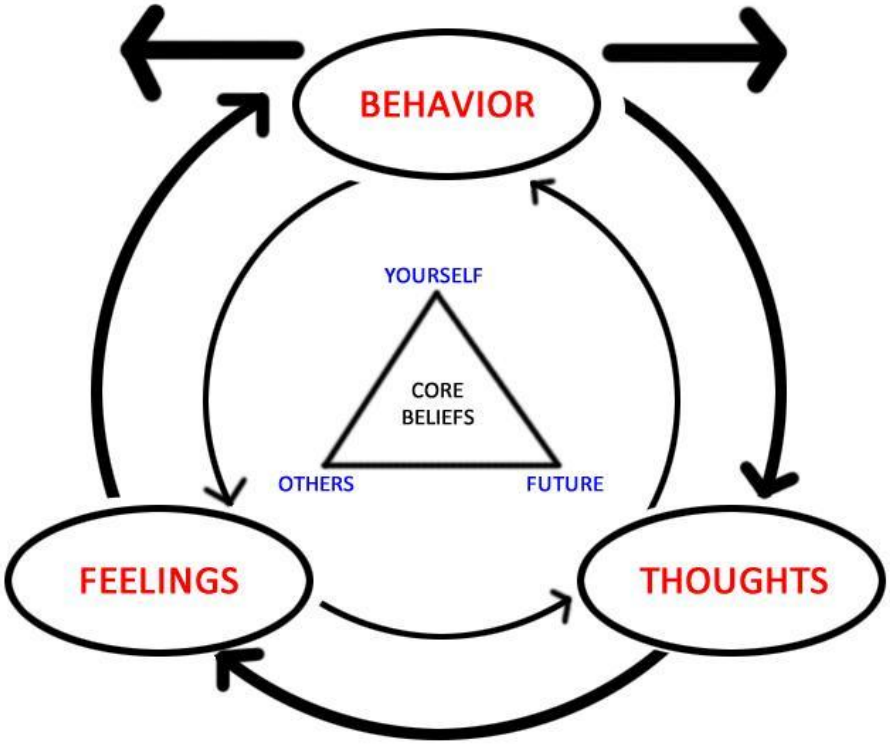


Image source: wikipedia.org

How to Monitor Humans?

...and super humans

Image source: costumekart.com

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Smartphone – A Sensor Hub

What is a sensor ?

- Touchscreen
- Light
- WiFi
- Wind speed
- Bluetooth
- GPS
- Proximity
- Barometer
- Tilt
- Magnetometer
- Accelerometer
- Gyroscope
- Temperature
- Humidity

Image source: Internet

How to Monitor Humans?

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How to Monitor Humans?

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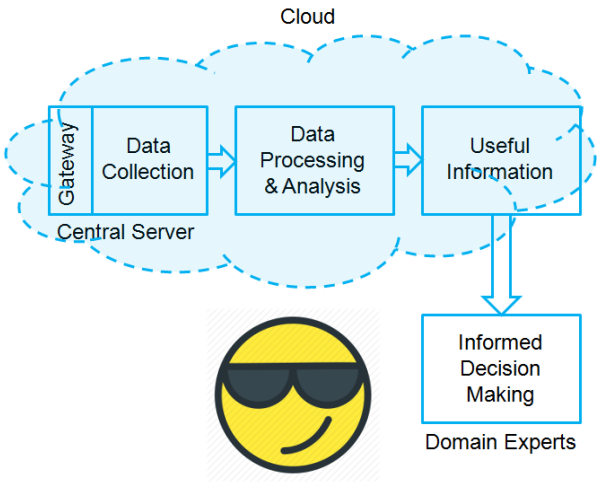


Image source: tenor.com

Image source: dailymail.co.uk

How to Monitor Humans?

...and super humans

Personality / State of mind (UI)
+
Operating Conditions (activity, surroundings, location)

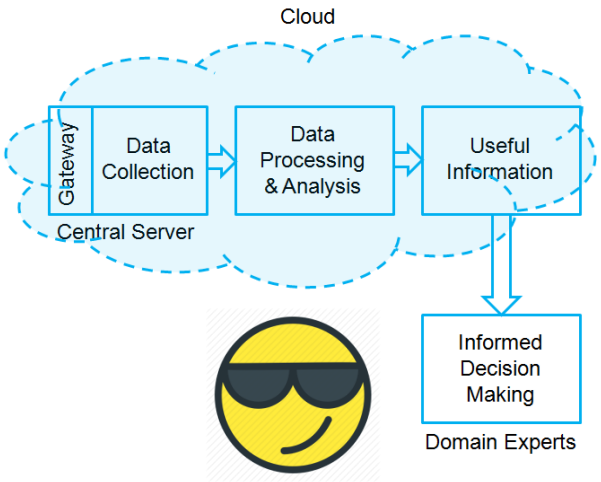


Image source: tenor.com

Image source: dailymail.co.uk

Download my App and allow me to monitor you!

Download my app and get discount on your first transaction!

Special discount on placing order from our app!

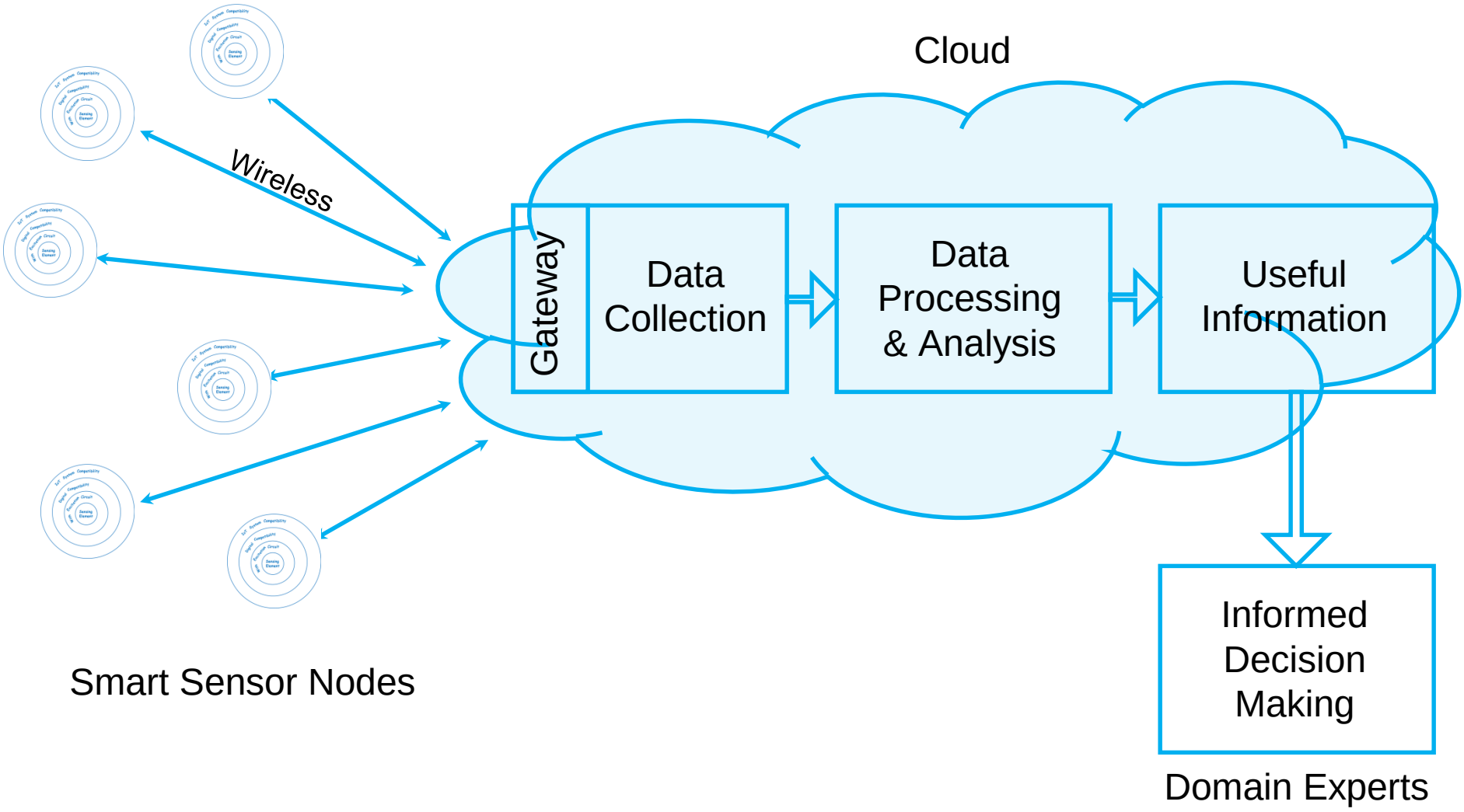
Download my app. Forever free services!

Download my app. Please...

Every active App transmits data to a separate cloud !

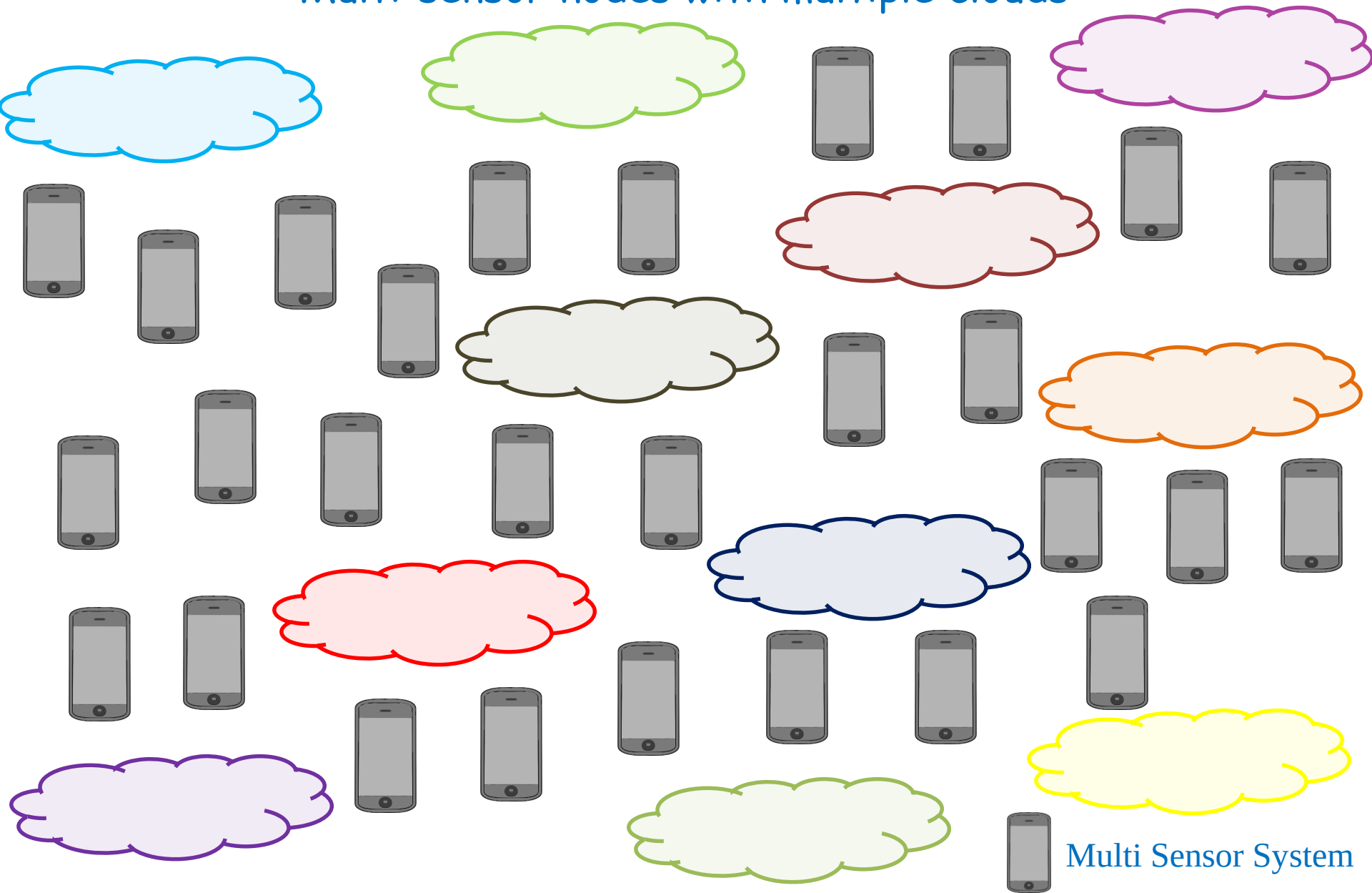
Image source: igdigital.com

A Typical IoT System



A Gigantic IoT System

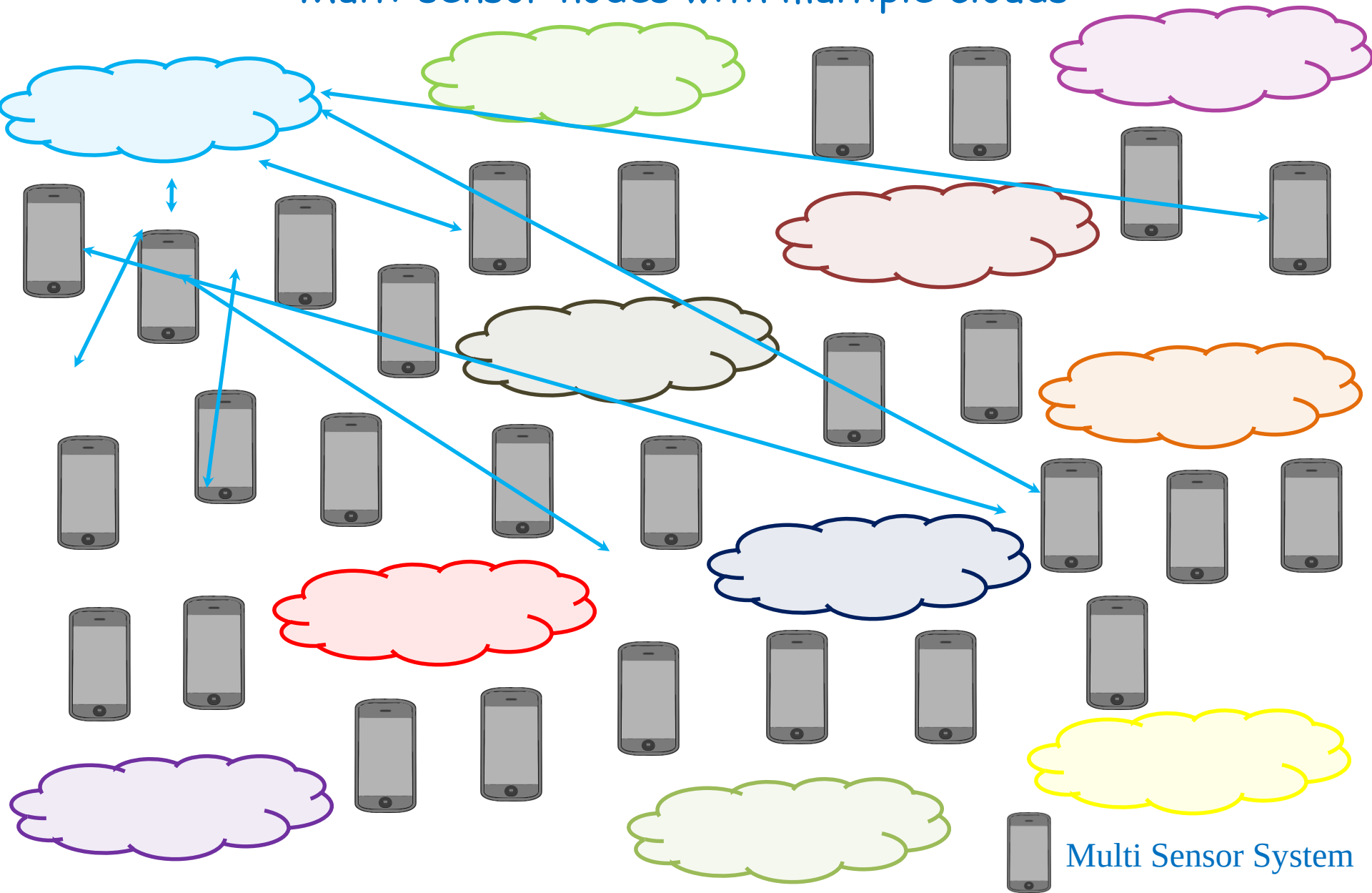
Multi-sensor nodes with multiple clouds



Multi Sensor System

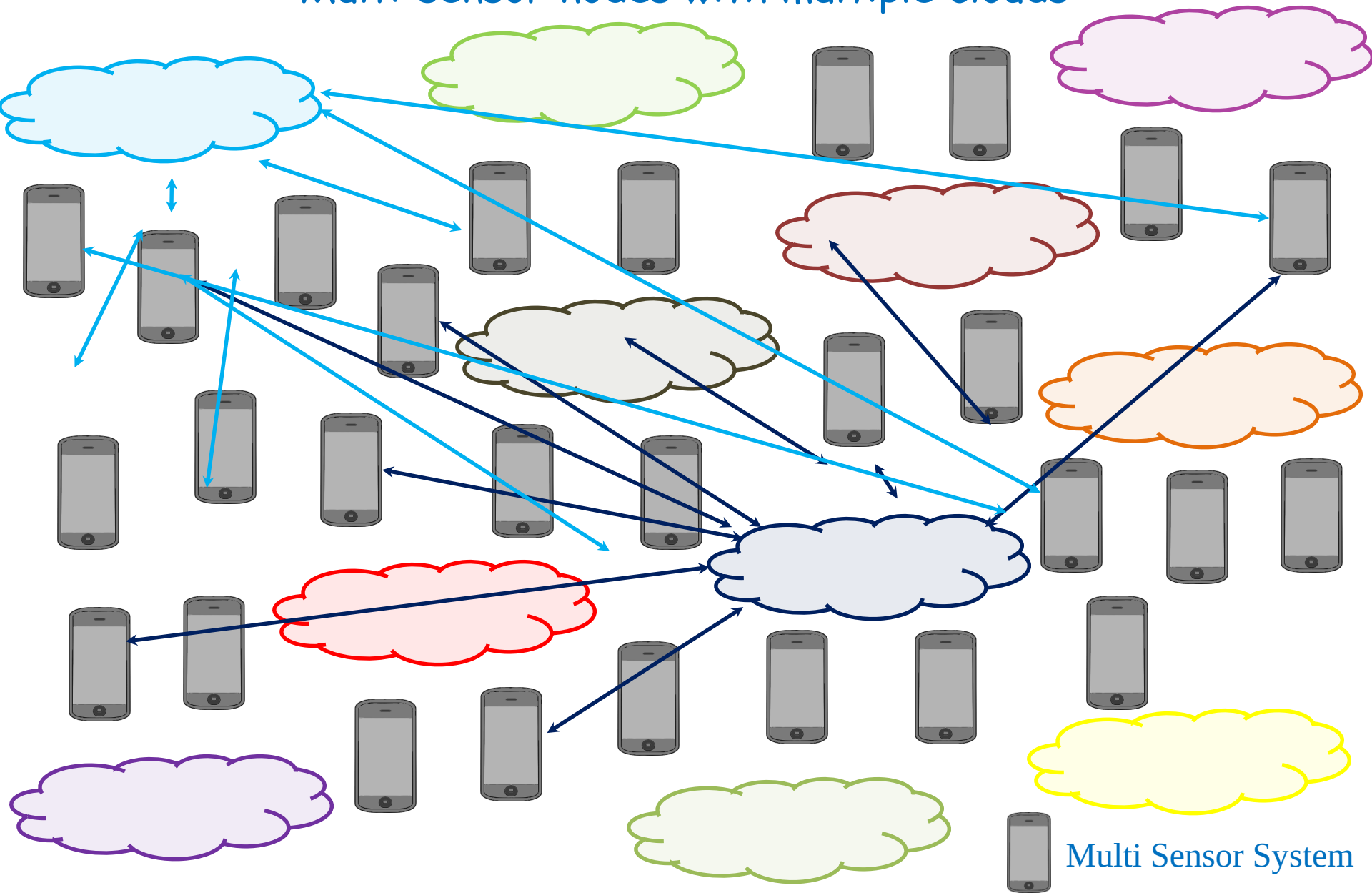
A Gigantic IoT System

Multi-sensor nodes with multiple clouds



A Gigantic IoT System

Multi-sensor nodes with multiple clouds



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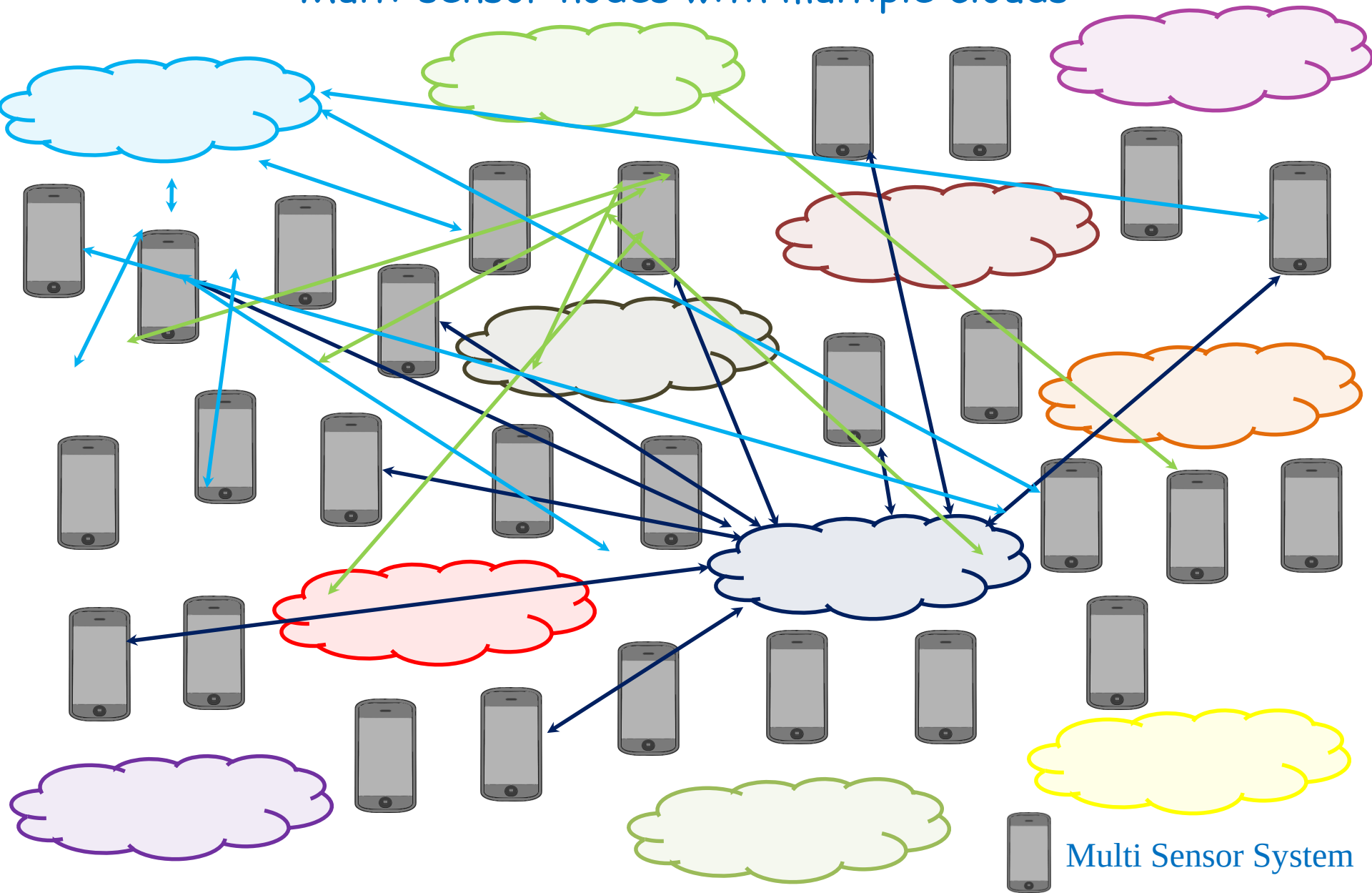

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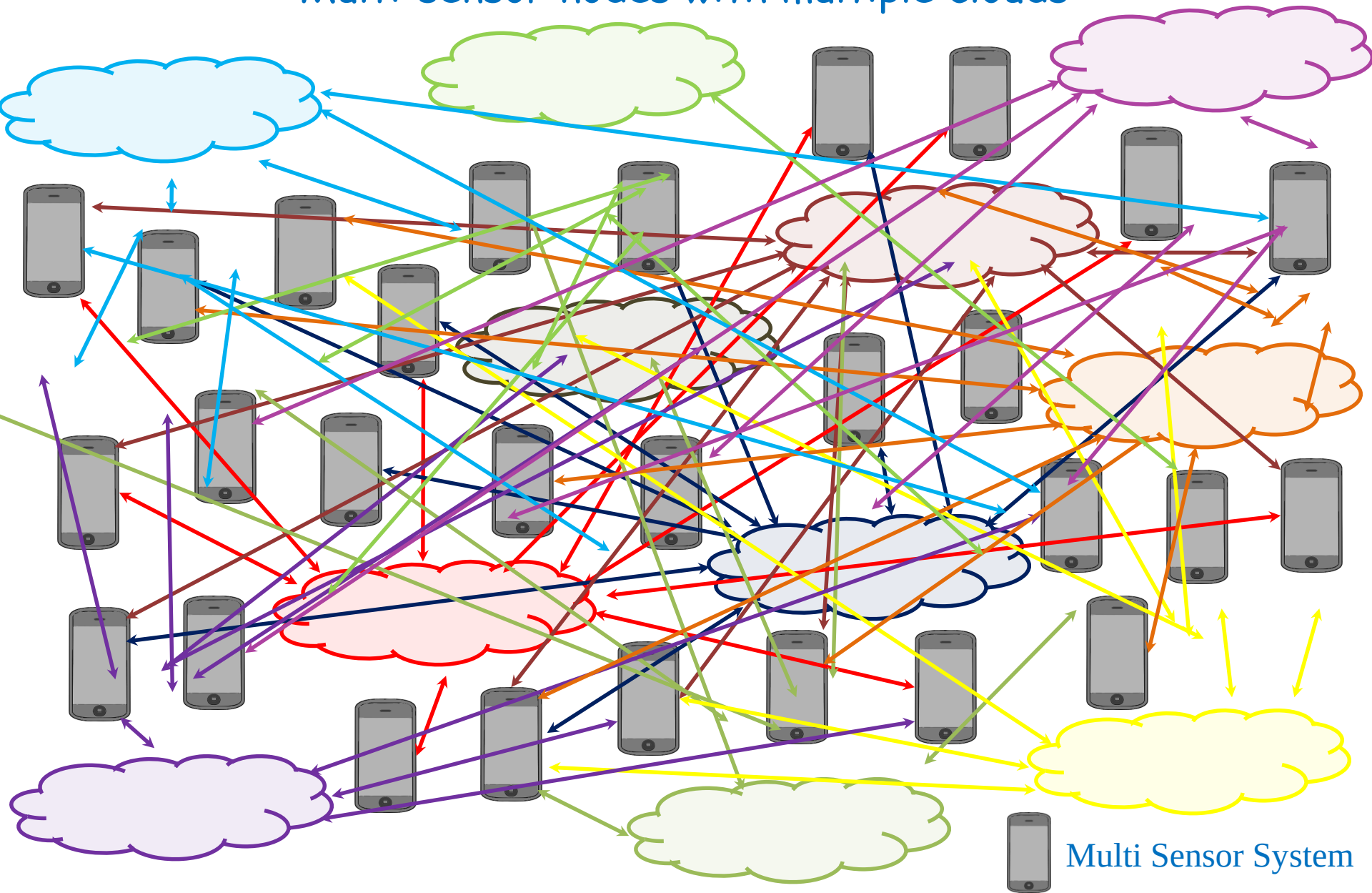


Smart Grid

- Grid: Electricity Network
- Smart Grid: Intelligent Electricity Network
  - Automatically monitor and manage grid
  - Using smart meters and other smart devices
  - Gain insights about usage for better efficiency
- For example
  - Load balancing
  - Accident prevention
  - Theft detection
  - Reduce power and revenue losses
- Two way flow of electricity and information

Smart Grid Components

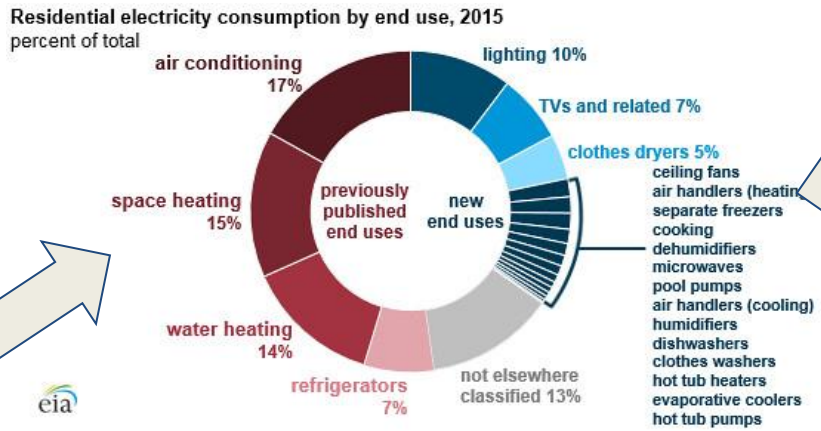
- Smart Appliances
- Smart Meters
- Smart Substations
- Synchrophasors

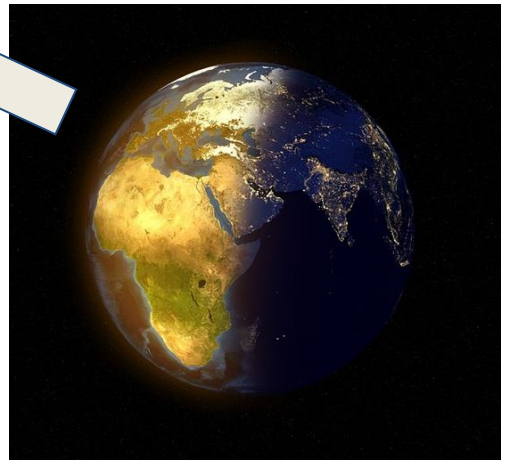
Smart Grid and IoT

IoT enabled home storage devices intelligently interact with the smart grid

- To understand the peak demand period
- If required, disconnect the home circuit from the grid to supply power on its own
- If required smart storage devices can add power supply to main grid.
- This two way electric flow convert consumer into prosumer (producer + consumer)

Smart Grid and IoT





Smart Grid and IoT: Challenges

- Privacy
  - Consumer data shared over the grid
  - Snooping, invasion, profiling possibile
- Security
  - Natural disasters, Physical/Cyber physical attacks
  - Blackouts (Venezuela 2019, Ukraine 2015)
- Fairness
  - How to distribute *fair share* of resources?

Reading

- https://www.telit.com/blog/iot-smart-grid-benefits/
- https://internet-of-things-innovation.com/insights/the-blog/smart-grid-technology-iot/#.XNVqYE5R2Uk
- https://www.slideshare.net/Eurotechchannel/iot-solutions-for-smart-energy-smart-grid-and-smart-utility-applications
- http://www.sanog.org/resources/sanog28/SANOG28-Conference_Smart-Grid-with-Internet-of-Things.pdf
- https://epic.org/privacy/smartgrid/smartgrid.html

Thank You