



Internet of Things: An Overview

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](mailto:karkare@cse.iitk.ac.in) (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](#)
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Code of Ethics

Internet

Internet

/ˈɪntənɛt/ 

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

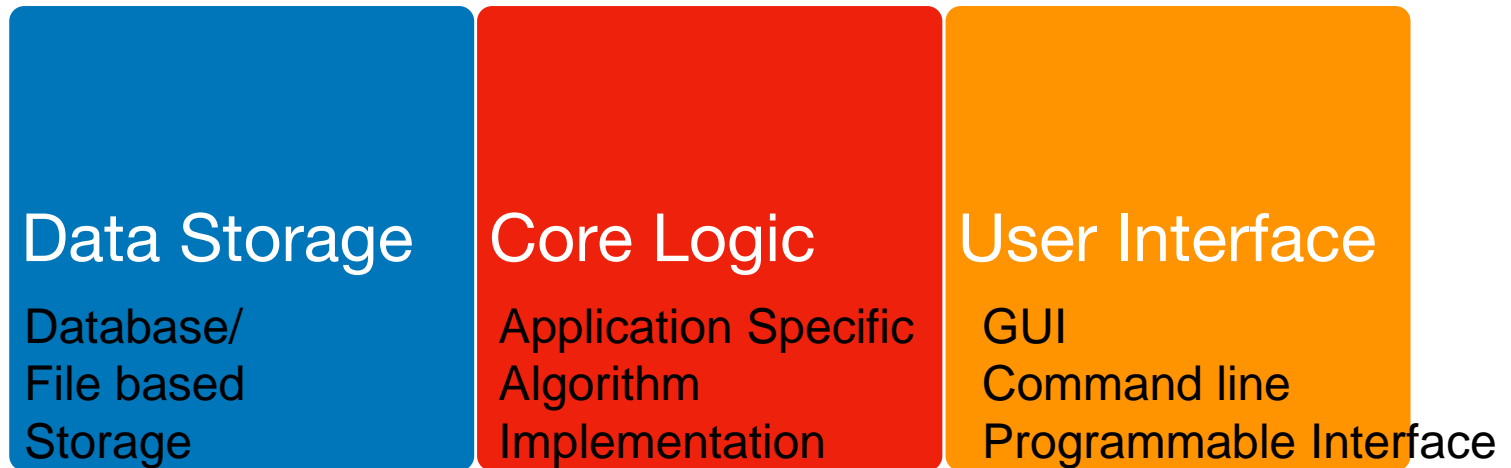
noun

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


```
graph TD; DS[Data Storage] <--> CL[Core Logic]; DS <--> UI[User Interface]; CL <--> UI;
```

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

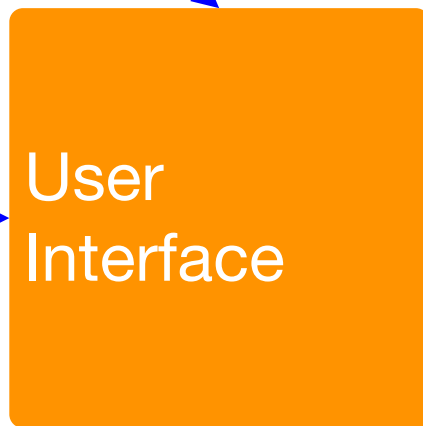
IoT and Cloud



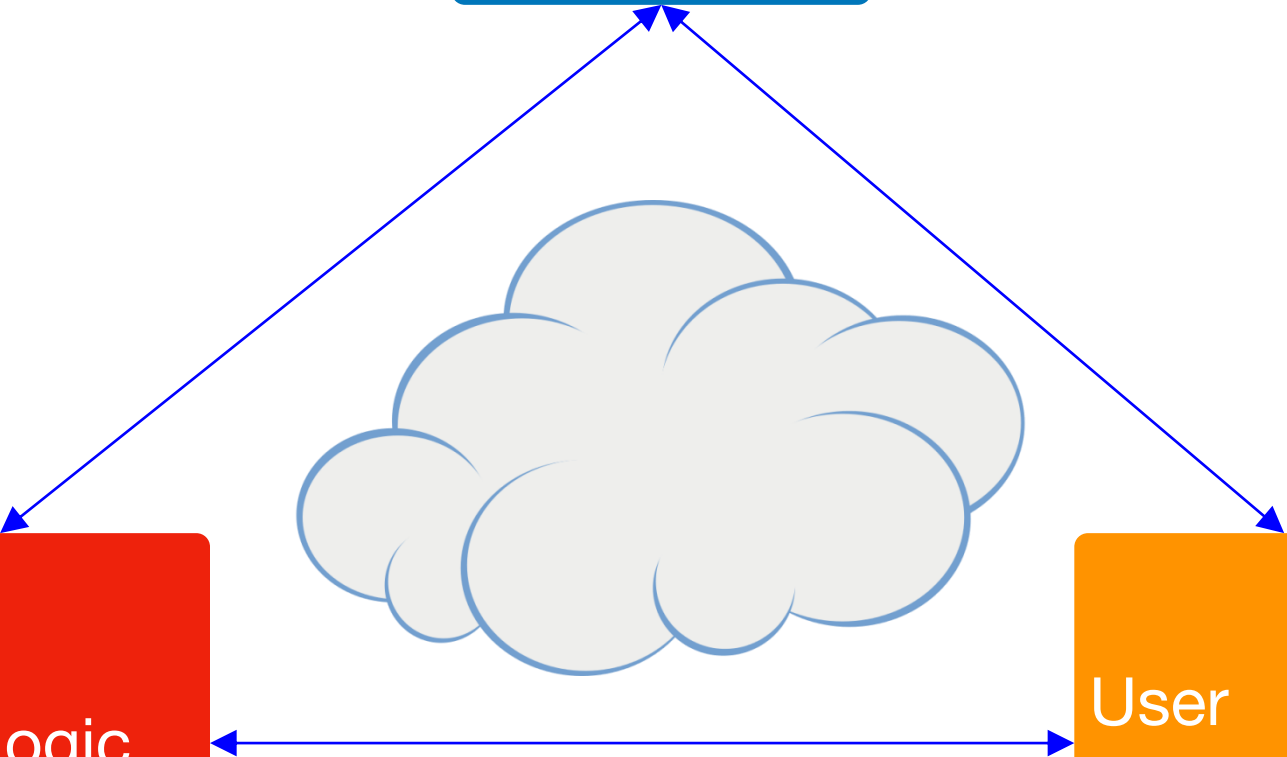
Data
Storage



Core Logic



User
Interface



Data
Storage

Core Logic

Sensors

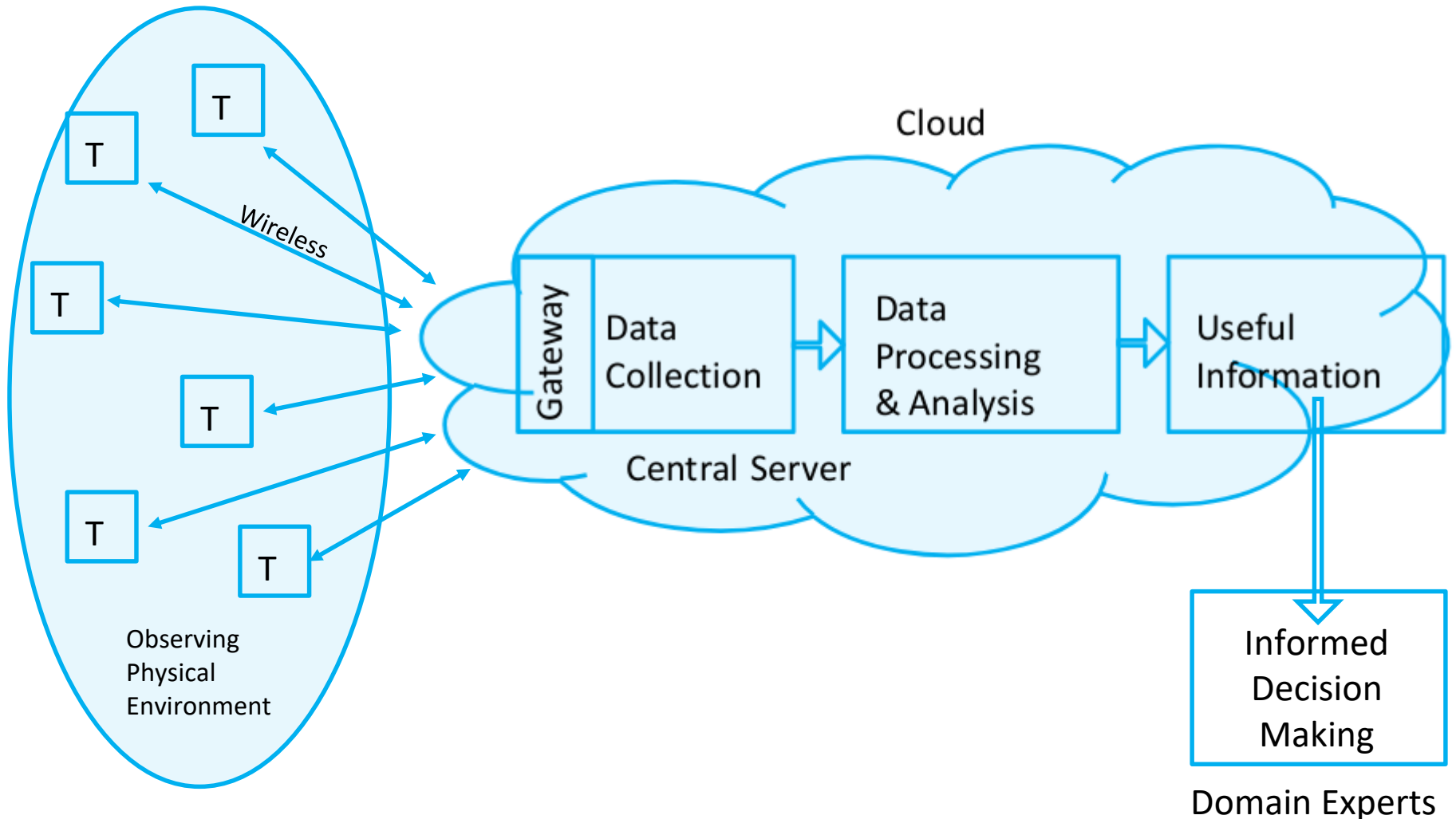
Motion,
Temperature,
RFID readers ...



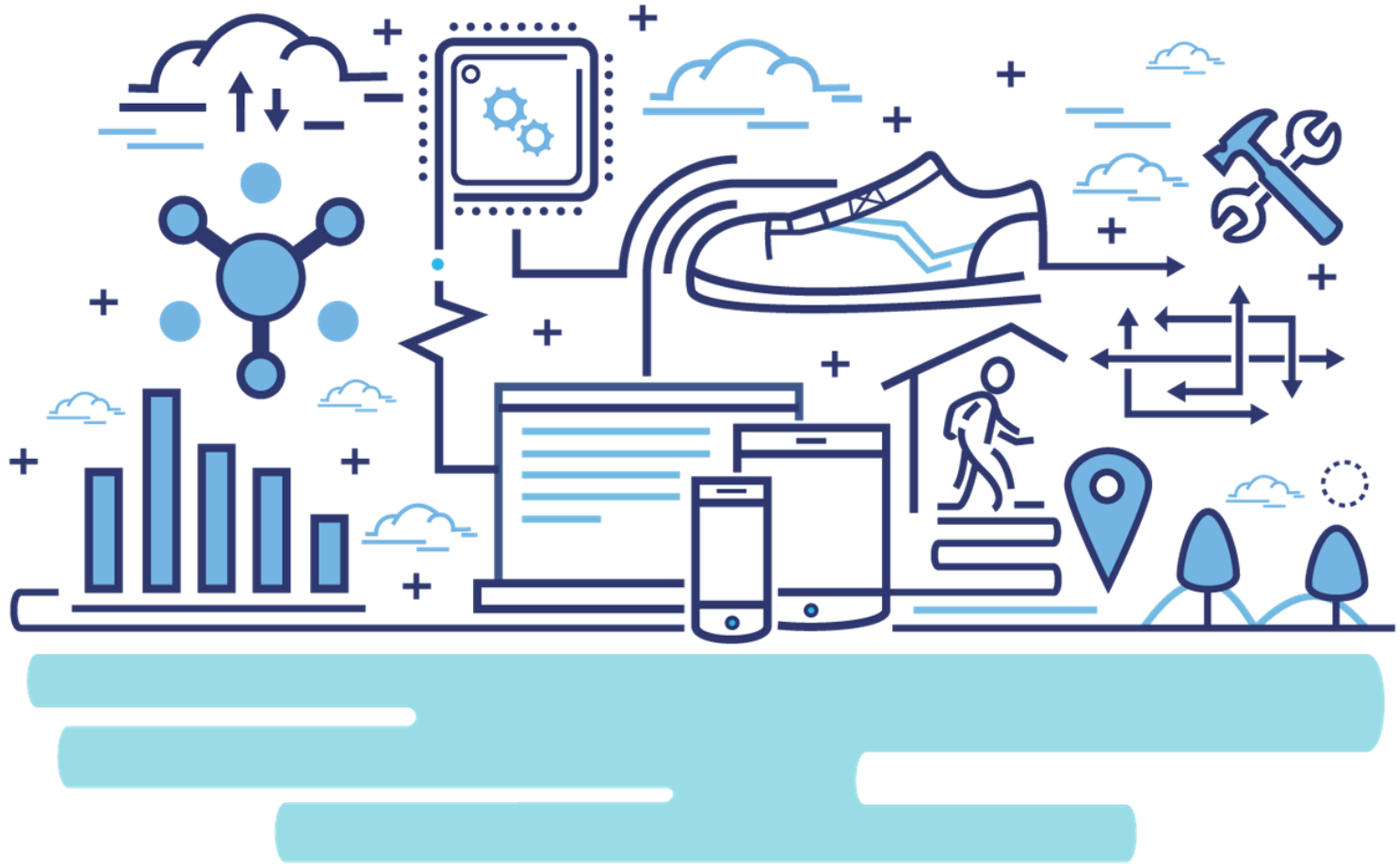
Internet of Things

- **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

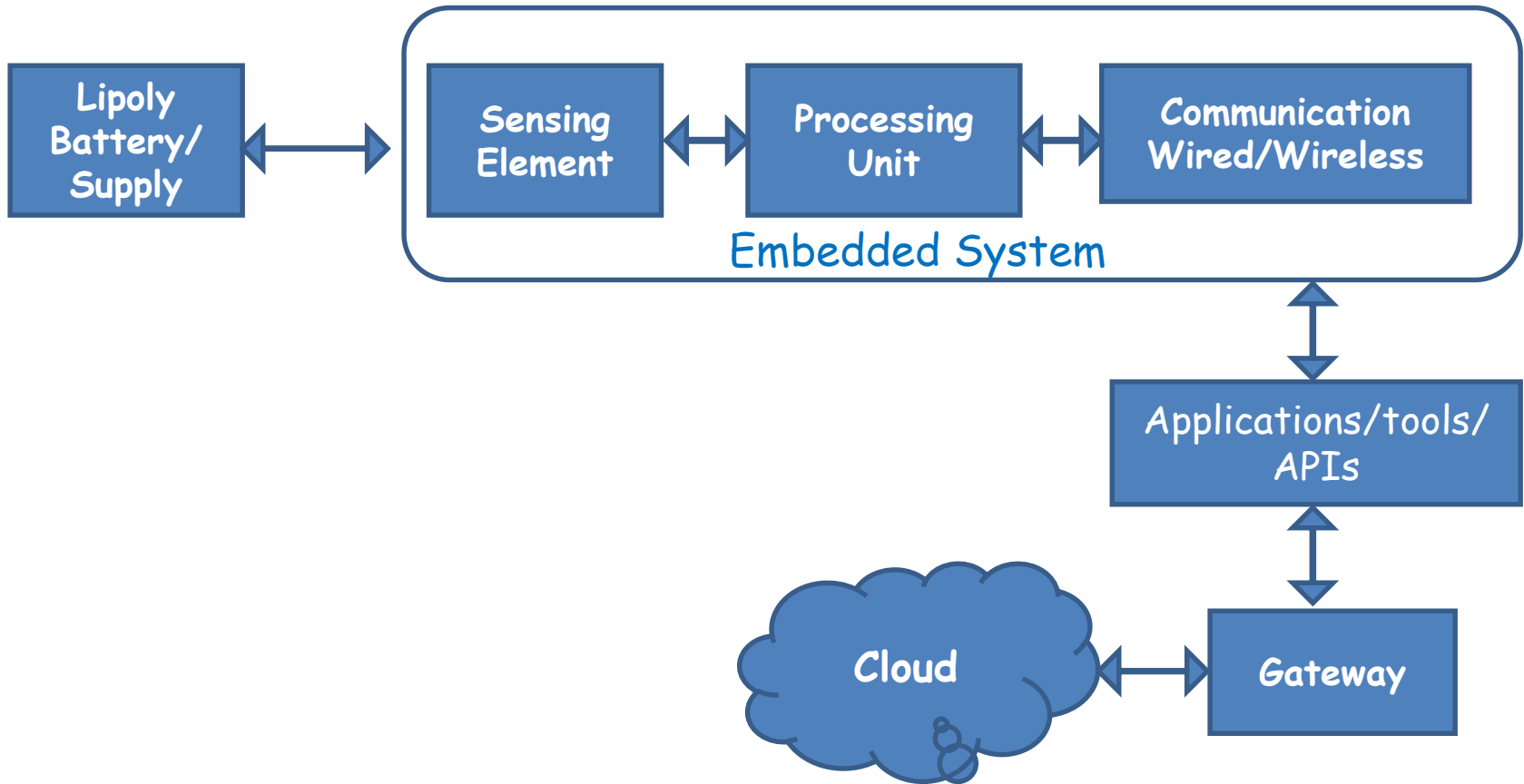


Machines \equiv Devices \equiv Sensors \equiv Things!



Sensors and IoT

An IoT System



Sensors

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

Sensors

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

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- Sensors are ubiquitous.

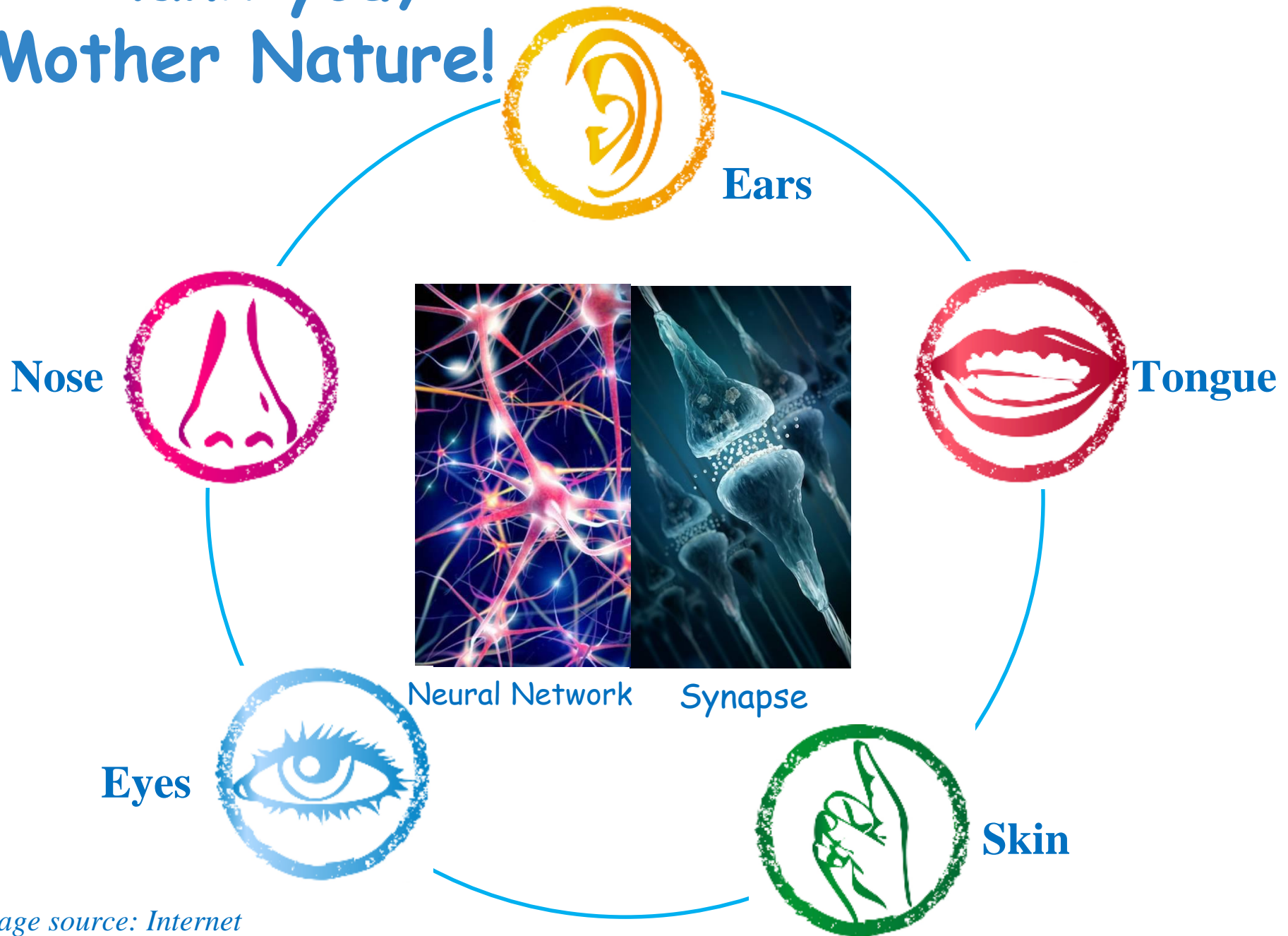
Sensors

- A **sensor** typically measures or identifies a particular physical quantity.
- Sensors convert the physical properties to electrical signals understandable by machines.
- Sensors are ubiquitous.
- Think about some quick examples!!

Thank you, Mother Nature!



Thank you, Mother Nature!



Sensors Are Everywhere!

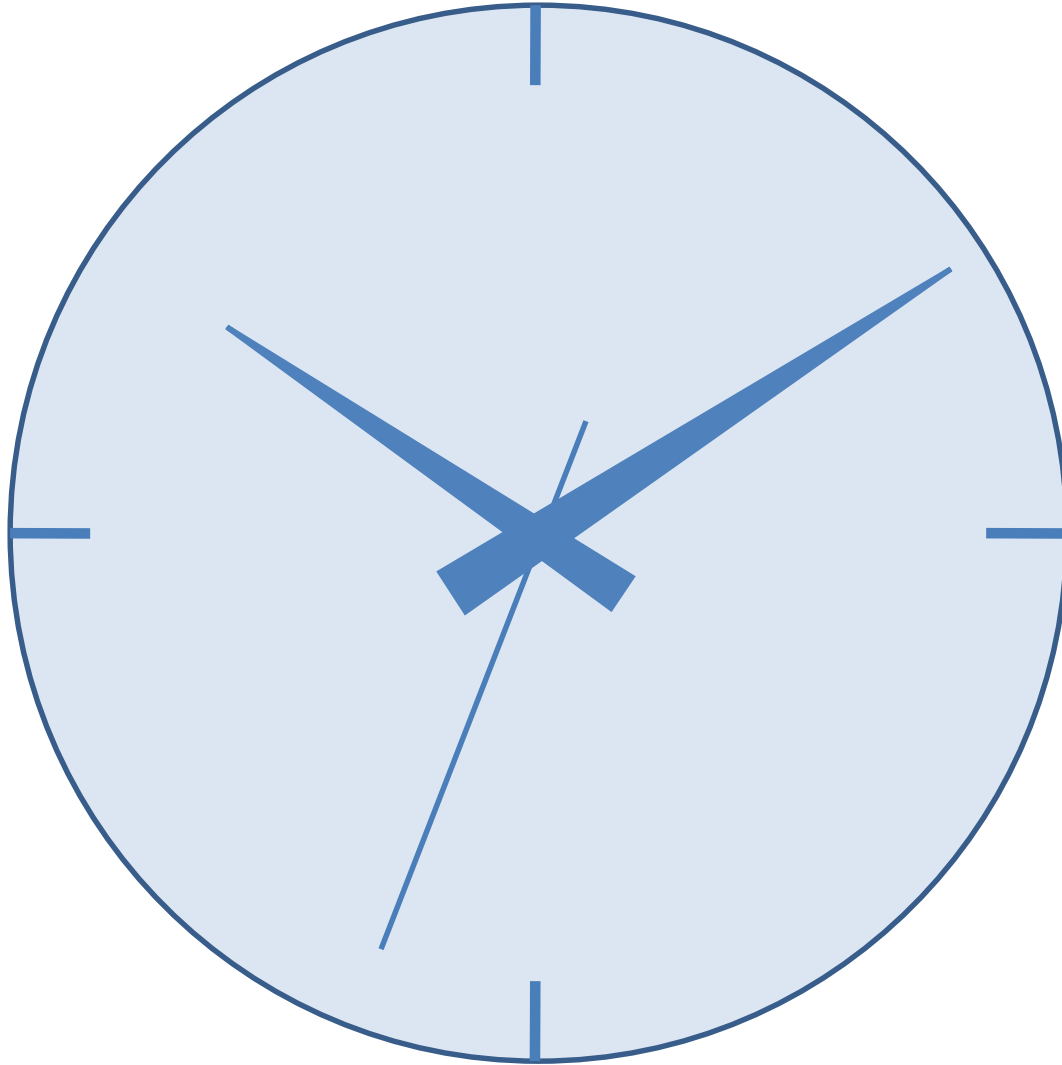


Image source: Internet

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?

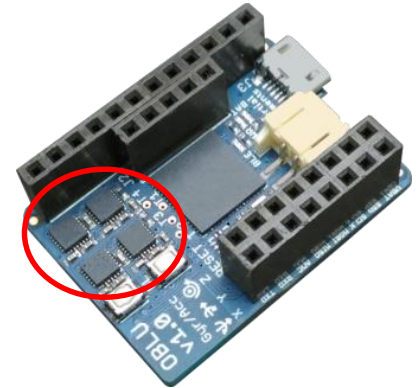
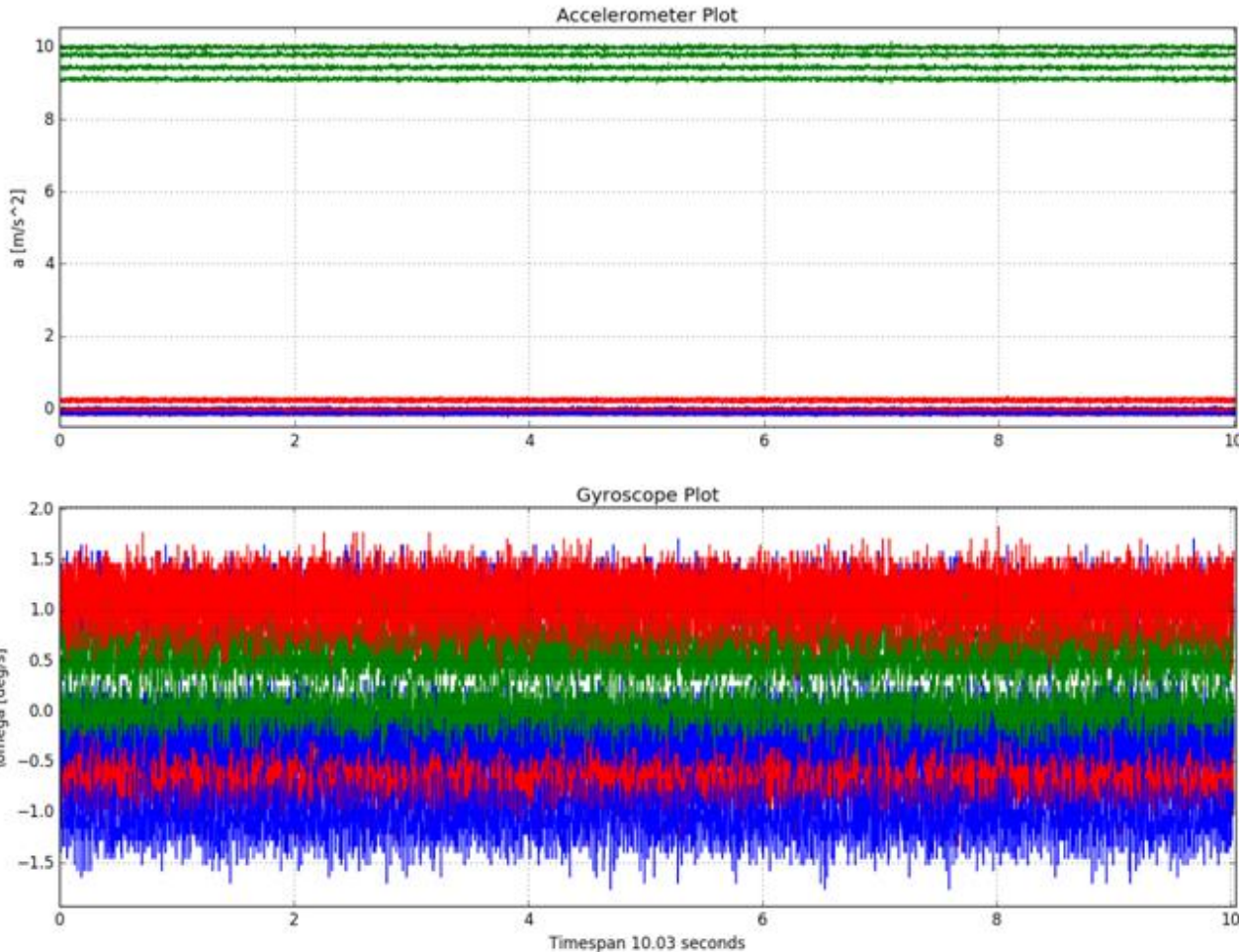


Is RFID tag a sensor?



Intrinsic Noise in Sensors

Response of a static multi-IMU system

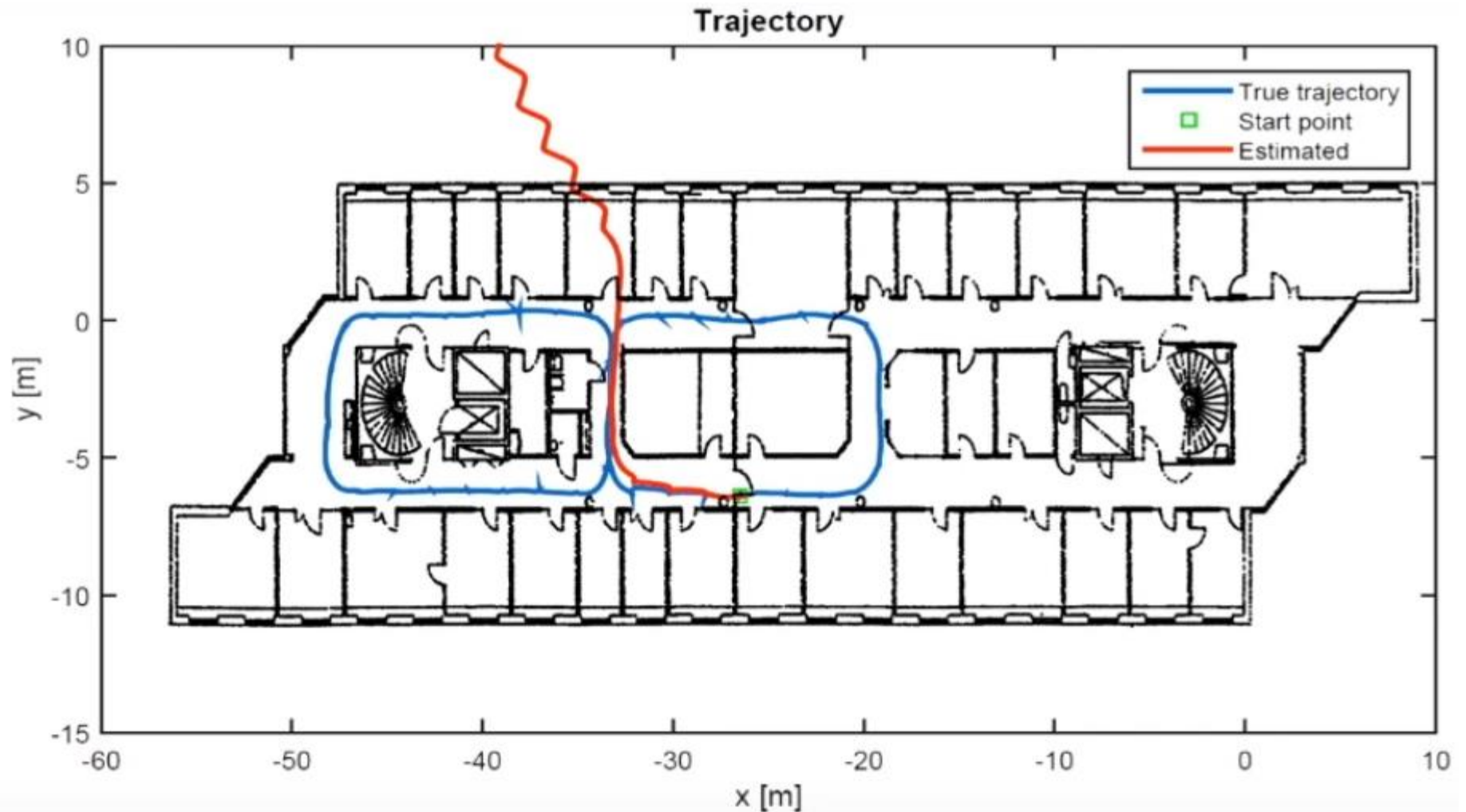


Did you observe

- Noise
- Non-aligned response

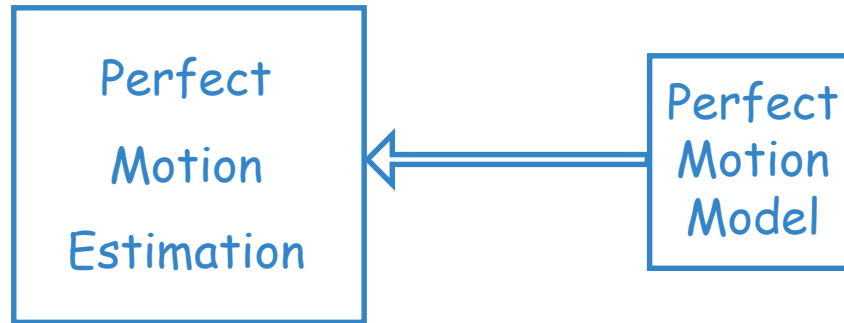
Same color data indicates same direction acceleration/rotation, but from different sensors (IMUs)

Example: Position Error Growth



Working with Low-cost Sensors

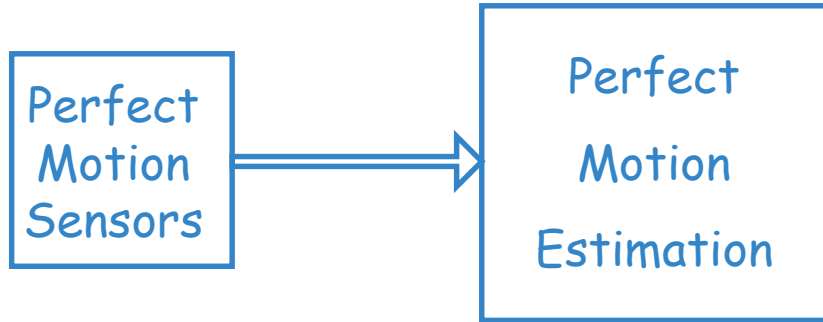
Example: Motion Sensors



(Motion sensors not required)

Working with Low-cost Sensors

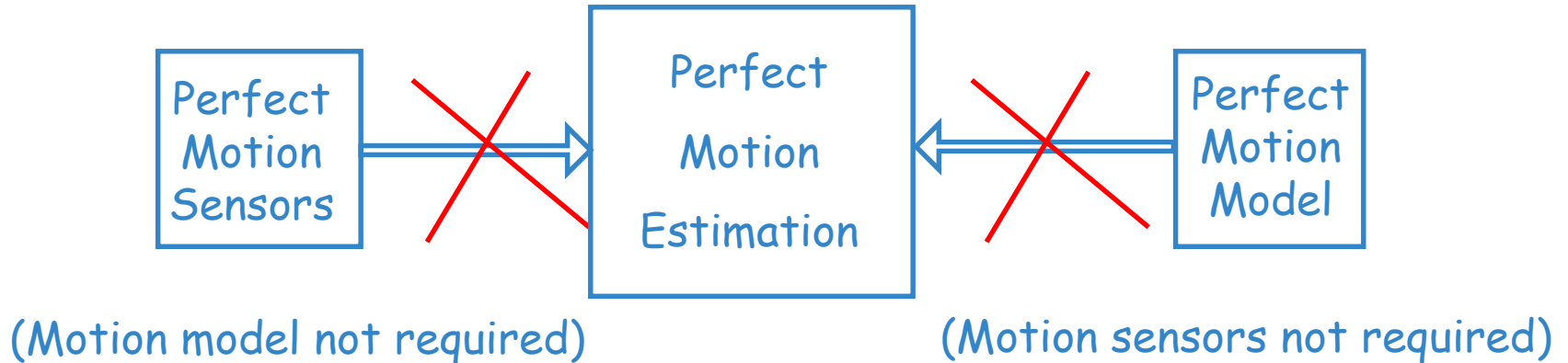
Example: Motion Sensors



(Motion model not required)

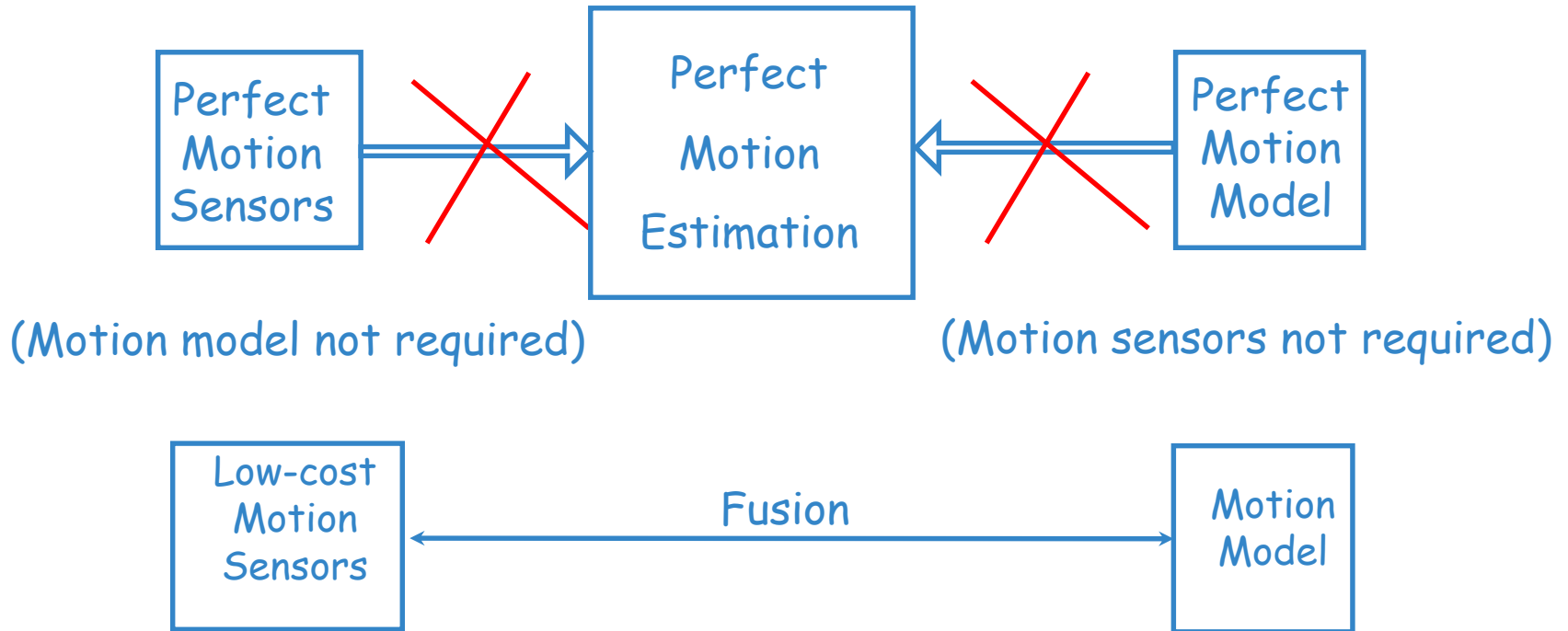
Working with Low-cost Sensors

Example: Motion Sensors



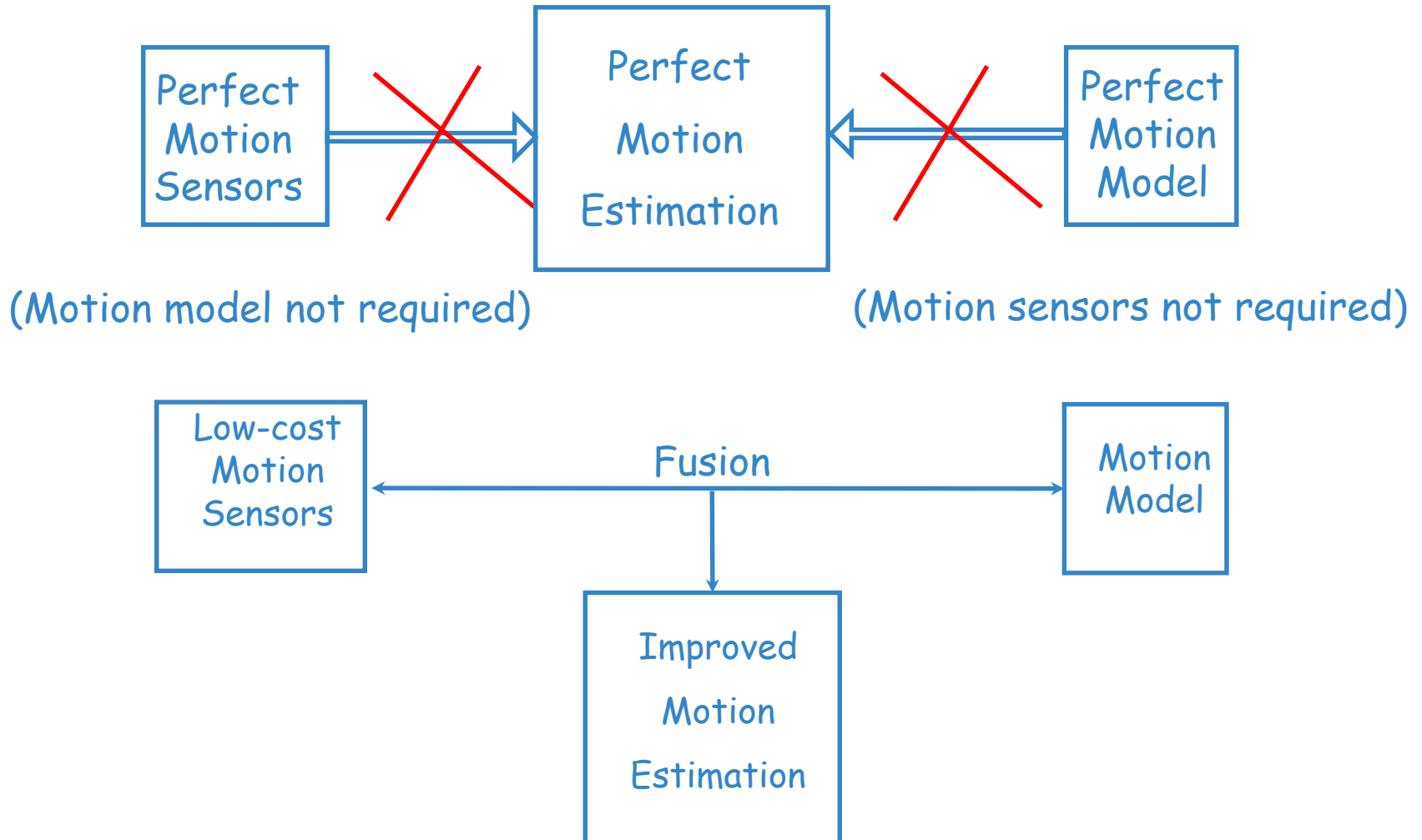
Working with Low-cost Sensors

Example: Motion Sensors



Working with Low-cost Sensors

Example: Motion Sensors



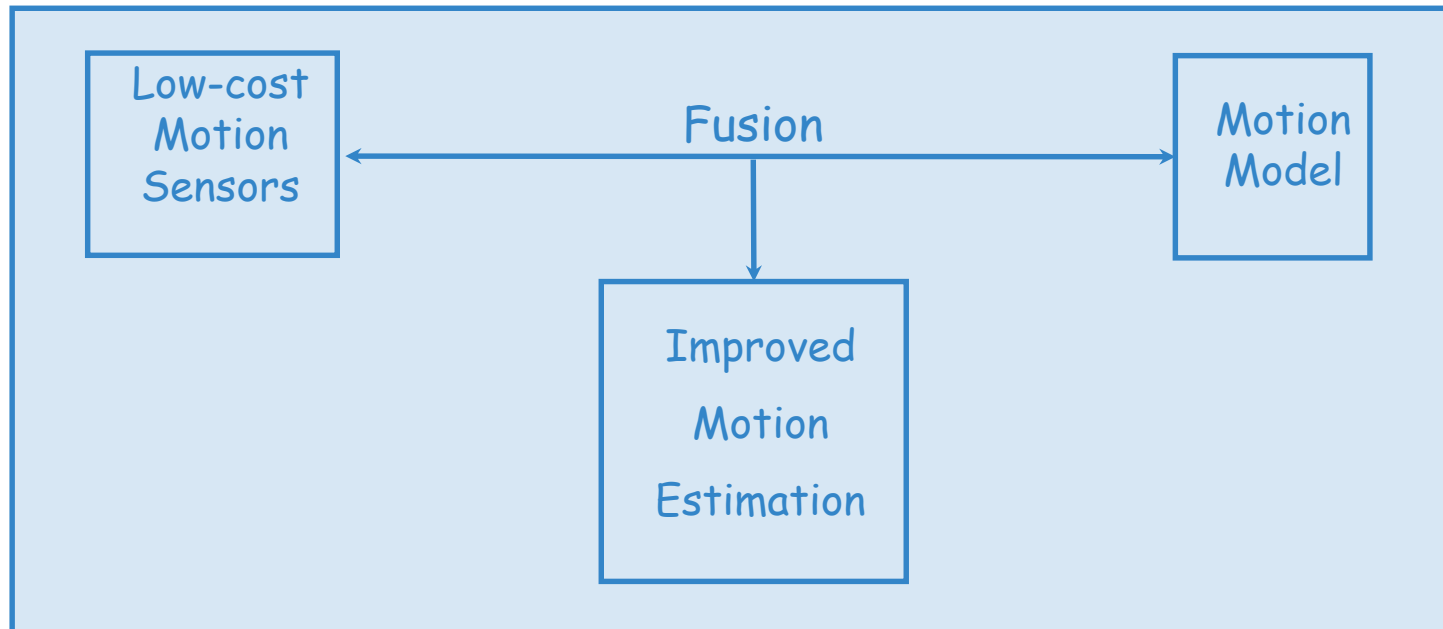
Working with Low-cost Sensors

Example: Motion Sensors



(Motion model not required)

(Motion sensors not required)



Example

Position Estimation of Stacker Reclaimer



Motion model: This huge machine moves in straight line!



Smart Sensor Nodes for IoT

Only a Sensing Element



Only a Sensing Element

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

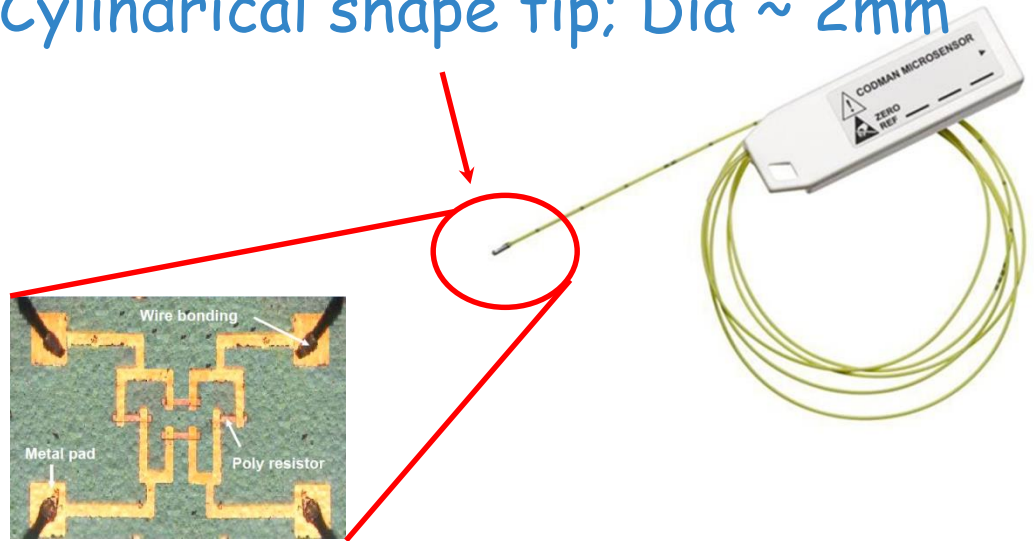
Cylindrical shape tip; Dia ~ 2mm



Only a Sensing Element

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

Cylindrical shape tip; Dia ~ 2mm

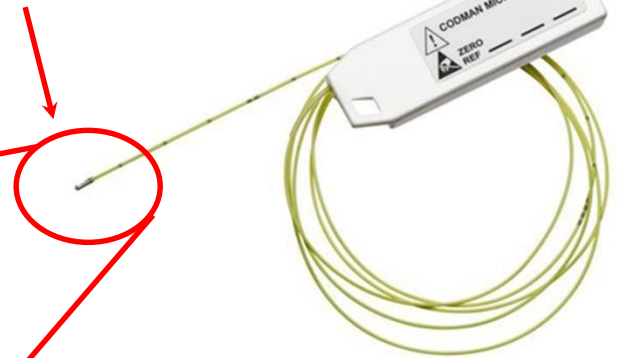
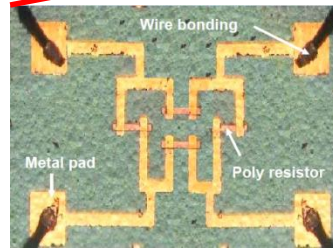


Only a Sensing Element

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



Cylindrical shape tip; Dia ~ 2mm



Analog o/p

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

A Sophisticated Sensor Node

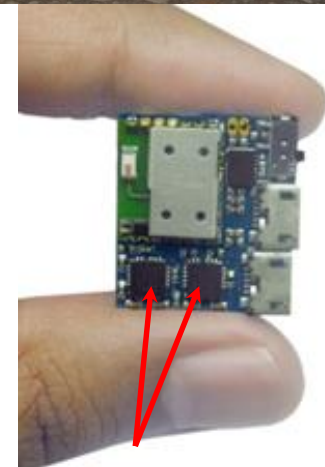
PDR Sensors for Indoor Pedestrian Positioning

What is inside?

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



Digital o/p



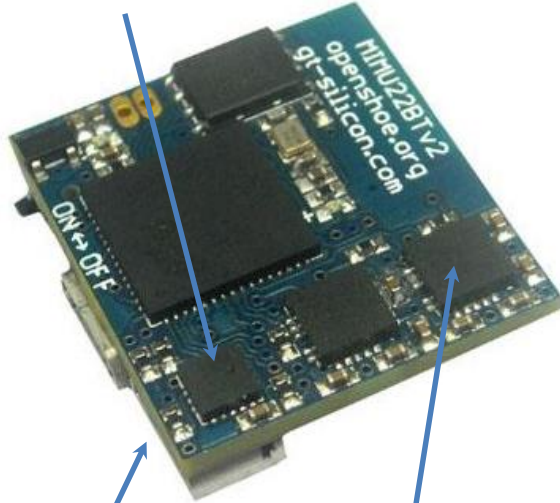
9-axis IMUs

Multi Sensor Systems

Multi Sensor Systems

Classical Multi Sensor System

Pressure Sensor



GPS

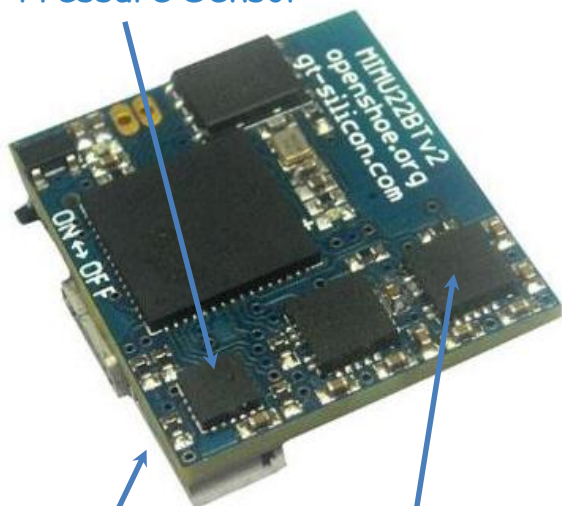
Motion Sensors

Fusing data from multiple
sensors enhances performance

Multi Sensor Systems

Classical Multi Sensor System

Pressure Sensor

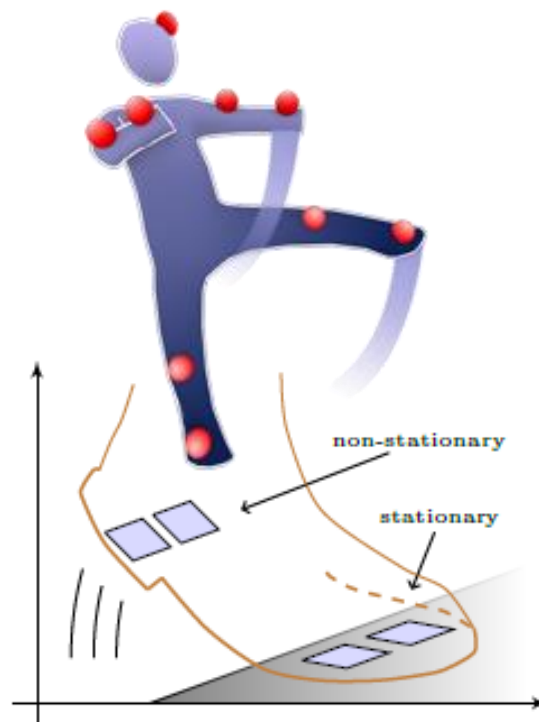


GPS

Motion Sensors

Fusing data from multiple sensors enhances performance

Multi-Sensor Joint System

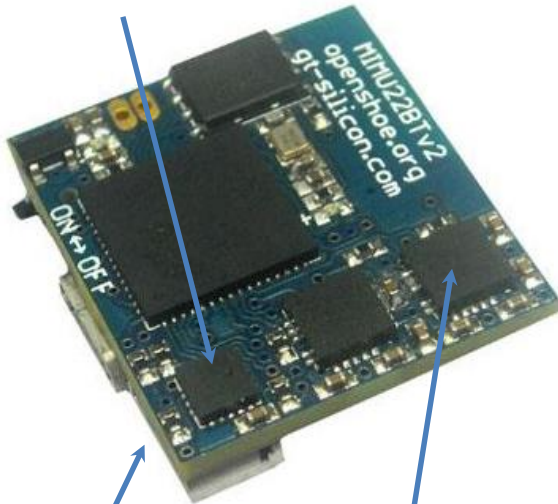


Multiple non-rigidly connected IMUs results in dynamic diversity

Multi Sensor Systems

Classical Multi Sensor System

Pressure Sensor

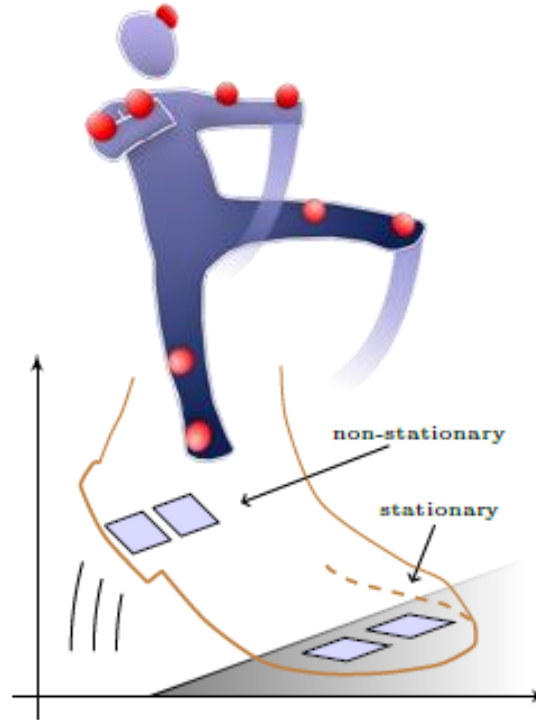


GPS

Motion Sensors

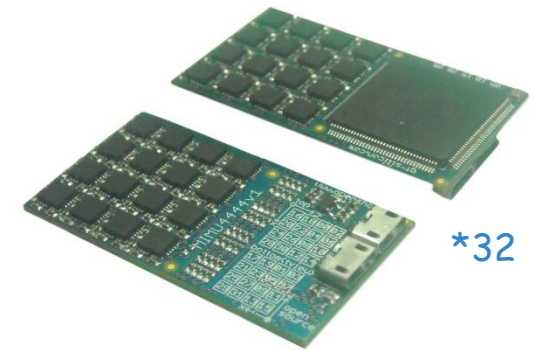
Fusing data from multiple sensors enhances performance

Multi-Sensor Joint System

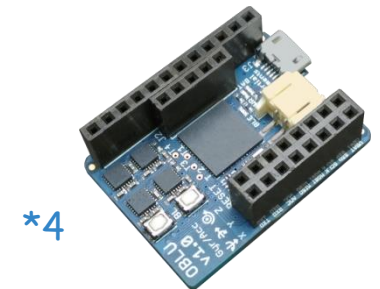


Multiple non-rigidly connected IMUs results in dynamic diversity

Collocated Multi-Sensor System



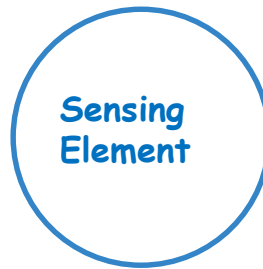
*32



*4

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

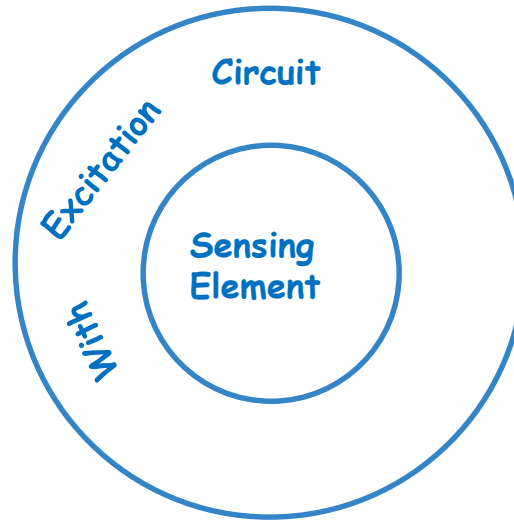
A Smart Sensor Node for IoT



Sensing Element

- MEMS / Chemical etc
- Responds to physical world

A Smart Sensor Node for IoT



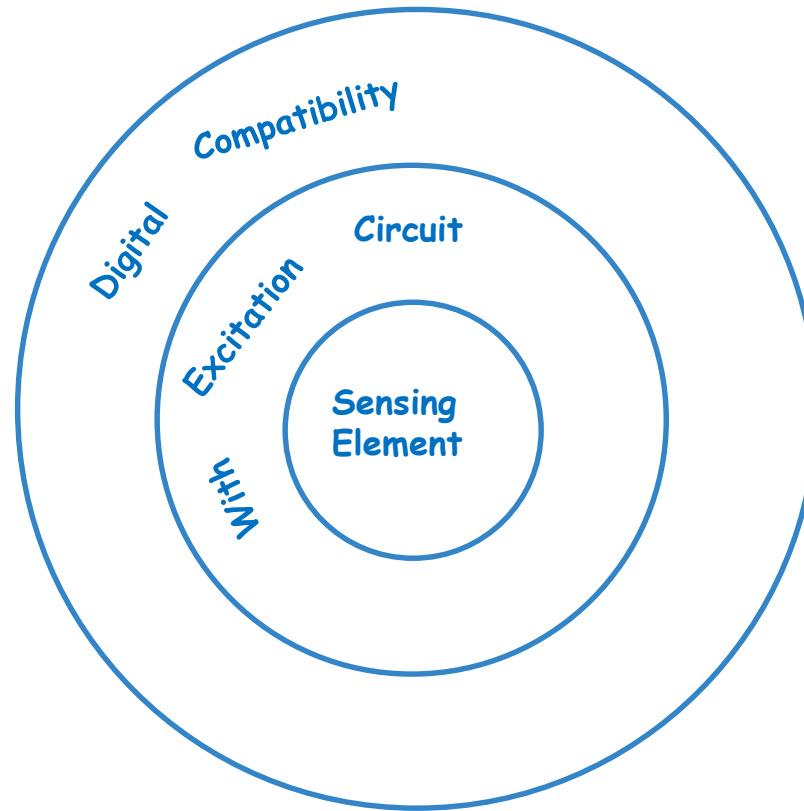
Sensing Element

- 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

Excitation Ckt

- To excite electrically
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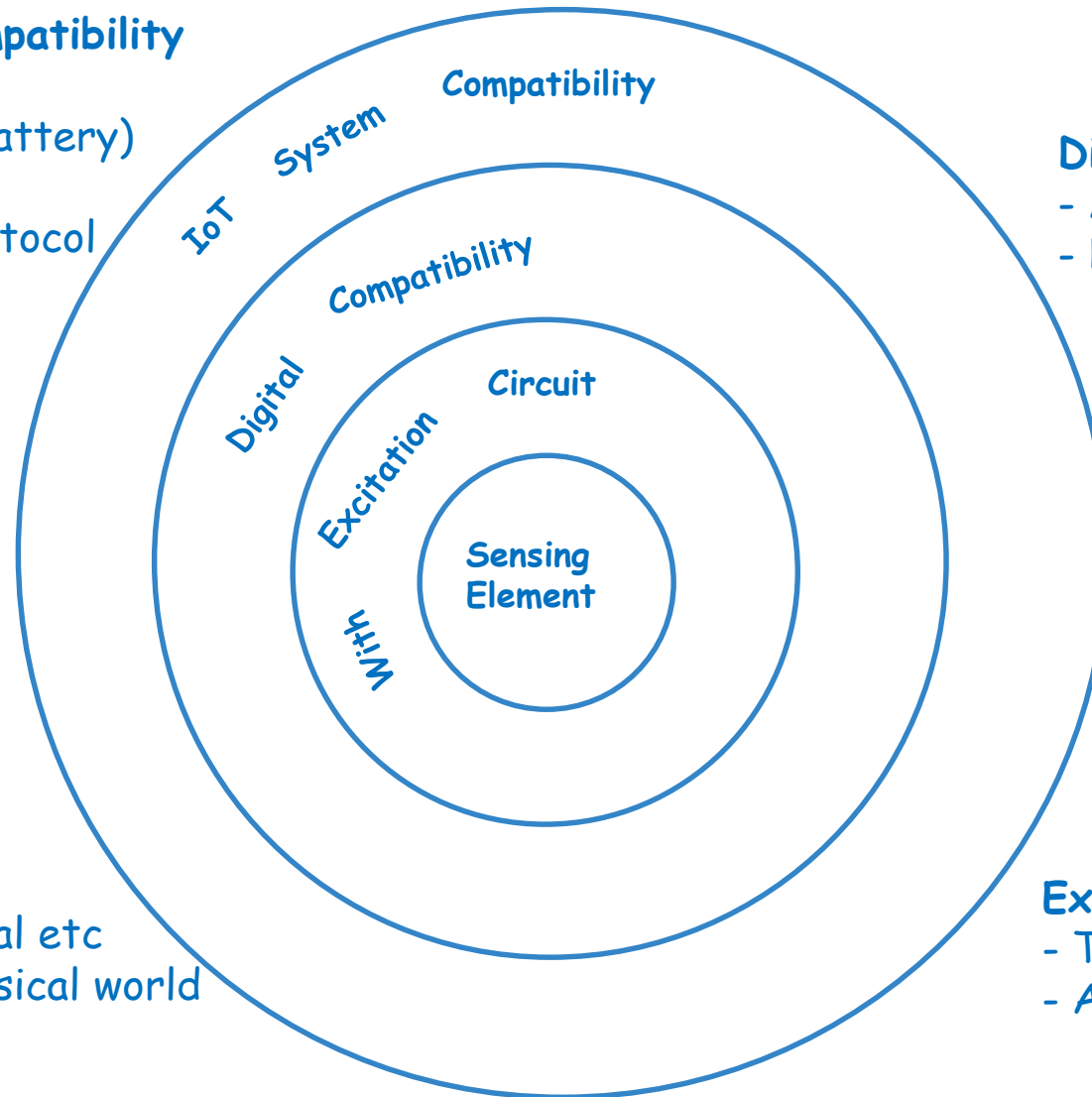
A Smart Sensor Node for IoT

IoT System Compatibility

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

Digital Compatibility

- Analog to Digital
- Data xfer protocols



Sensing Element

- MEMS / Chemical etc
- Responds to physical world

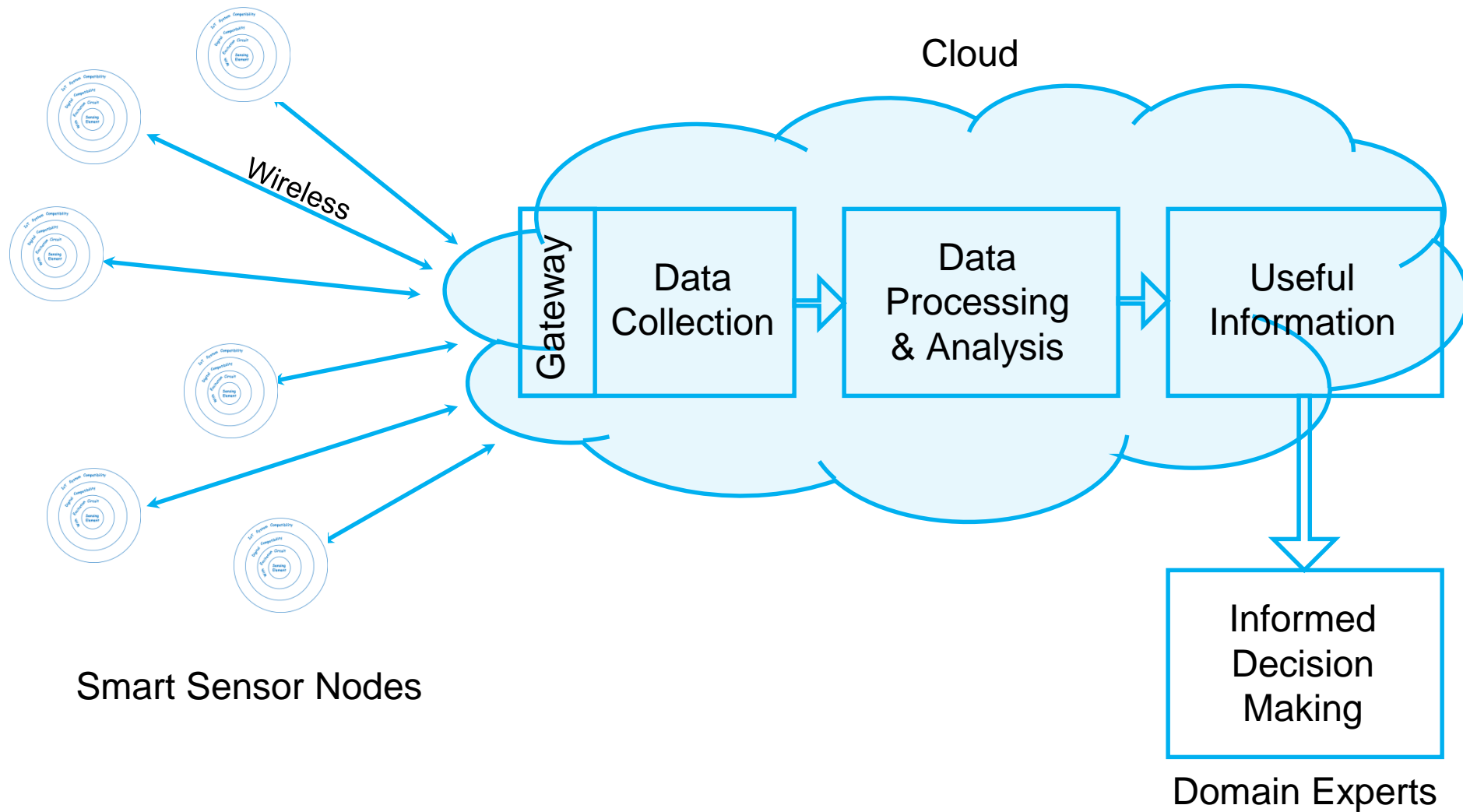
Excitation Ckt

- To excite electrically
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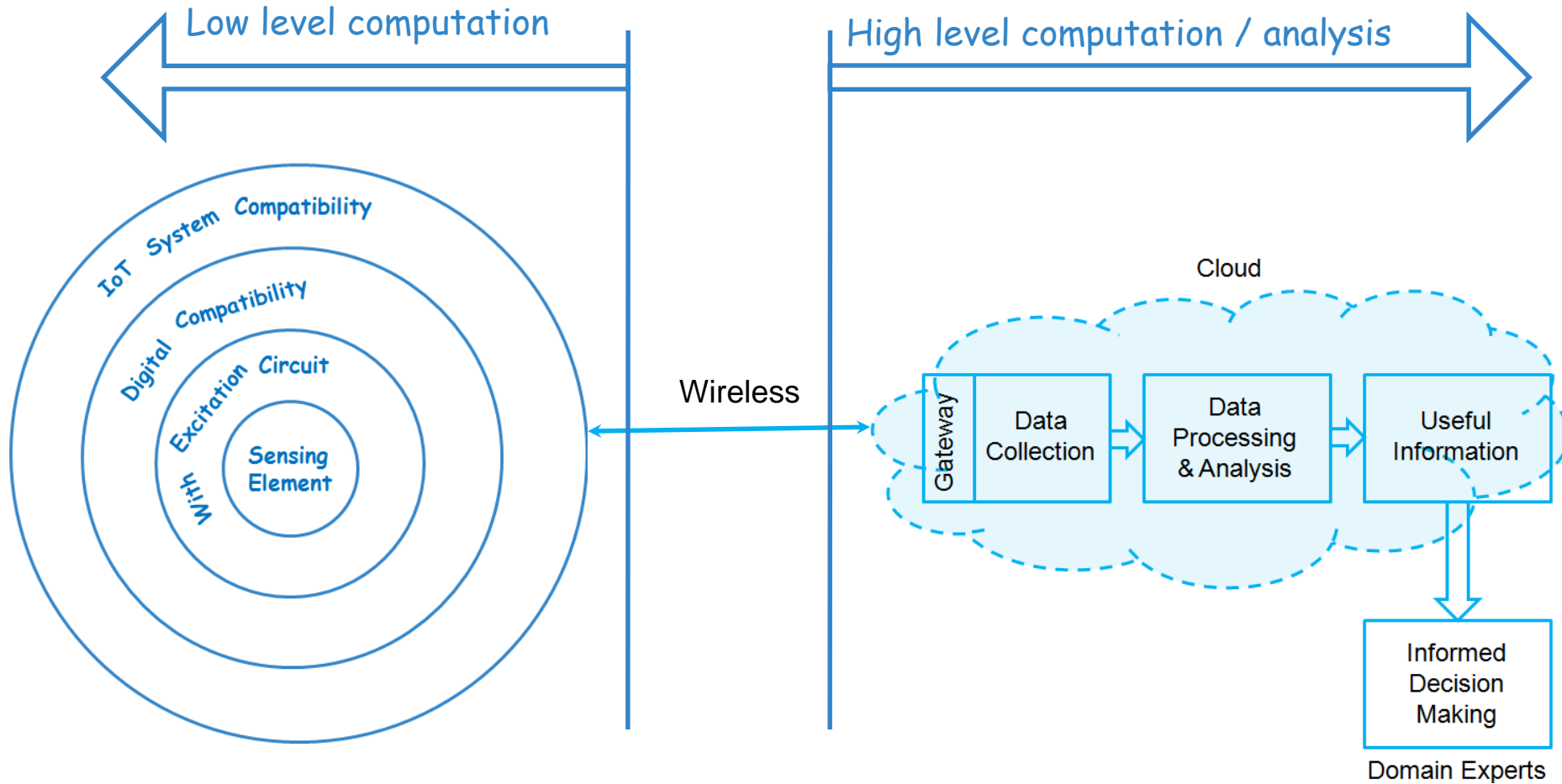
A Smart Sensor Node for IoT

- 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

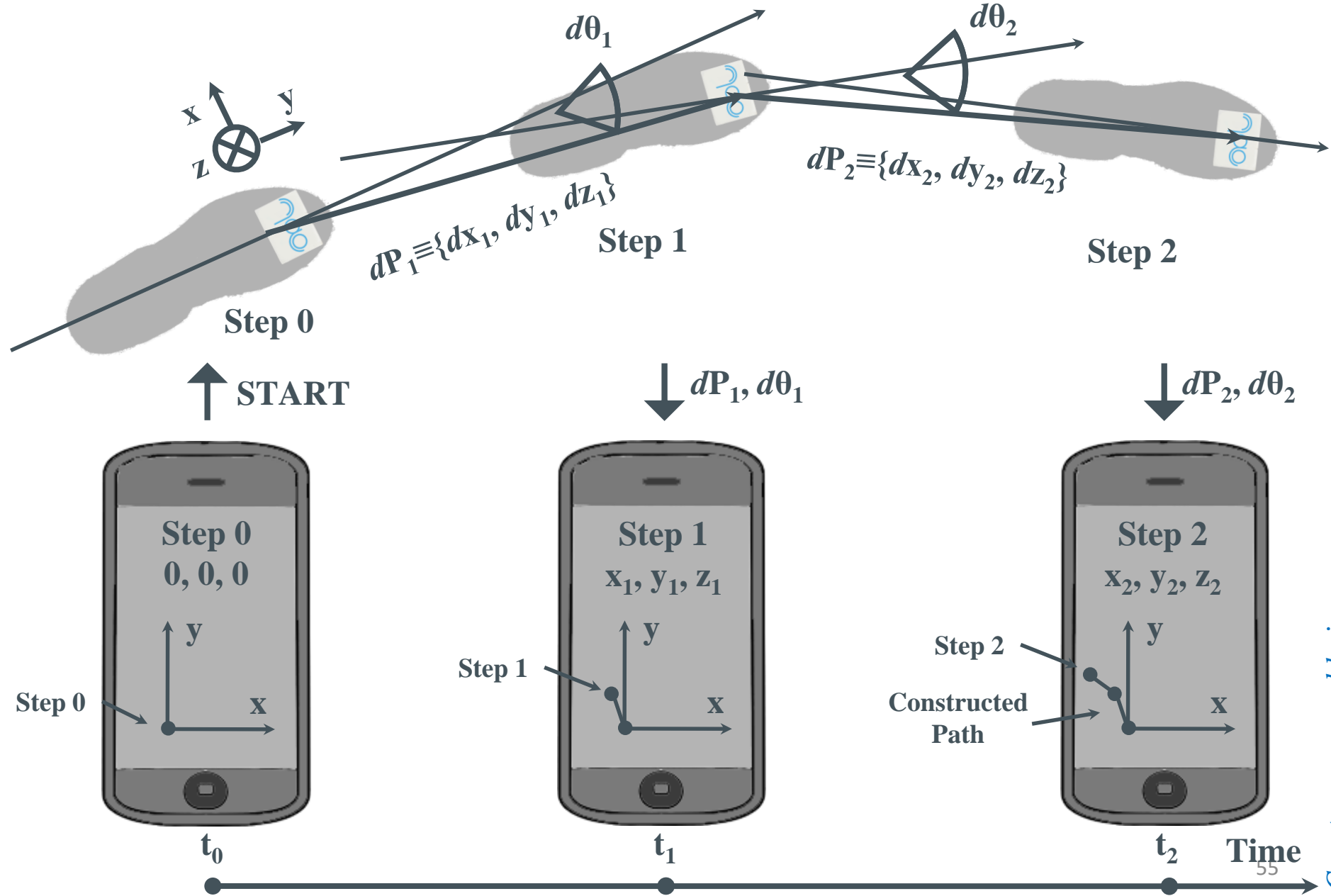
Positioning w/o GPS!

Wireless Transmission

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

Shoe Sensor proving high level information

Extremely Simplified Interface!





IoT System Overview

Capturing Real World

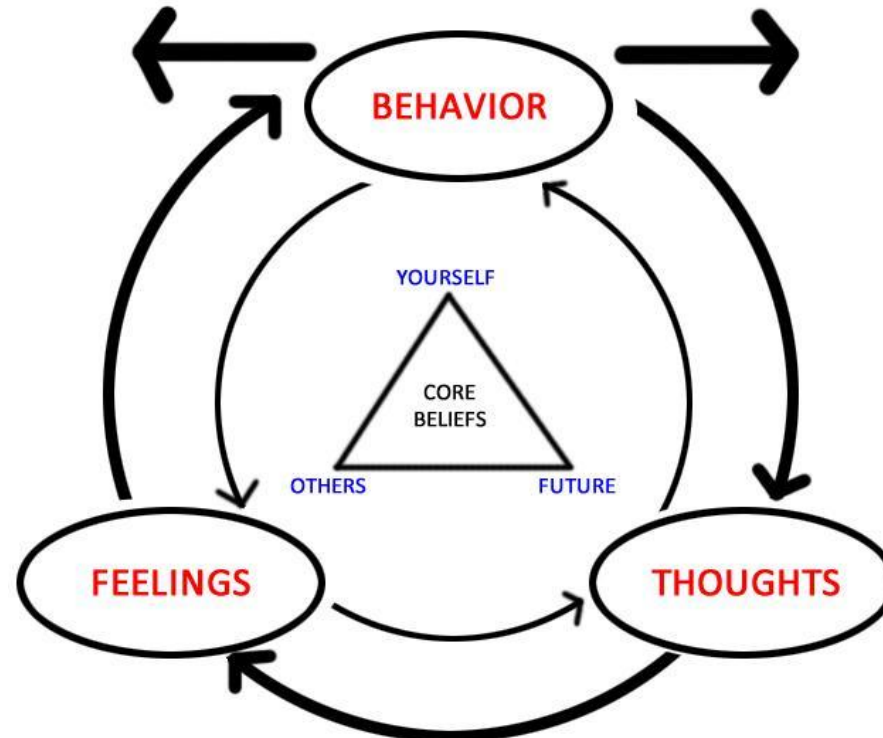
- What attributes of a system you would like to capture?
 - System's state and immediate surrounding
- How would you monitor a moving machine? Say, a robot.
 - By attaching sensor devices

What if you have to monitor humans?

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

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



How to Monitor Humans?

...and super humans



Image source: costumekart.com

How to Monitor Humans?

...and super humans



Image source: costumekart.com

Smartphone - A Sensor Hub

What is a sensor ?



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

How to Monitor Humans?

...and super humans

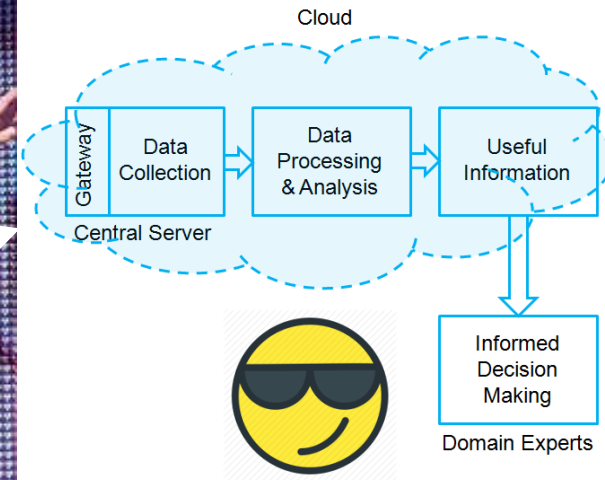
Download my App and
get \$2 discount on
your first transaction!



Image source: costumekart.com

How to Monitor Humans?

...and super humans



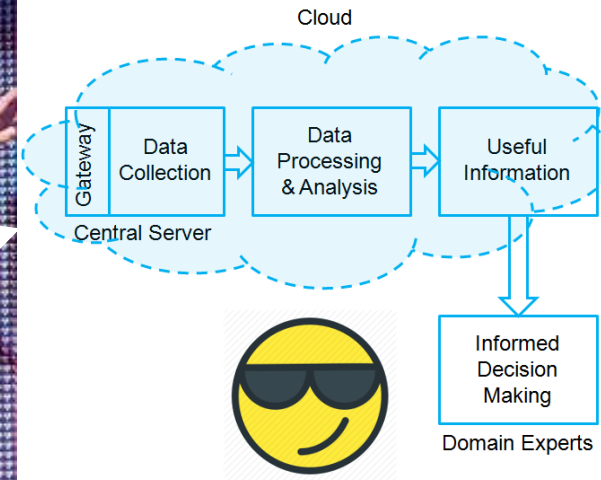
How to Monitor Humans?

...and super humans

Hurray!



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



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!

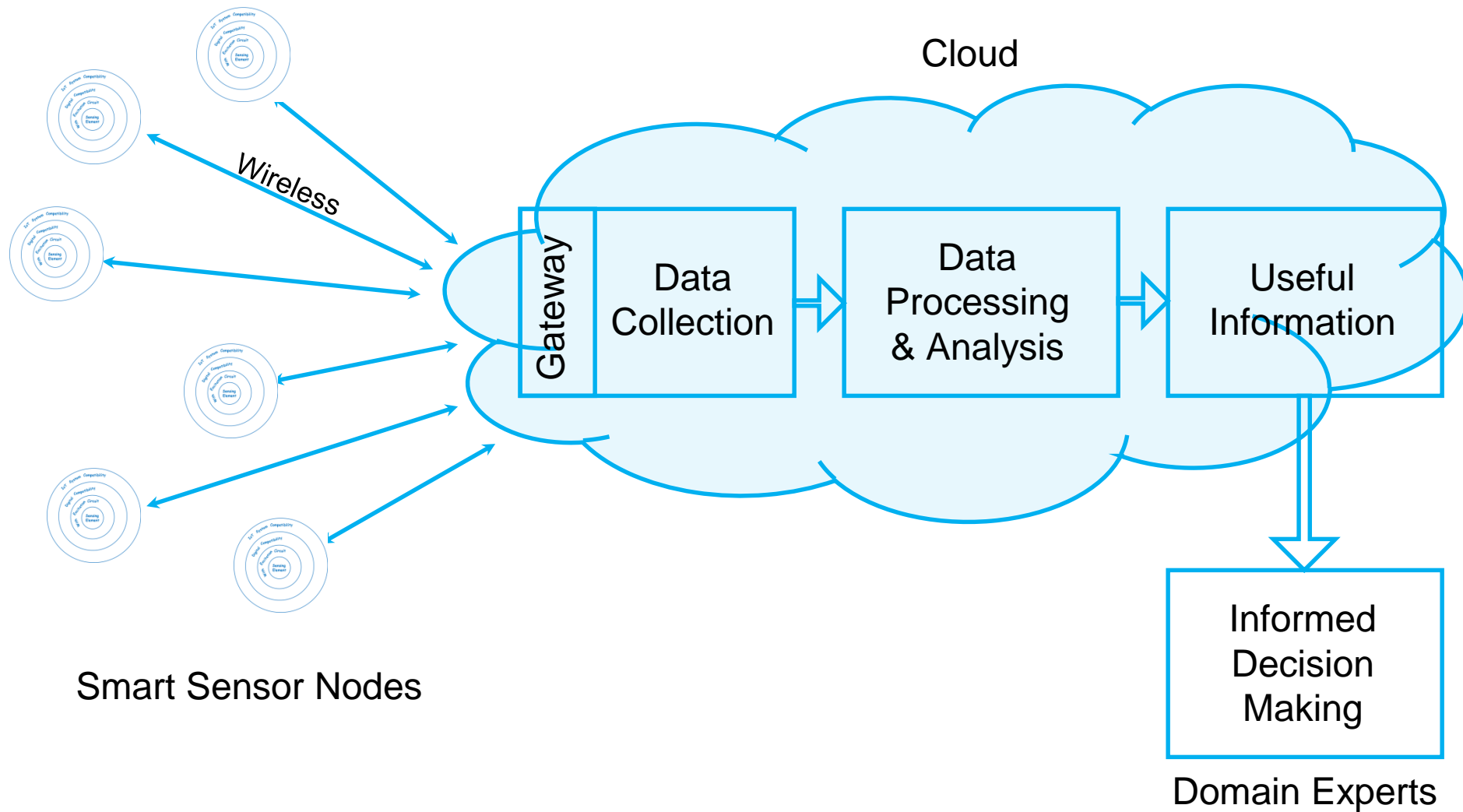
Download my app. Forever free services!

Download my app. Please...

Every active App transmits data to a separate cloud !

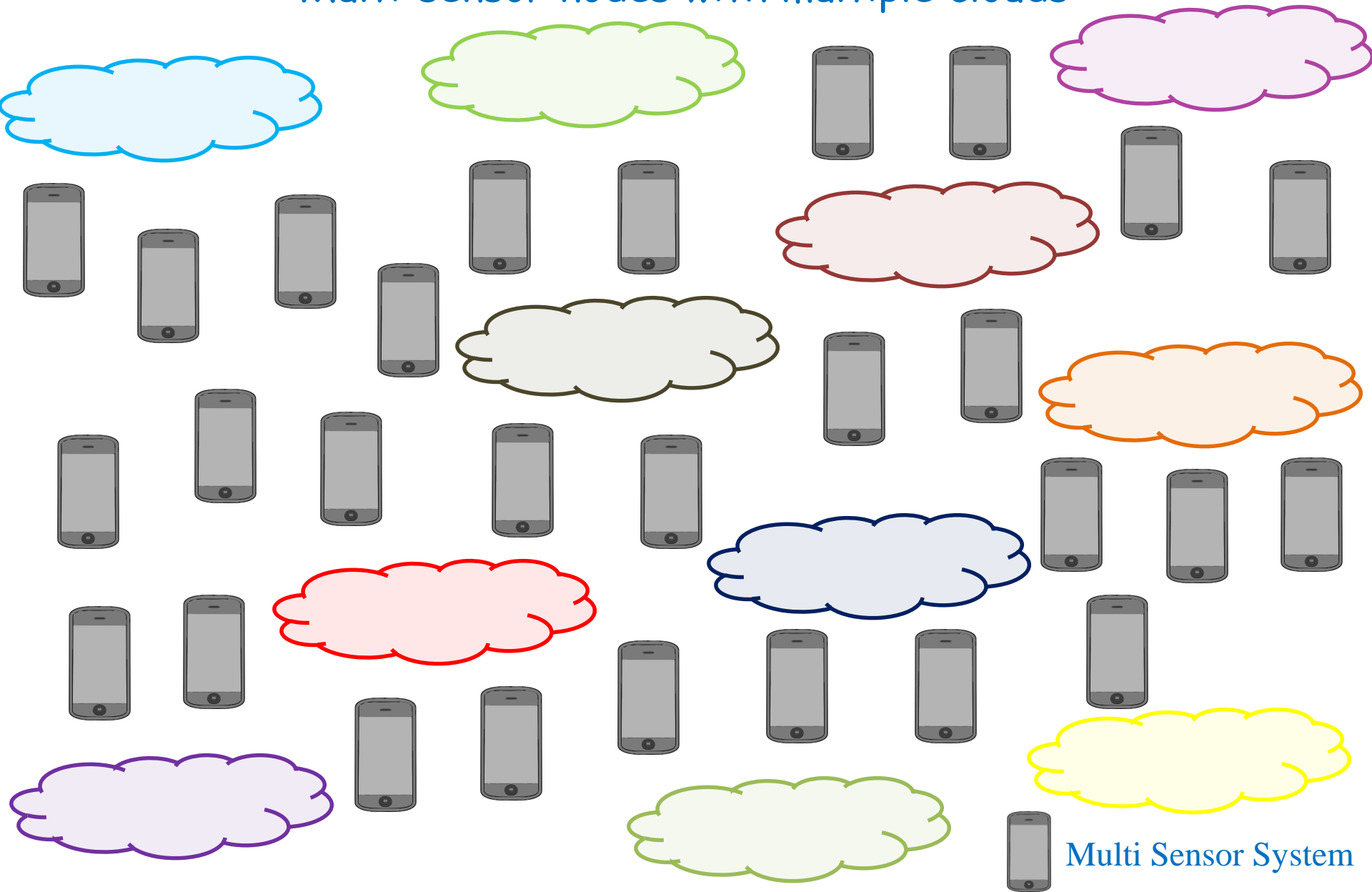


A Typical IoT System



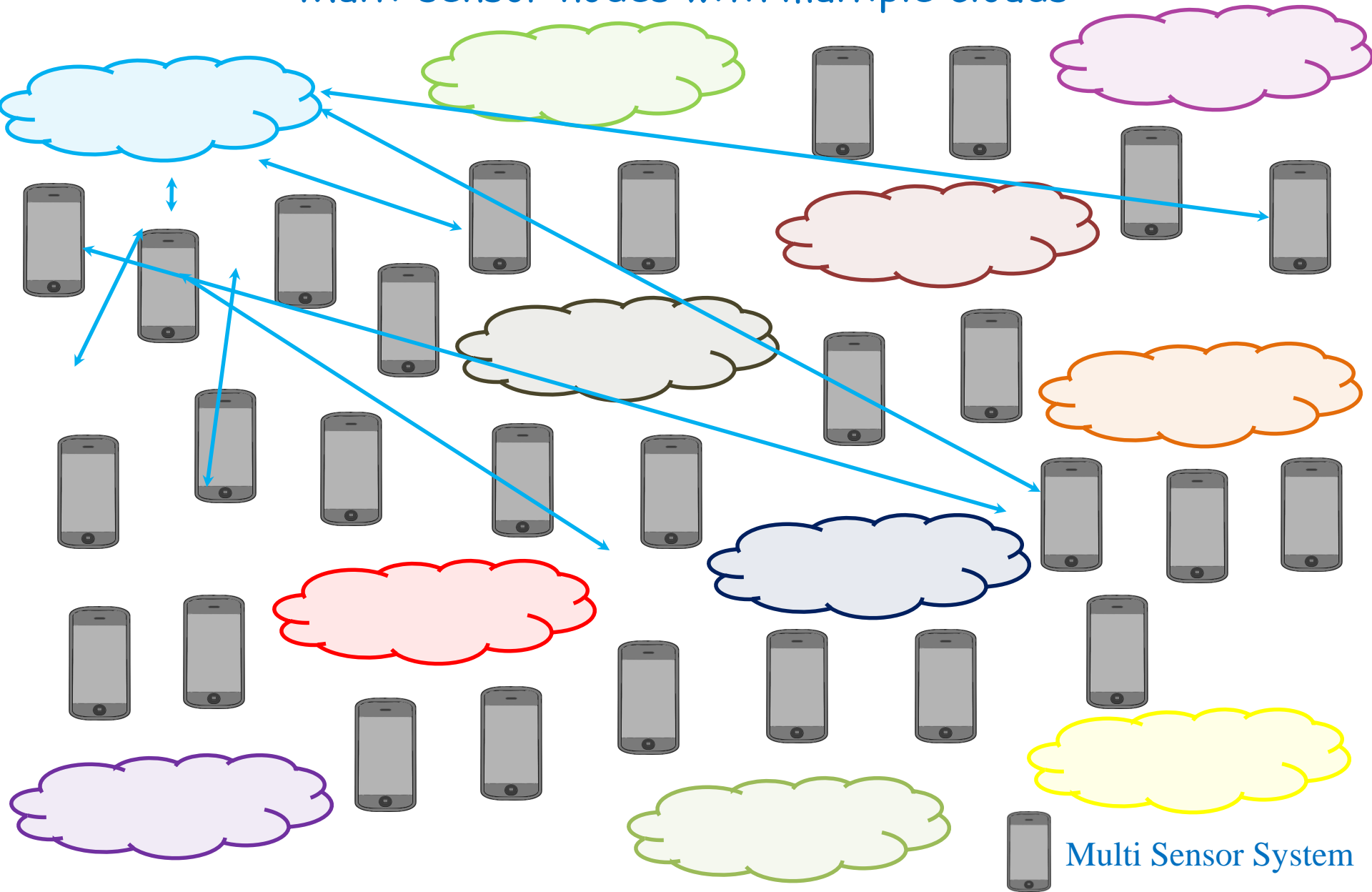
A Gigantic IoT System

Multi-sensor nodes with multiple clouds



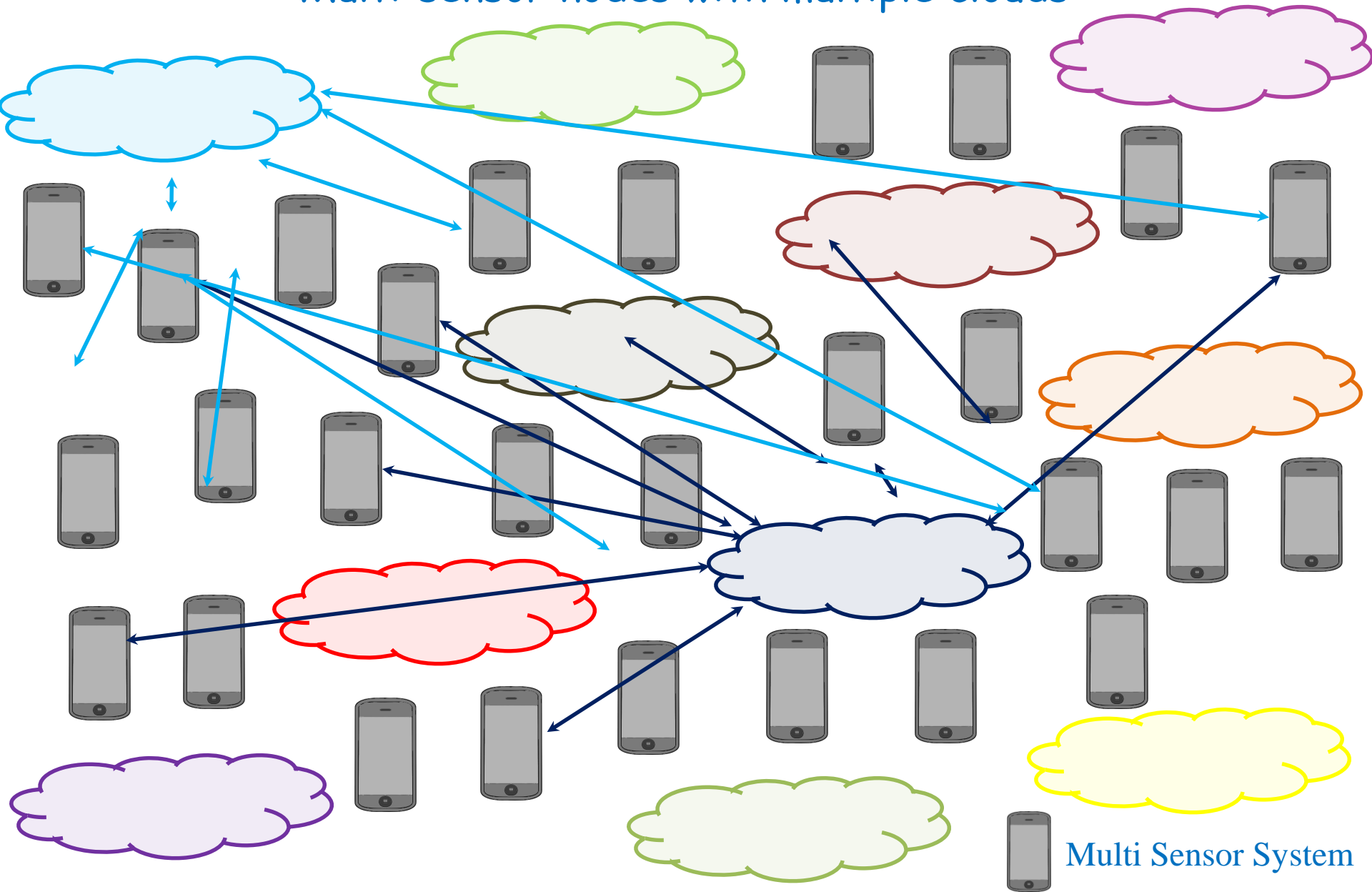
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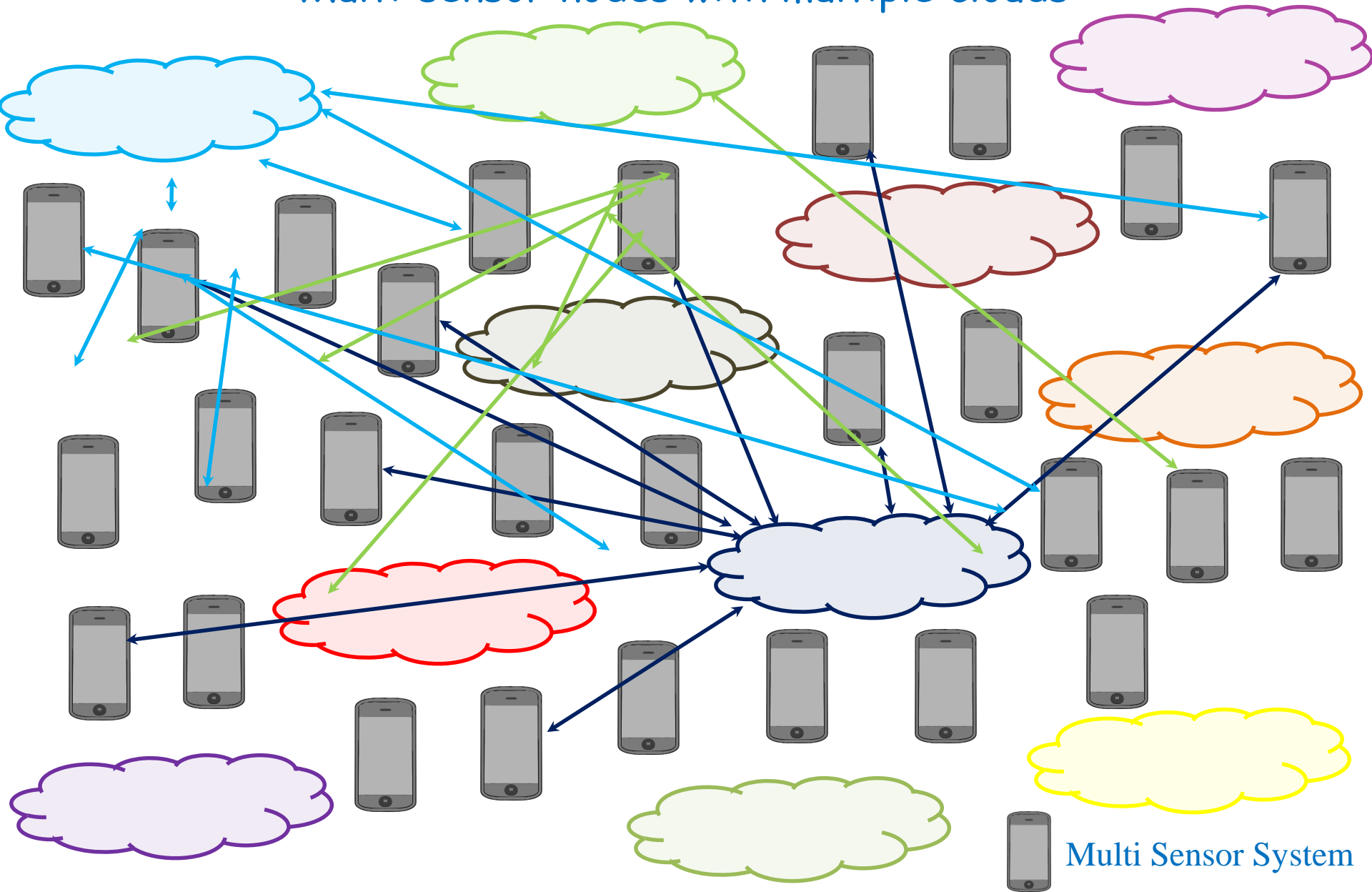
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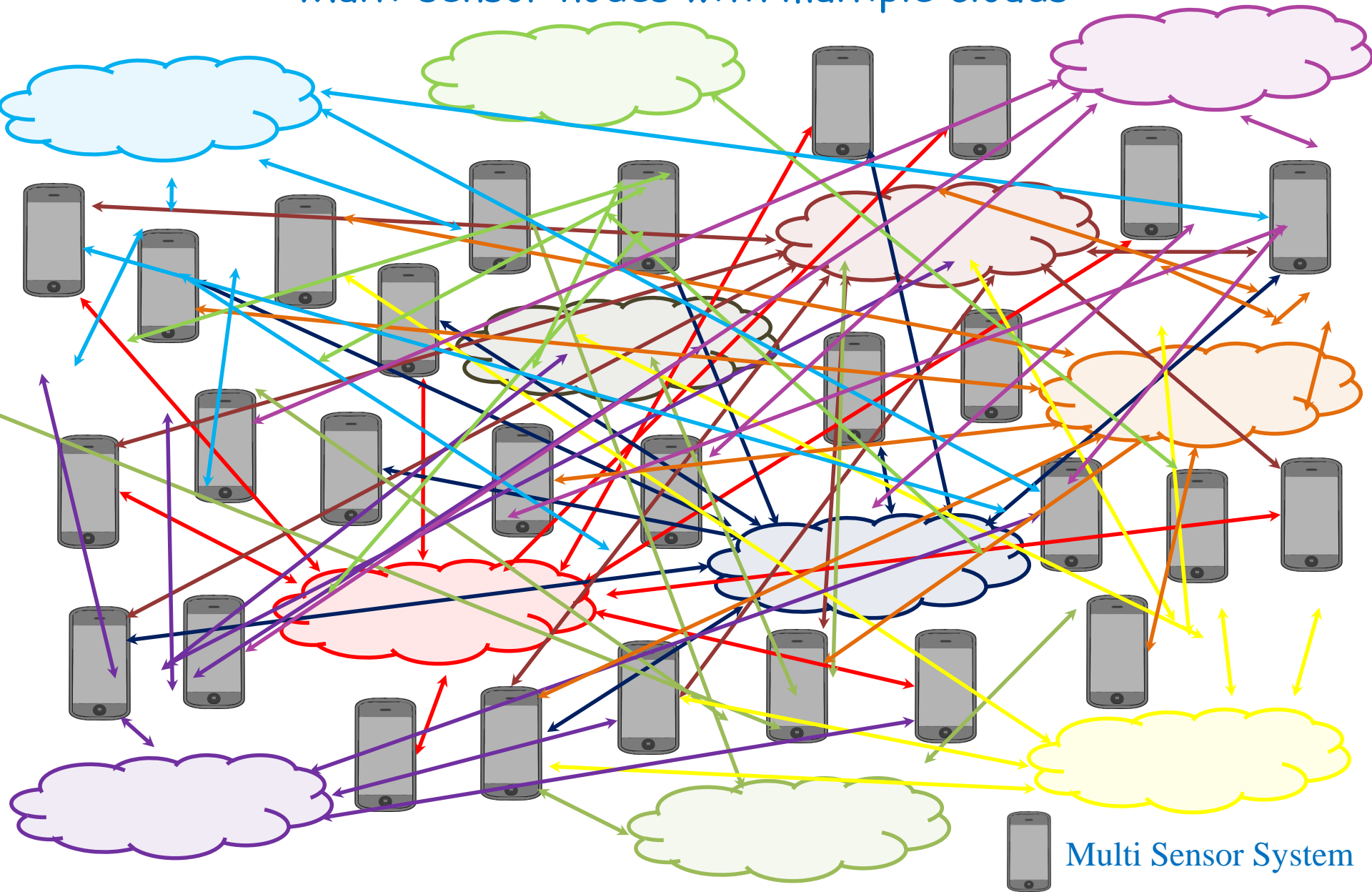
A Gigantic IoT System

Multi-sensor nodes with multiple clouds



A Gigantic IoT System

Multi-sensor nodes with multiple clouds



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

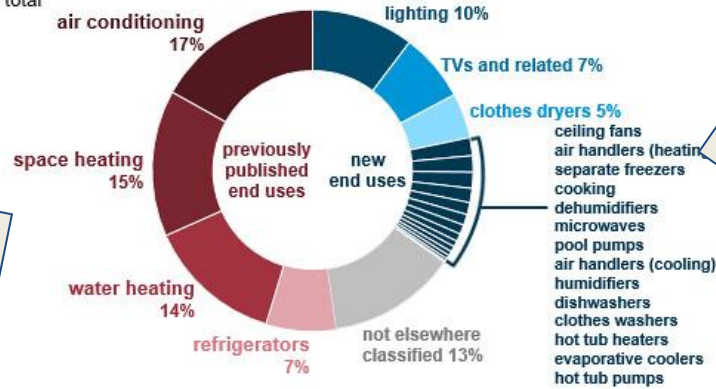
Smart Grid and IoT

IoT enabled home storage devices intelligently interact with the smart grid

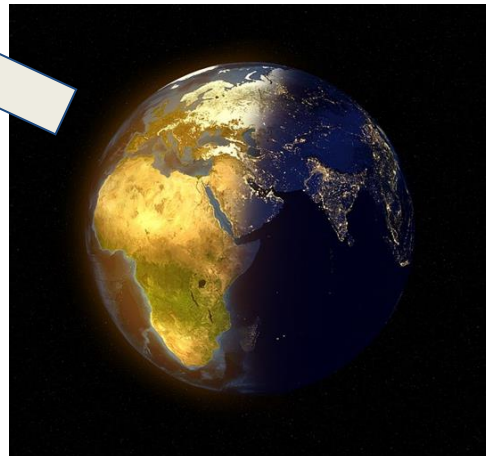
- To understand the peak demand period
- If required, disconnect the home circuit from the grid to supply power on its own
- If required smart storage devices can add power supply to main grid.
- This two way electric flow convert consumer into prosumer (producer + consumer)

Smart Grid and IoT

Residential electricity consumption by end use, 2015
percent of total



eia



Smart Grid and IoT: Challenges

- Privacy
 - Consumer data shared over the grid
 - Snooping, invasion, profiling possible
- 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