PRAIRIE VIEW A&M UNIVERSITY

Module 01: Introduction to the Internet of Things (IoT)

Developed By

Ahmed Abdelmoamen Ahmed

Kiranmai Bellam

Yonggao Yang

Lesson 01: What is IoT and Why is it Important?

Supported By

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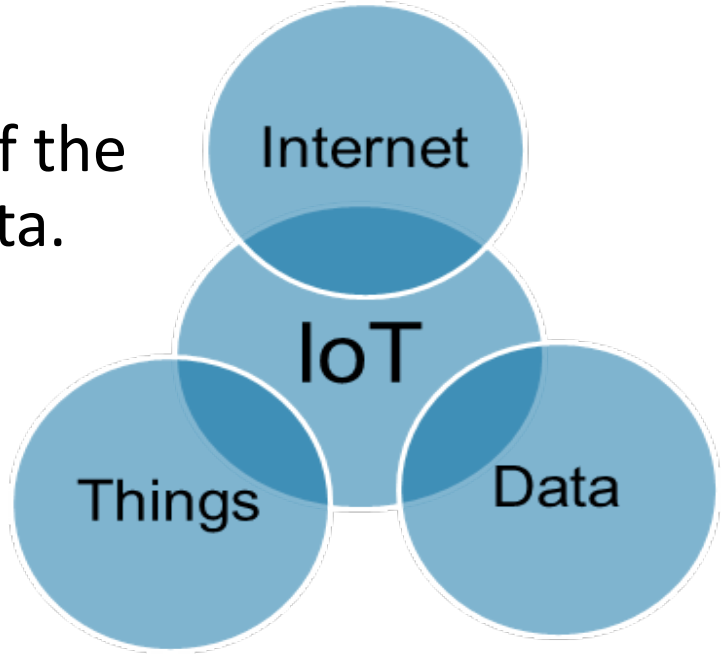
Learning Outcomes

- Upon completion of this lesson, students will be able to:
  - Describe the key concepts behind the Internet of Things (IoT)
  - Explain the definition and usage of IoT systems in different contexts
  - Gain knowledge about IoT applications across various segments

What is the Internet of Things (IoT)?

- IoT is a **network** of interconnected objects (**things**) that are embedded with **sensors**, **actuators**, software, and other technologies for the purpose of connecting and exchanging **data** with other devices and systems over the **internet**.

- IoT is the intersection of the Internet, Things and Data.



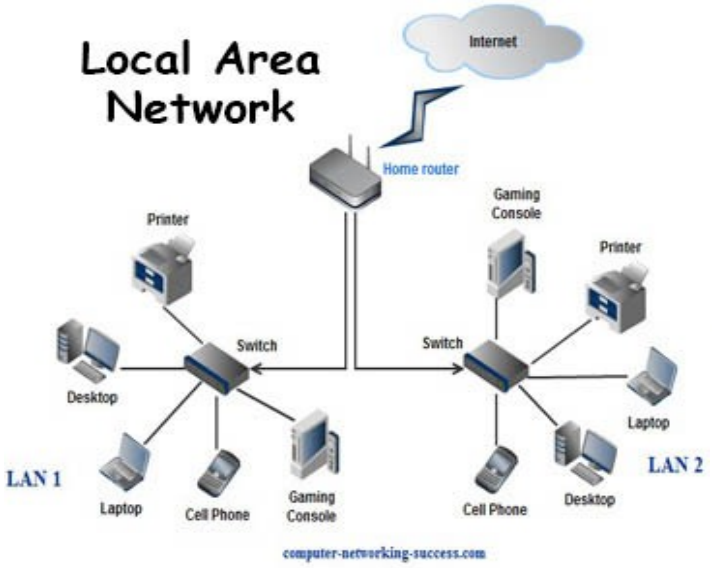
What is the Internet of Things (IoT)?

- After excluding computers and handheld devices (e.g., cellphones and tablets), there are 16.5 billion connected things in 2020 worldwide
- IoT collects that data from millions of sensors embedded in everything from cars, to refrigerators, to space capsules

IoT - Historical Perspective

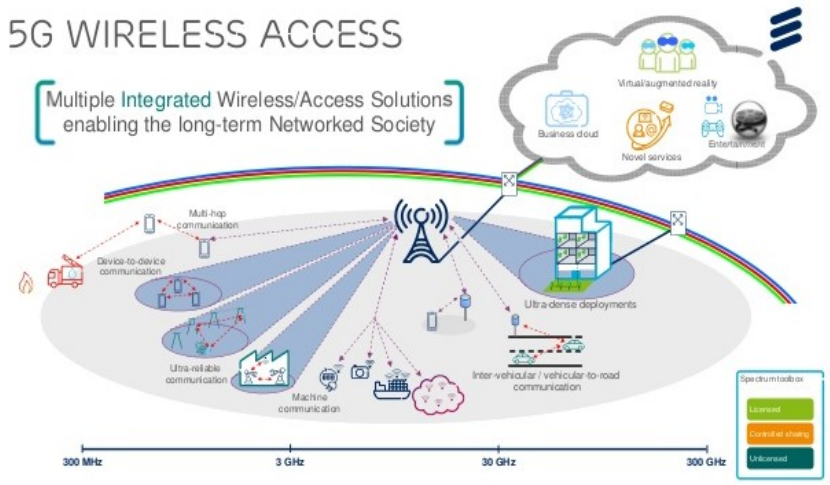
Yesterday

local Area Networks (LAN), Static services (email, web)



Today

Wireless Mobile, ubiqitous Internet access, Cloud Mobile Services & Resources



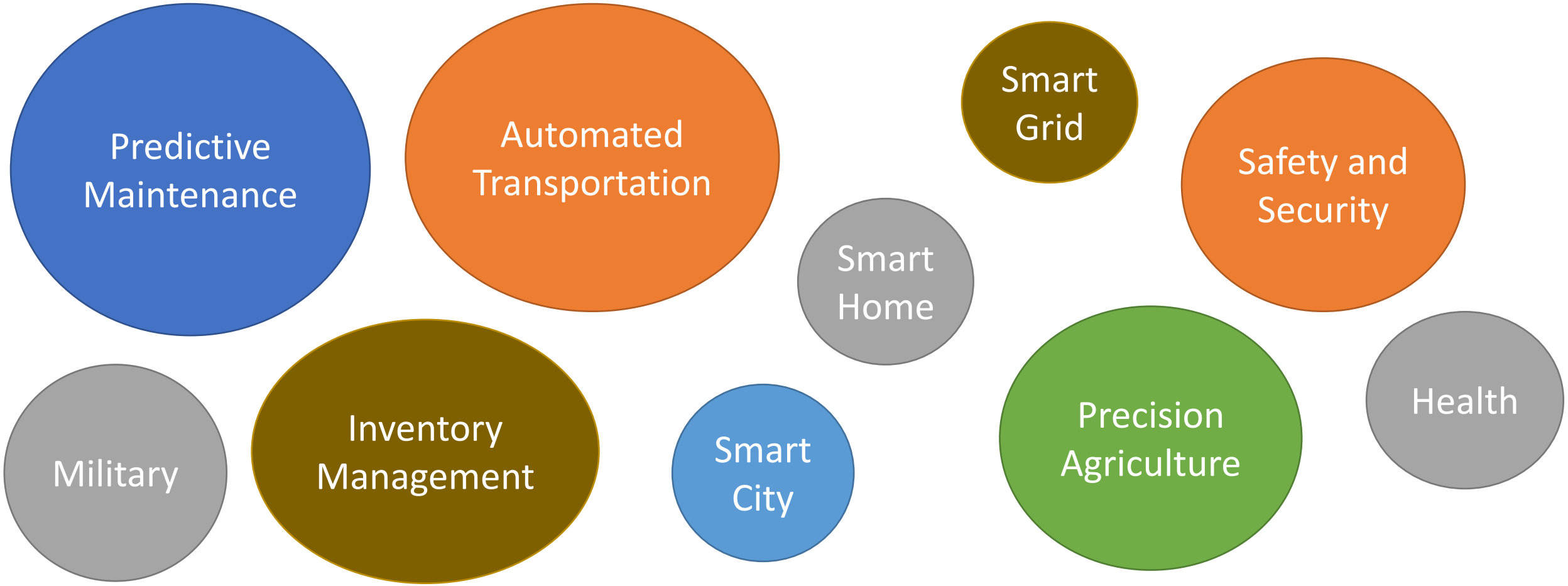
Today/Tomorrow

Machine to machine (M2M), Internet of Things (IoT), Smart World services

Evolution

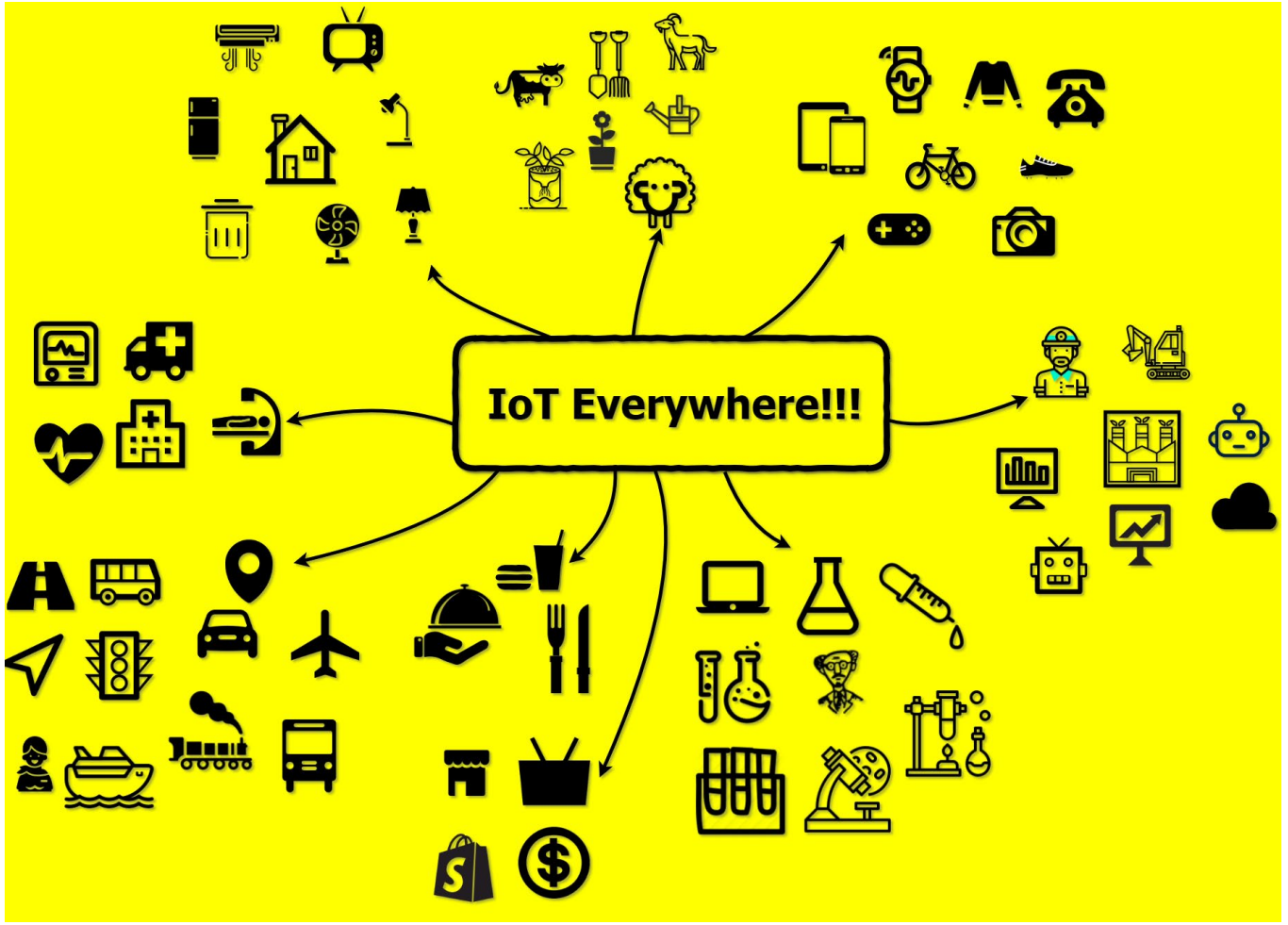
IoT Domains

- With sensors becoming increasingly ubiquitous, there is tremendous potential for innovative IoT applications across a wide variety of domains



IoT is Everywhere: From Home to Work

- Automated Transportation
- Smart Farming
- Smart Surveillance Cameras
- Thermostats
- Baby Monitors
- Smart TVs
- Refrigerators
- Children’s Toys
- Automatic Light Bulbs

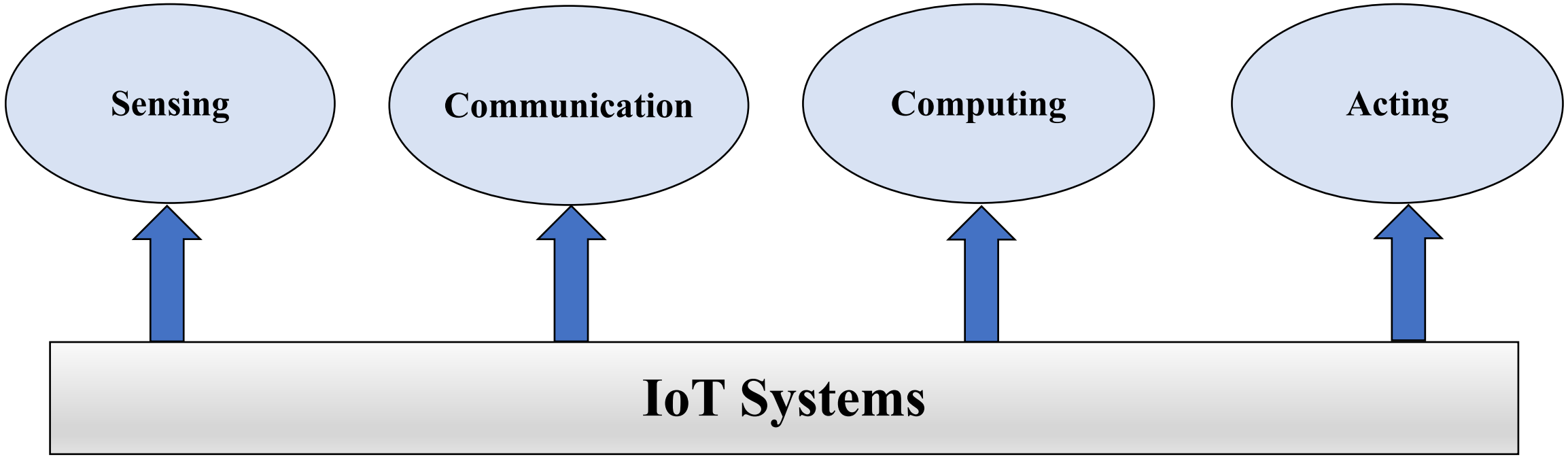


IoT sensing: more sensors than ever

- Pervasiveness of Sensing devices (digital data)
  - E.g. current smartphones are equipped with a number of embedded sensors

- A Mobile Smartphone can provide a lot of context information about you and your activities:
  - your mobility (even wthout GPS)
  - your movement between floors in a building
  - Your speech
  - Your contacts
  - Your interaction with other objects

Four Main Components of IoT Systems

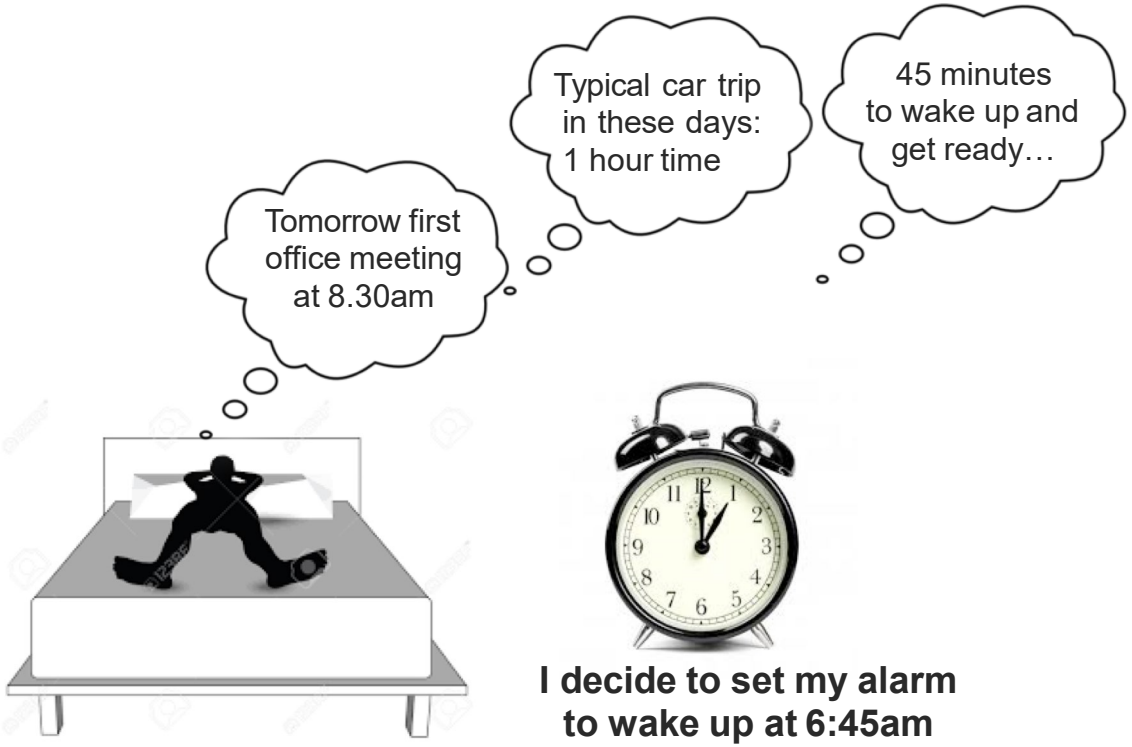


IoT sensors and Actuators

- **Sensor:** a connected device enabling the sensing of physical parameters of the scenario or controlled environment, whose values are transformed into digital data.
- **Actuator:** a connected device enabling the activation of actions on the controlled environment.
- **Controller:** a connected device implementing an algorithm to transform input data in actions.
- **Smart things:** digital devices providing service functions realized by the synergy between sensors, actuators and controllers (possibly implemented by local/distributed execution platforms and M2M/Internet communications).

A Smart Home Example

- One typical evening planning next working day…



A Smart Home Example

What could (will) possibly go wrong?

1) At 4.30am it starts snowing
2) Truck obstruction along the usual path
3) Traffic congestion on alternative paths
4) No parking at destination
5) Bathroom cold when having shower
6) Coffee cold when having breakfast
7) Left my car keys at home when in garage
8) Elevator busy when leaving my flat
9) Total time to get ready+breakfast: 55 min.

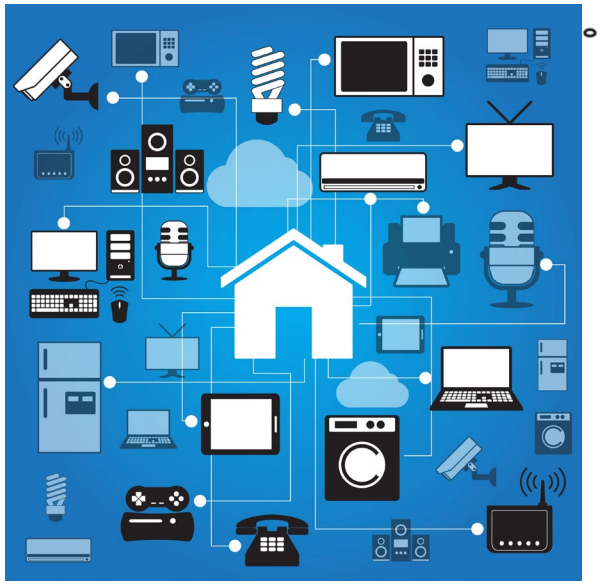
Leaving 10 minutes late + 30 minutes additional travel time

I missed the morning meeting!

A Smart Home Example

Define your user's objective!

Smart IoT Services



45 minutes to wake up and get ready…

Typical car trip in these days: 1 hour time

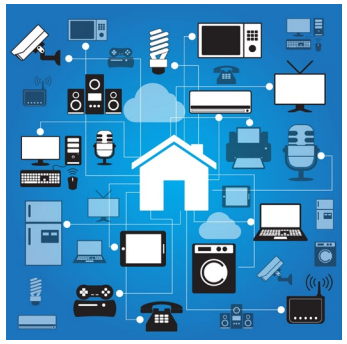
Based on my typical habits decides to set my alarm to wake up at 6:45am

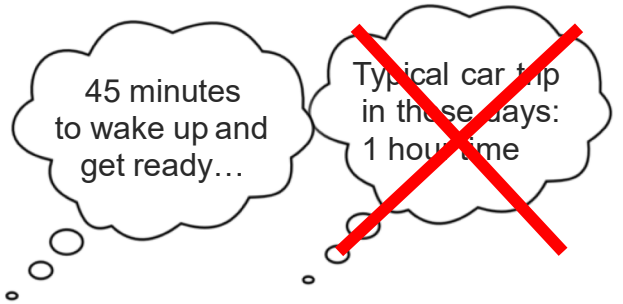
A Smart Home Example

This is the PROGRAMMING effort!

Based current info decides to set my alarm to wake up at 6:30am

Smart IoT Services





What could (will) possibly go wrong?

1) At 4.30am it starts snowing

Get notified in real time by the weather monitoring system or device.

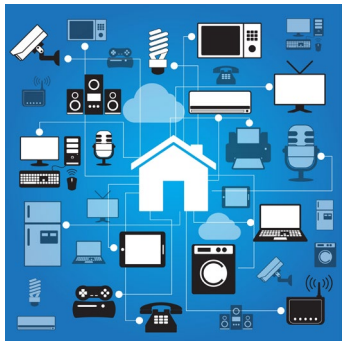
Based on forecasts it anticipates the alarm clock to 6:30am (15 minutes before)

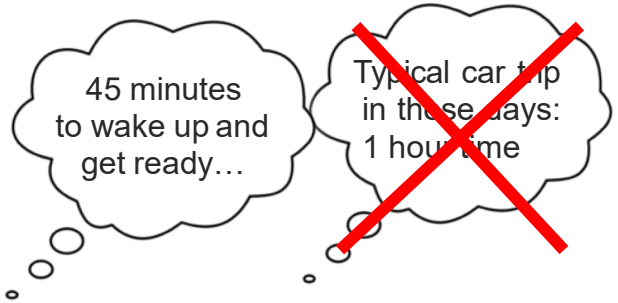
A Smart Home Example

This is the PROGRAMMING effort!

Based current info decides to set my alarm to wake up at 6:30am

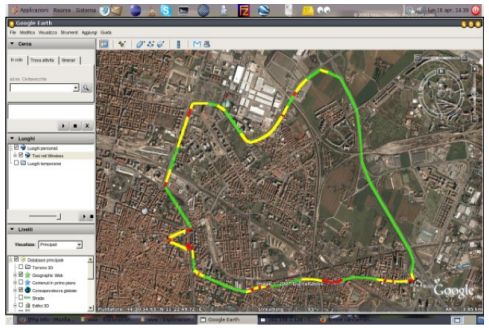
Smart IoT Services





What could (will) possibly go wrong?

1) At 4.30am it starts snowing
2) Truck obstruction along the usual path
3) Traffic congestion on alternative paths



Get notified in real time by the Traffic monitoring information.

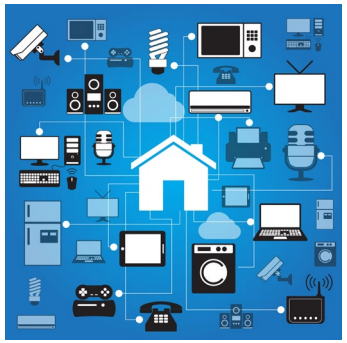
Computes a new path and evaluates congestion delay, it further anticipate alarm clock to 6:00am (30 minutes before)

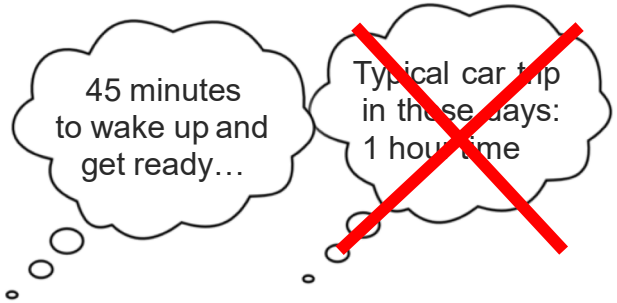
A Smart Home Example

This is the PROGRAMMING effort!

Based current info decides to set my alarm to wake up at 6:00am

Smart IoT Services





What could (will) possibly go wrong?

1) At 4.30am it starts snowing
2) Truck obstruction along the usual path
3) Traffic congestion on alternative paths
4) **No parking at destination**

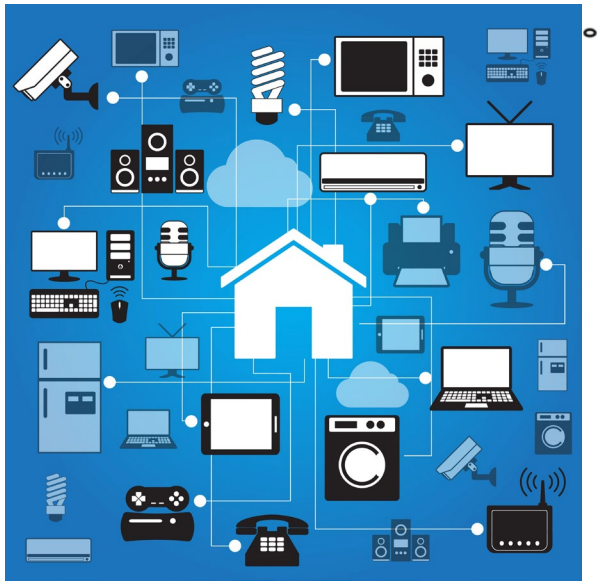
Based on previous experience data and the available parking reservation services decides to reserve a indoor parking slot in a garage.

Reservation code uploaded on the mobile phone to access garage at destination

A Smart Home Example

Define your user's objective!

Smart IoT Services



45 minutes to wake up and get ready…

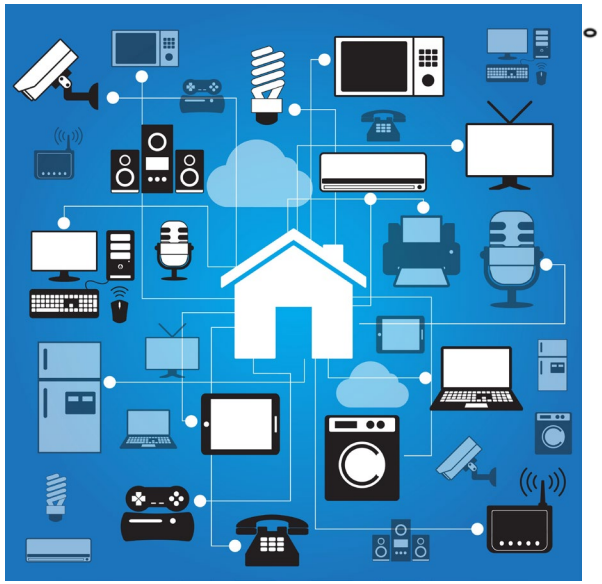
ALARM activated at 6:00 am

Get message on smart phone explaining the reason why the alarm has been anticipated.

A Smart Home Example

Define your user's objective!

Smart IoT Services



45 minutes to wake up and get ready…

ALARM activated at 6:00 am

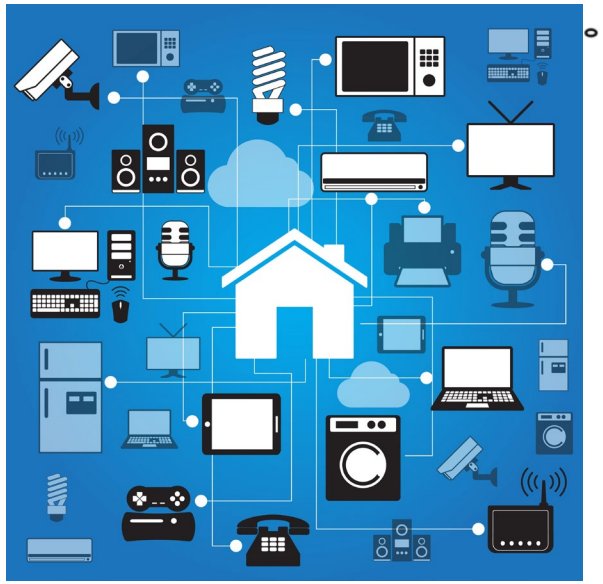
5) Bathroom cold when having shower

HOWEVER, 10 minutes before at 5:50am… started warming up the bathroom to 23 degrees

A Smart Home Example

Define your user's objective!

Smart IoT Services



45 minutes to wake up and get ready…

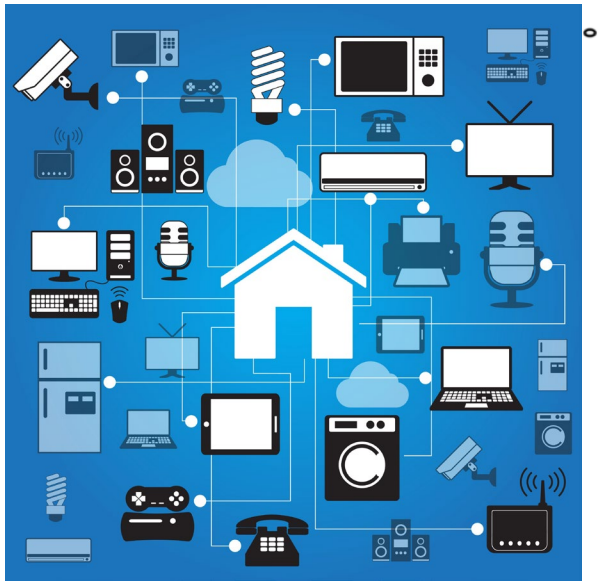
6) Coffee cold when having breakfast

The mirror notifies I am leaving the bathroom, and while I get dressed in my bedroom, the COFFEE MACHINE is activated in the kitchen, and the warming up of the bathroom is switched off.

A Smart Home Example

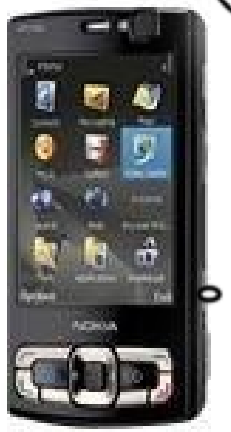
Define your user's objective!

Smart IoT Services



45 minutes to wake up and get ready…

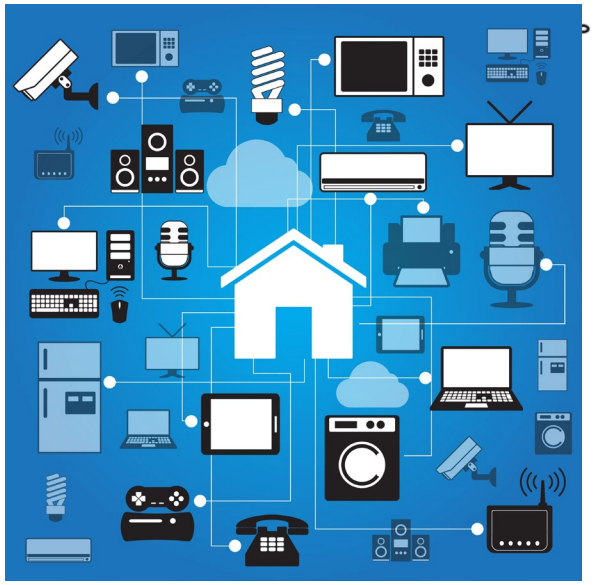
When I leave my home passing through the main door I got a message on my phone advising me that I do not have the CAR KEYS with me…



A Smart Home Example

Define your user's objective!

Smart IoT Services



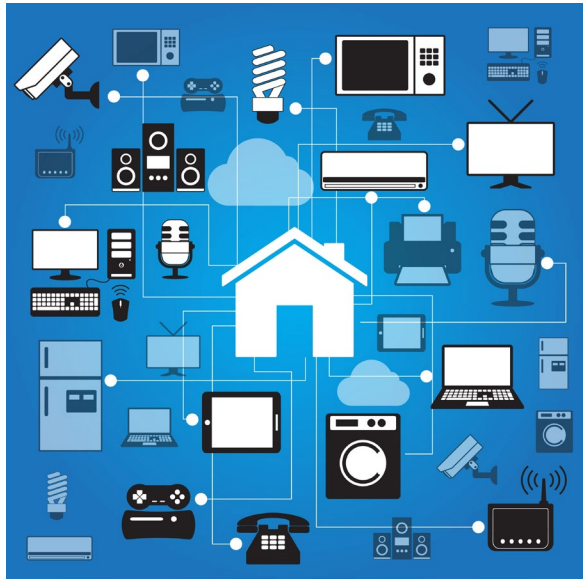
45 minutes to wake up and get ready…

When I re-enter the door my phone informs me that the keys are in proximity of the lamp on the table in the living room, and the LAMP flashes to help me to find the KEYS

A Smart Home Example

Define your user's objective!

Smart IoT Services



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A Smart Home Example

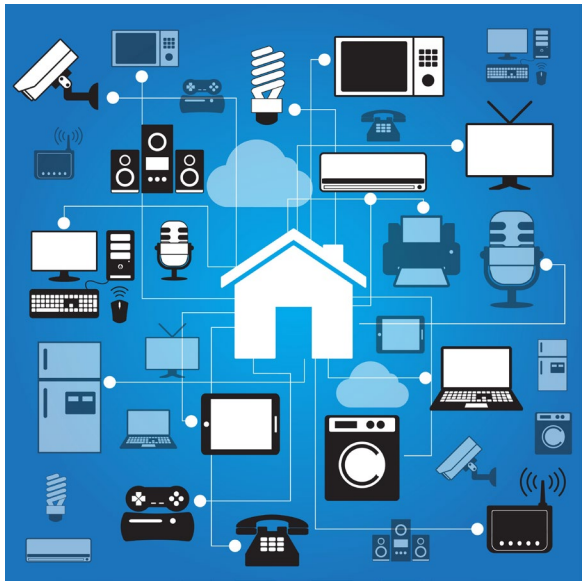
45 minutes
to wake up and
get ready…

Define your user's objective!

Smart IoT Services

When I reach the elevator, it has been already called and it is waiting for me with open doors.

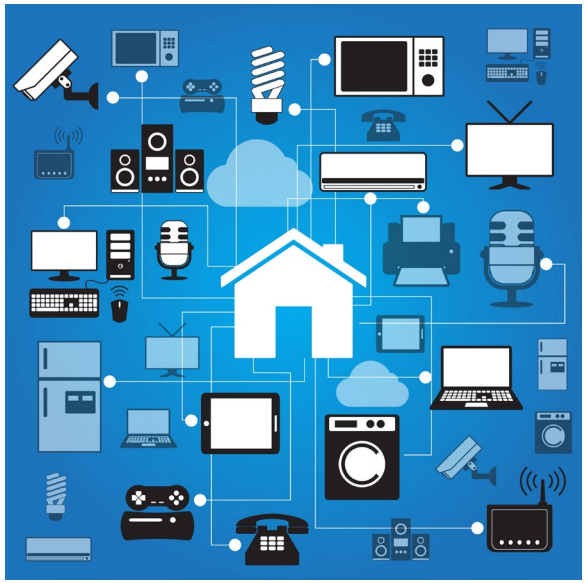
Tomorrow first office meeting at 8.30am



A Smart Home Example

Define your user's objective!

Smart IoT Services



Check possible delays on the path…

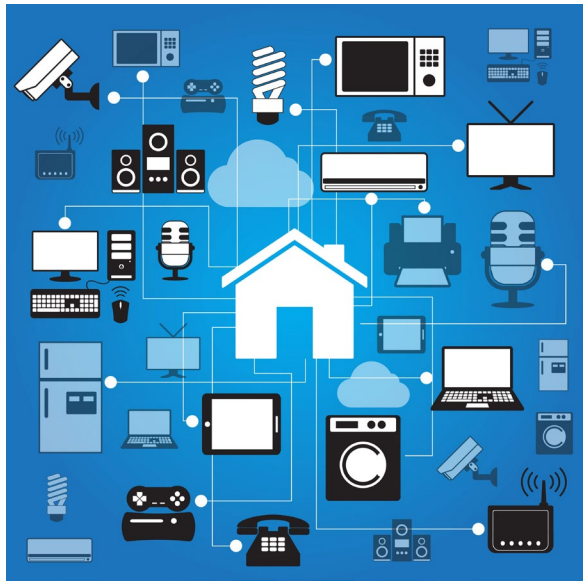
I am leaving with my car right in (planned) time, with my path already set in the navigation system, getting alerted of any problem on the path and need to make detours in real time.

… and when at destination I will have my car parked in reserved indoor garage with no delays. Barriers open with my contactless smartphone code…

A Smart Home Example

Define your user's objective!

Smart IoT Services



Resolved all the troubles…

I participate at the 8:30am meeting

Right in Time!

IoT Characteristics

Pervasive

- IoT devices are Ubiquitous
- Embedded everywhere

Connectivity

- Networks exist on much smaller and cheaper scale

Heterogeneous

- Many technologies interact with each other

Scalability

- Order of magnitude higher than current Internet

Sensors

- IoT loses its distinction without sensors
- Sensors transform IoT from a passive network of devices into an active system

Active Engagement

- IoT introduces a new paradigm for active content, product and service engagement

Small Devices

- IoT devices have become smaller, cheaper, and more powerful over time.
- IoT exploits small devices to deliver its precision, scalability, and versatility

Intelligence

- IoT enhances every aspect of life with the power of data collection, artificial intelligence and smart networks

Advantages of the IoT

Improved Customer Engagement and Decision making

- Transform passive engagement into vibrant and active engagement with users
- Gain insight into potential new products and service
- Deliver post-sales services efficiently

Efficiency and lower operating costs

- Use cheap technology to lower the operating expenses and promote energy conservation
- Monitor the performance, quality, and reliability of products and services

Reduced Waste

- Make areas of improvement clear
- Provide real-world information leading to the more effective management of resources

Technology Optimization

- Improve customer experience and better understand product use
- Unlock the world of critical functional and field data
- Deliver revenue-generating post-sales services

Enhanced Data Collection

- Collect sensing data from the right places in the right times
- Remote troubleshooting of products

New business opportunities

- IoT provides the the ability to collect data from the network and use advanced analytics to uncover new business insights and opportunities

Disadvantages of IoT

Network security

- IoT creates an ecosystem of connected devices communicating over networks which leave users exposed to various kinds of security attacks

Data privacy

- The sophistication of IoT provides substantial personal data in extreme detail without the user's active participation

Complexity

- IoT systems are complicated in terms of design, deployment, and maintenance
- IoT often uses multiple technologies and a large set of new enabling technologies

Flexibility

- IoT systems are flexible in integrating easily with each other, which may cause conflicts between different vendors or locked systems

Compliance

- IoT technology must comply with regulations
- IoT complexity makes the issue of compliance seem incredibly challenging

Unemployment

- The wide-use of IoT will result in a significant loss of mundane jobs
- IoT will have a devastating impact on the employment prospects of less-educated workers

Evolution from Embedded Systems to IoT and Cyber Physical Systems (CPS)

IoT

- Sensing of the physical world
- Internet connectivity
- Used in China and EU

CPS

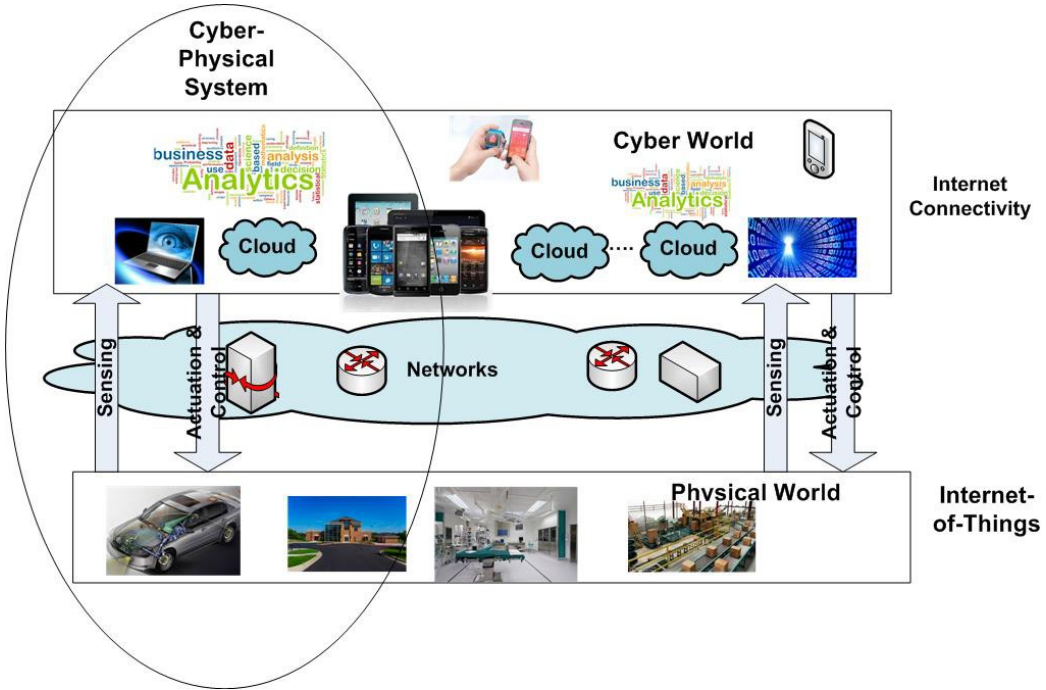
- Control of combined organizational and physical processes
- Tight human machine interaction
- Used in USA and EU

Embedded Systems (e.g., Board)

Networked Embedded Systems

Cyber-Physical Systems (e.g., networked distributed traffic)

Internet of Things (e.g., Smart City Transport)



IoT in Agriculture: Smart Farming

- By using IoT sensors to collect environmental, farmers can make informed decisions, and improve every aspect of their work – from livestock to crop farming.

How is IoT Shaping Agriculture?

Smart Agriculture Sensors

- E.g. weather conditions, soil quality, crop's growth progress or cattle's health.
- Data can be used to track the state of the agriculture field as well as equipment efficiency.

Cost Management and Waste Reduction

- Monitor anomalies in the crop growth or livestock
- Mitigate the risks of losing the yield
- Lead to higher revenue.

Process Automation

- Increase business efficiency through process automation
- By using smart devices, farmers can automate multiple processes across your production cycle
- E.g. irrigation, fertilizing, or pest control.

Enhanced Product Quality and Volumes

- Achieve better control over the production process
- Maintain higher standards of crop quality and growth capacity through automation.

Monitoring Climate Conditions

- Weather stations combine various smart farming sensors
- Weather stations collect various data from the environment and send it to the cloud
- These measurements can be used to map the climate conditions
- It can be also used to choose the appropriate crops, and take the required measures to improve their capacity (i.e. precision farming)

Greenhouse Automation

- The use of IoT sensors enables farmer to get accurate real-time information on greenhouse conditions such as lighting, temperature, soil condition, and humidity.

- Weather stations can automatically adjust the conditions inside the greenhouse to match the given parameters.

Crop Management

- Crop management devices, just like weather stations, can be placed in the field to collect data specific to crop farming such as temperature, leaf water potential, overall crop health, etc.

- Farmers can monitor their crop growth and any anomalies to effectively prevent any diseases or infestations that can harm the yield

Cattle Monitoring and Management

- IoT agriculture sensors that can be attached to animals on a farm to monitor their health and log performance.
- Livestock tracking and monitoring help collect data on stock health, well-being, and physical location.
- Such sensors can identify sick animals so that farmers can separate them from the herd and avoid contamination.
- Using drones for real-time cattle tracking also helps farmers reduce staffing expenses.

Agricultural Drones

- Also known as UAVs (unmanned aerial vehicles), drones are better equipped than airplanes and satellites to collect agricultural data.
- Drones can also perform a vast number of tasks that previously required human labor such as planting crops, fighting pests and infections, agriculture spraying, crop monitoring, etc.

IoT Wearables

Wearables' Characteristics

- Small electronic devices
- Comprised of one or more sensors
- Associated with clothing or worn accessories, such as watches, wristbands, glasses, and jewelry
- Have some sort of computational capability
- Capture and process data about the physical world
- Some presenting data in some sort of display

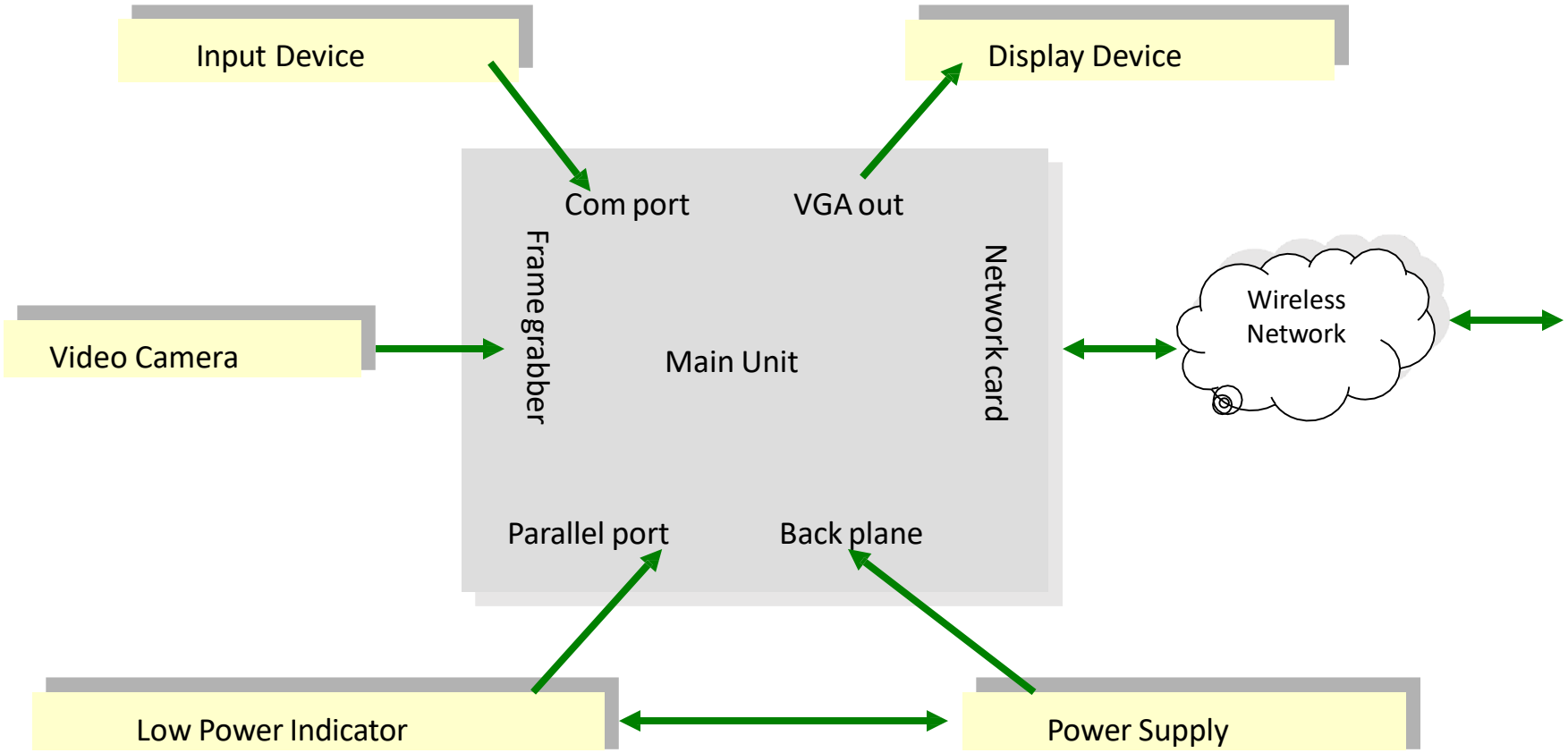
Connectivity

- Wearable devices are not always connected to the Internet
- Offer connectivity, such as Bluetooth- or NFC-(Near Field Communications) based connectivity to smartphones
- Connect to smartphone applications

IoT Wearables

- Adding information & value to wearables' capabilities
- More sensors and functionalities
- Integration with services and data provided by other devices (including other wearables)

IoT Wearable System



Wearables Input & Output Devices

Input Devices

- Keyboard alternative, included chording keyboards and special purpose keyboards
- Mouse alternatives, including trackballs and joysticks
- Tab alternatives, including buttons and dials
- Eye trackers
- Head trackers
- Pens
- Gesturing
- Bar code readers
- Textiles
- Video capture devices, microphones, GPS locators
- Speech recognition
- Other devices (e.g., skin sensors)

Output Devices

- Head Mounted Displays (HMDs)
- Flat panels, text-to-speech
- Tactile output
- Non-speech auditory output
- Paper and olfactory output (scent)

Wearables Functionalities and Application Areas

Sensors

- Light
- Sound
- Speed/acceleration
- Humidity
- Temperature
- Accelerometers

Consumer-oriented applications

- Fitness and sports
- Fashion and apparel
- Home automation
- Gaming

Non-consumer-oriented applications

- Defense and security
- Manufacturing and industry
- Healthcare

Wearables Examples

Apple Watch

- Includes a heart rate sensor, GPS, and an accelerometer
- Fully integrated into the Apple ecosystem

Sensoria Fitness T-shirt

- Comprised of embedded textile sensors
- Enables tracking of heart rate

Adidas Smart Run

- Wrist device that monitors the wearer's heart rate and location data
- Blended into Adidas miCoach system

Wearables Examples

FitBit's Flex

- Sleek wristband
- Provides real-time statistics on a user's daily fitness activity

Google Glass

- Head-mounted wearable computer
- Projects a transparent screen in front of the user's field of vision

Nike+ Sportwatch

- Measures the distance traveled
- Measures pace and speed of the wearer's run

Wearables Examples

Samsung's Galaxy Gear

- Android-based smart watch
- Synchronizes with a cellphone to achieve smartphone-like capabilities

Sony Core

- Wrist-worn waterproof wearable smart band with a built-in sensor
- Records activity levels throughout the day

Garmin SmartWatch

- Built-in sports apps
- Smart scales with wireless connectivity
- Enables a more active lifestyle

IoT Future Trends

Wearables Ecosystems

- Complete programming and application development environments beyond the device level
- Wearables as parts of the IoT ecosystem

Interoperability

- Across devices of different types and from different vendors
- Across different ecosystems
- Single entry point for managing personal data

Novel IoT Services

- Integrated IoT wearables services combining data and services from multiple ecosystems
- Driven by innovation for fitness, healthcare, industry, etc.

IoT and Manufacturing Maintenance Activities

Preventative and condition-based monitoring

- Prevent malfunctions
- Equipment that needs to operate within a certain temperature range, the company can use IoT sensors to actively monitor when it goes out of range
- Measuring vibrations to detect operations that are out of spec
- Leverages Big Data Analytics including predictive modelling

Predictive Maintenance

- Leverage multiple modalities to predict when maintenance will be required
- Examples: vibration analysis, oil analysis, thermal imaging, etc.

Asset Monitoring and Management Using IoT

Asset Management using IoT

- Monitoring assets for their status (including predictive maintenance) using IoT Technologies
- New service offerings and business models for equipment suppliers

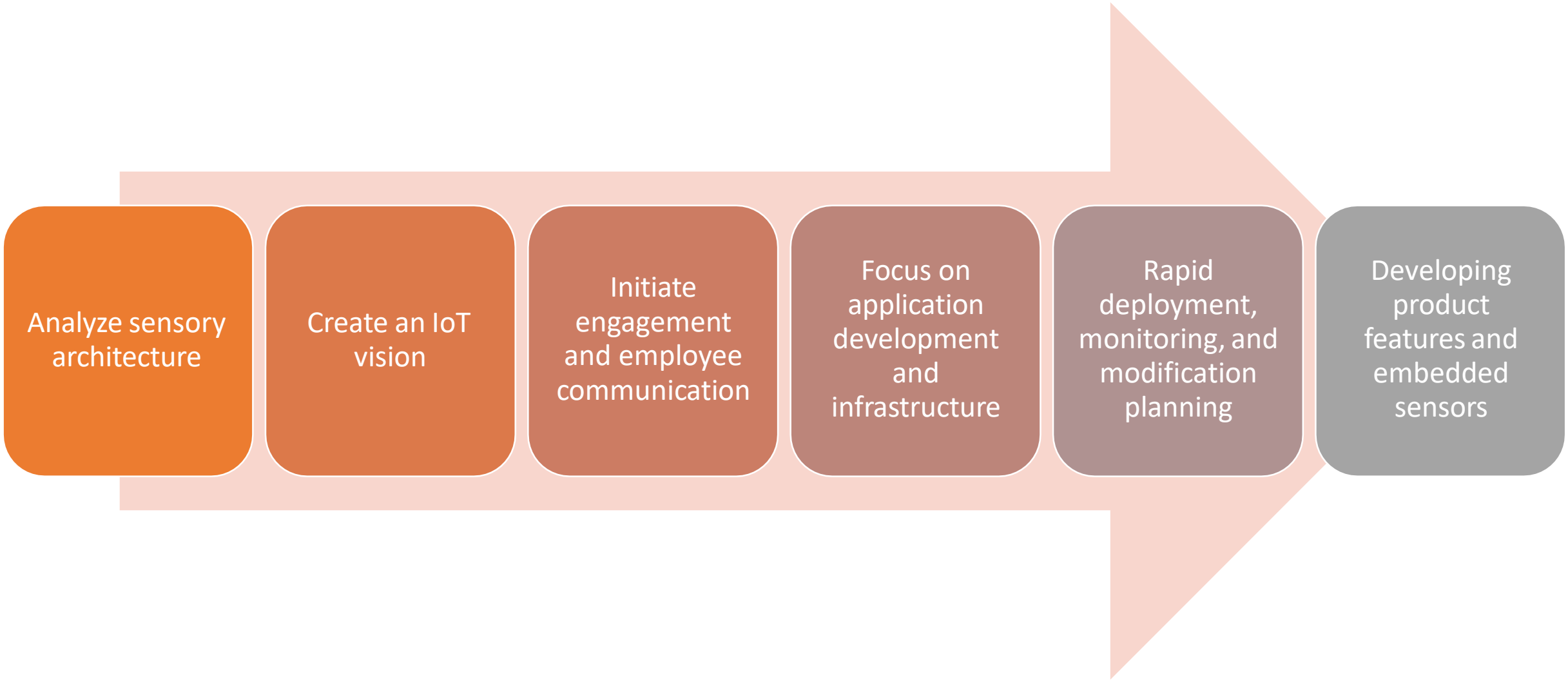
Example Business Models

- Models around hours of operation rather than equipment sale; buyers use the equipment in an “as-a-service” offering
- New and very closely linked business relationships between manufacturers and their suppliers

Industry example

- GE’s maintenance cost per (flight) hour model for its aviation business

IoT Applications Development Process



IoT Applications - Smart City

Urbanization

- Urban population worldwide amounts currently to approximate 4.1 billion people
- Expected to double by 2050
- Resource depletion; need for efficient management of resources
- Exclusion, inequality, and rising insecurity challenges

Demographic changes

- Number of seniors aged 60 or over is the fastest growing segment of the population at a rate of 3.26%
- Decline in infant mortality & high fertility
- Proliferation of the younger population
- Need for employment opportunities

Changing lifestyles

- Changes in family patterns
- New habits in work and mobility, e.g., tele-working, vehicle sharing, & renting
- Need for novel urban services in support of these changes

Climate change

- Climate changes & global warning
- Policies for efficient use of water, energy, and other resources
- Measures for sustainable growth

Smart Cities and IoT

Smart Cities are empowered by IoT technologies

- Empowers internet-based connectivity across devices
- IoT will generate up to $11.1 trillion a year in economic value by 2025
- Smart cities are one of the IoT settings with the highest business value

Relevant IoT technologies

- Connectivity: WiFi, 4G/LTE, 5G
- Devices interaction: IoT middleware
- Scalable processing: Cloud computing
- Data processing: Data mining, Data analytics, BigData

Smart City Development Model

Phase 1: Digital Infrastructure

- Broadband networks
- Sensor networks
- Public Open Data
- Certification & validation of infrastructures
- "Digital city"

Phase 2: Services Development

- Smart Energy, Smart Transport, Urban Mobility
- Stakeholders Involvement
- "Smart City"

Phase 3: Services Integration & Citizens Participation

- Integration and reusability of data & services
- Citizen engagement
- "Integrated Smart City"

IoT & Smart Cities Services Trends

Interoperability

- Control center integrating all systems and projects in the smart city using IoT technologies

Citizen Engagement

- Engagement in IoT Services design (e.g., co-creation, integration of artistic concepts)
- Citizen-centric services

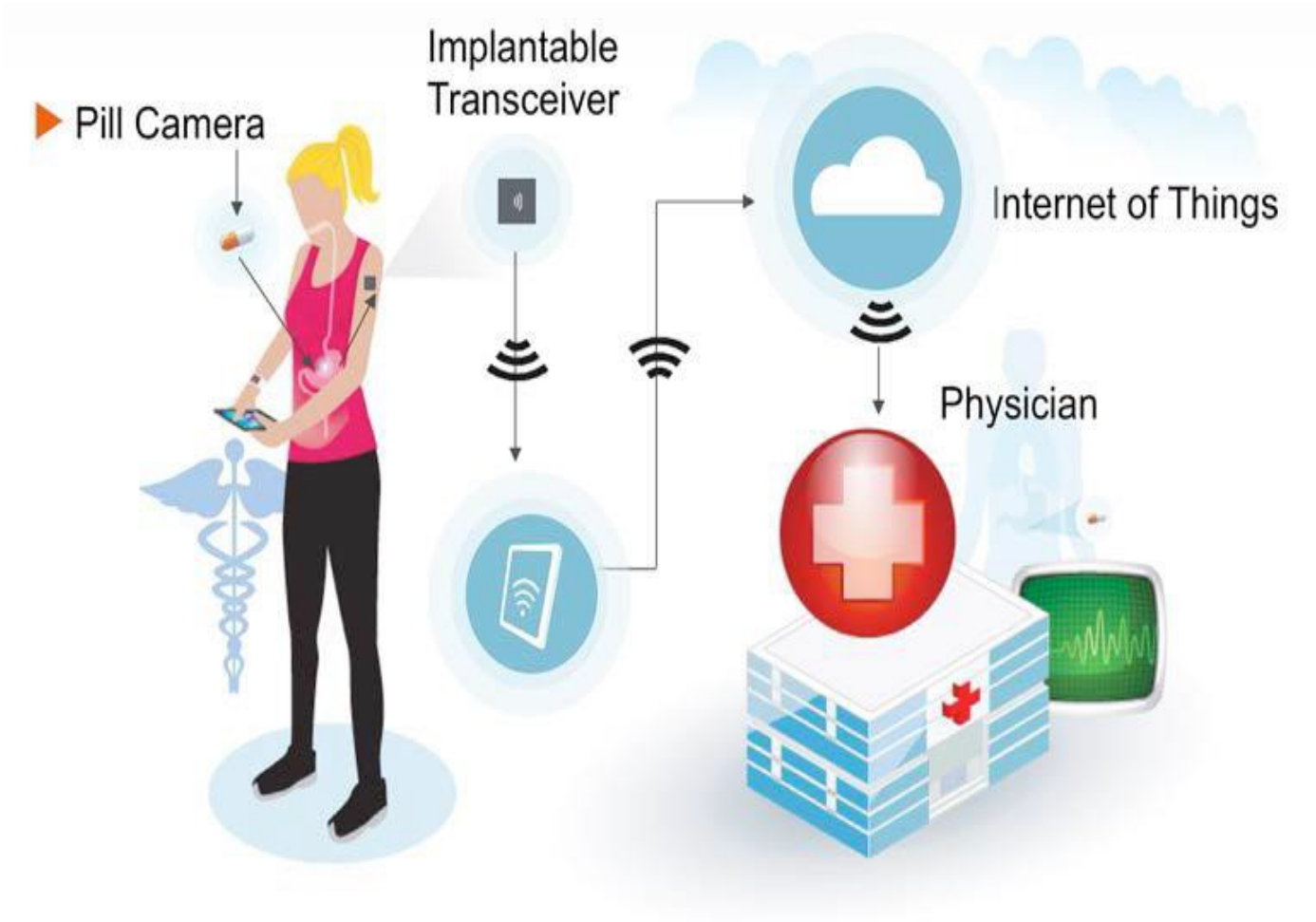
Public Private Partnerships

- Public sector deploys connectivity infrastructure (Wifi); while private sector deploys services

IoT in Healthcare

Patient Monitoring

- Sensors collect patient data
- Microcontrollers process, analyze, and wirelessly communicate the data
- Microprocessors enable rich graphical user interfaces
- Healthcare-specific gateways through which sensor data is further analyzed and sent to the cloud



IoT and Clinical Care

Target

- Replace the process of having a health professional come by at regular intervals to check the patient's vital signs

Benefits

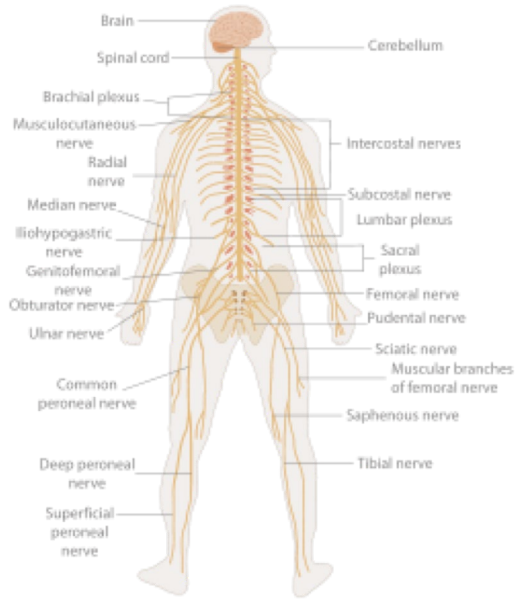
- Improve quality of care
- Lowers the cost of care by eliminating the need for a caregiver to actively engage in data collection and analysis

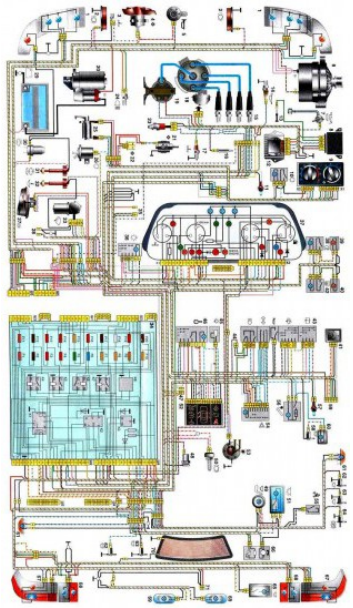
Implementation

- Constant monitoring using IoT-driven, noninvasive sensors
- Collect comprehensive physiological information
- Uses gateways and the Cloud to analyze and store the information
- Send the analyzed data wirelessly to caregivers for further analysis and review

Connected Car and IoT Transport Sensors

- An economy cars: more than 200 sensors (brakes, belts, air bags, doors, etc.)
- A luxury car: more than 600 sensors (A/C, ABS, lights, radar, road conditions, etc.)
  - 70 sensors just in the engine of a 2005 Ford Focus (today 15X w.r.t. 15 years ago)
  - Vehicle safety and comfort has improved via sensors and actuators





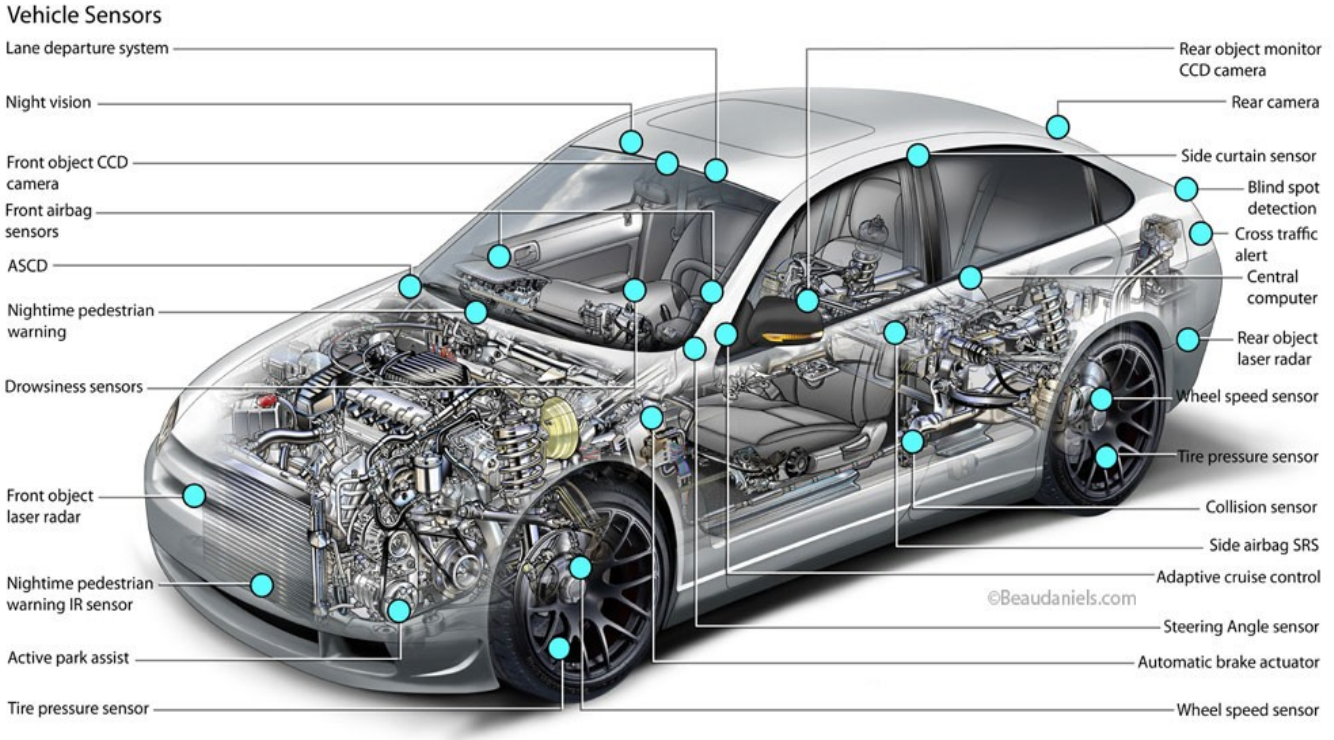


Image source: Beaudaniels-illustration.com

The vehicle's automatic control (beyond driver) is more likely a "**nervous system**" reacting to possible problems, obstacles and contributing to comfort and safety

Connected Car and IoT Transport Sensors

- Road Condition Sensor
- Magnetic Sensor
- Vehicle Distance Sensor
- Forward Obstacle Sensor
- Blind Spot Monitoring Camera
- Drive Recorder
- Side Obstacle Sensor
- Air Pressure Sensor
- Airbag
- Road-To-Vehicle/Vehicle-to-Vehicle Communication System
- Rear View Camera
- Water Repelling Wind Shield
- Seatbelt Pretensioner
- Driver Monitoring Sensor
- Headup Display
- Steering Angle Sensor
- Electronic Control Throttle
- Electronic Control Brake
- Fire Detector Sensor
- Vehicle Speed, Acceleration Sensor
- Collision Detection Sensor
- Pedestrian Collision Injury Reduction Structure
- Electronic Control Steering
- Message Display System
- Hands-Free System
- Inside Door Lock/Unlock
- Rear Obstacle Sensor
- GPS Sensor

Source: *Application Developers Alliance, "Internet of Things: Automotive as a Microcosm of IoT", White Paper, 2019*

Connected Car: Indicative Applications

Infotainment

- Brings information functions (i.e., navigation, location-based services, rear seat web browsing, social networking, etc.) into the vehicle's entertainment system.
- E.g., CarPlay for using iTunes, watch videos, run navigation apps on the in-dash display with a touch screen interface & Apple's voice-companion Siri (vocal commands)
- Bring the entire apps ecosystem to the dashboard and present endless possibilities for an in-car experience
- Examples: Read out email & calendar reminders, order food, switch on the heater, etc.

Vehicle-to-Vehicle (V2V) Communication

- Wireless exchange of the position, speed, and location data between nearby vehicles
- E.g., toward improving the safety of commuters

Vehicle-to-Infrastructure (V2I) Communication

- Wireless exchange of information between vehicles and roadside infrastructure
- Communicate with the roads, digital signage, traffic lights, safety, and control systems
- E.g., avoid crashes and traffic congestion