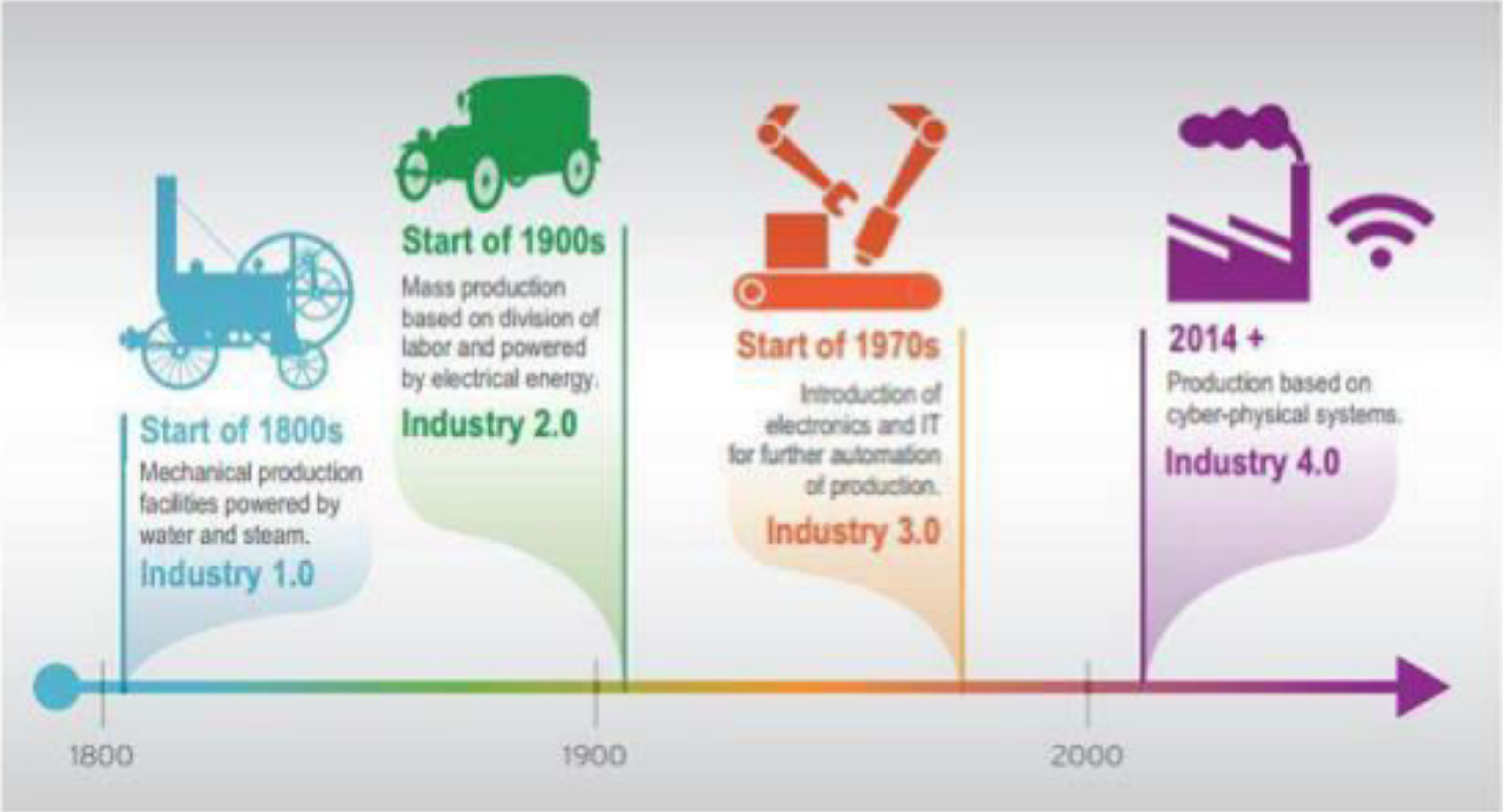
# Introduction to 4IR, Internet of Things and Embedded Systems

# Four Stages of the Industrial Revolution




*Source: Industry 4.0 (or Zukunftsprojekt Industrie 4.0), a German government high-technology initiative to promote the computerization of traditional industries such as manufacturing.*

# What is the Fourth Industrial Revolution?

- Klaus Schwab, founder and executive chairman of the Geneva-based WEF, published a book in **2016** titled "The Fourth Industrial Revolution" and coined the term at the Davos meeting that year.
- Schwab argued a technological revolution is underway "that is blurring the lines between the **physical**, **digital** and **biological** spheres."
- Simply put, the Fourth Industrial Revolution refers to how technologies like **artificial intelligence**, autonomous vehicles and the **internet of things** are **merging with humans' physical lives**. Think of voice-activated assistants, facial ID recognition or digital health-care sensors.
- Schwab argued these technological changes are drastically altering how individuals, companies and governments operate, ultimately leading to a **societal transformation** similar to previous industrial revolutions.

# The first three industrial revolutions

- Zvika Krieger, the head of technology policy and partnerships at WEF, told CNBC that there is a common theme among each of the industrial revolutions: **the invention of a specific technology that changed society fundamentally.**
- The First Industrial Revolution started in Britain around 1760. It was powered by a major invention: **the steam engine**. The steam engine enabled new manufacturing processes, leading to the creation of factories.
- The Second Industrial Revolution came roughly one century later and was characterized by **mass production** in new industries like steel, oil and electricity. The light bulb, telephone and internal combustion engine were some of the key inventions of this era.
- The inventions of the semiconductor, personal computer and the internet marked the Third Industrial Revolution starting in the 1960s. This is also referred to as the "**Digital Revolution**."

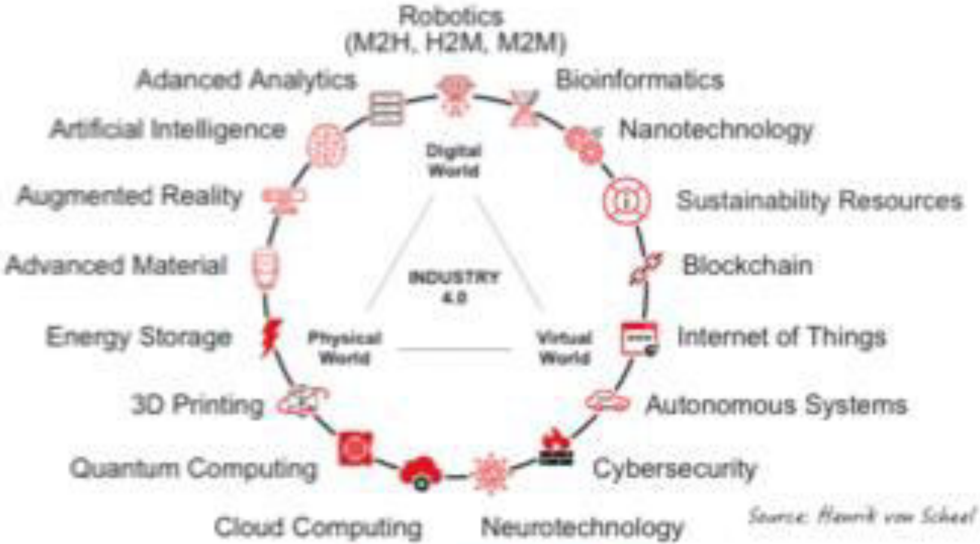
# Difference between Third and Fourth

- Fourth Industrial Revolution is different from the third for two reasons: the gap between the digital, physical and biological worlds is shrinking, and technology is changing faster than ever.
- For evidence of how quickly technological change is spreading, observe the adoption of the telephone. It took 75 years for 100 million people to get access to the telephone; the gaming app "Pokemon Go" hooked that many users in less than one month in 2016.

# The Issues and Concerns

- Some experts warn of a "**winner-take-all economy**," where high-skilled workers are rewarded with high pay, and the rest of workers are left behind.
- A 2018 report by investment firm UBS found **billionaires have driven** almost 80 percent of the 40 **main breakthrough innovations** over the past four decades.
- In 2016, Schwab predicted **inequality** would be the greatest societal concern associated with the Fourth Industrial Revolution.
- "There has never been a **time of greater promise**, or **one of greater potential peril**"

# Next wave of Industry 4.0 unstoppable forces that disrupts everything




Source: Henrik von Scheel

**1st wave 2009 - 2016**

- Digitalization
- Internet of Things
- Automation
- M2M Robotics
- Big Data
- Cloud Computing

**2nd wave 2016 - 2025**

- Artificial Intelligence
- Blockchain
- Quantum Computing
- Sustainable Resources
- H2M Robotics
- Energy Storage

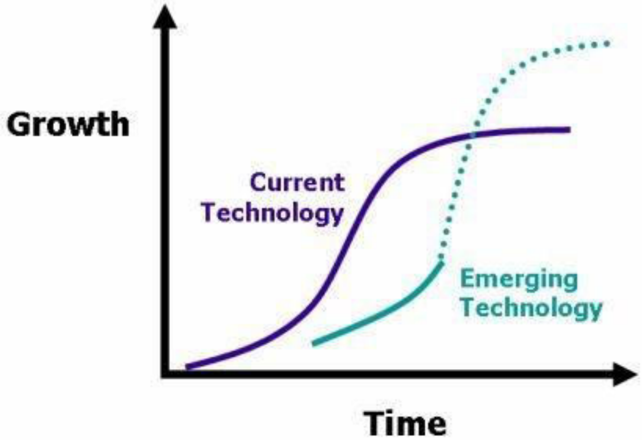
**3rd wave 2025 ...**

- Energy Storage
- Neuro-technology
- Cybersecurity
- Nanotechnology
- Bioinformatics
- ...

# We are Way Behind the Developed Countries

# We have Adopted Leapfrog Strategy for Pakistan

- Andrew Ng has proposed a brilliant strategy for **developing countries that have fallen behind in the technology race**.
- The idea is to *skip over the intermediary technologies* and **leapfrog** into the future by adopting 4IR technologies.
- With this approach, it is possible to achieve **exponential growth in a shorter period of time.**



# The Internet of Things (IoT) will power the Fourth Industrial Revolution

- The Fourth Industrial Revolution is changing the very software-defined automation allows manufacturers to link all stages of the value chain, rapidly adapt to changing markets, and create highly personalised products on a mass scale.
- The opportunities presented by this revolution are incredible. According to McKinsey, the economic impact of smart factories could reach up to $2.3 trillion per year by 2025.
- **At the heart of the Fourth Industrial Revolution is the Internet of Things (IoT), which uses digital technology to connect sensors, actuators, and machines to each other and to factory workers.**

# What is IoT?

- The Internet of Things, or IoT, refers to the billions of physical devices around the world that are now connected to the internet, collecting, sharing and analyses of data.
- Thanks to cheap processors and wireless networks, it's possible to turn anything, from a pill to an aeroplane to a self-driving car into part of the IoT

# Definition

The Internet of Things is the network of physical devices that combine IP connectivity with software, sensors, actuators, and other electronics to directly integrate the physical world into our computer-based systems, resulting in efficiency improvements and economic benefits.

Simpler Definition:

The Internet of Things is a network of Internet connected devices that communicate embedded sensor data to the cloud for centralized processing.

# IoT is about Billions of Devices

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Thanks to cheap processors and wireless networks, it's possible to turn anything, from a pill to an aeroplane to a self-driving car into part of the IoT

# The Current and Future Impact of IoT

The IEEE has compiled data and makes the following claims about its current and future impact:

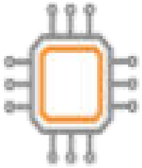
- In 2015, the global wearables market had already increased 223% from the previous year (and data on Statista shows it increasing by another 243% between 2015 and 2022)
- By 2020, 250 million vehicles were connected to the Internet
- IoT will add 15 trillion dollars to the global economy over the next 20 years
- There will be 50 billion Internet-connected devices by the year 2020.

# Benefits of IoT

The interconnection of these multiple embedded devices will be resulting in automation in nearly all fields and also enabling advanced applications. This is resulting in improved accuracy, efficiency and economic benefit with reduced human intervention. The major benefits of IoT are:

- Improved Customer Engagement
- Technical Optimization
- Reduced Wastage
- Integrate and Adapt Business Model
- Better Business Decision

# End-to-end IoT

| Connectivity & Security technology | Connectivity & Security technology | Connectivity, Security and edge analytics | Relationships & reach | IoT services / Platforms |
| --- | --- | --- | --- | --- |
| Silicon | IoT Devices | Gateways | Networks | Cloud |
|  | | |  | |
| Silicon, embedded Oses, embedded systems | IoT devices for connecting them | Gateways & recipes for connecting them | Network technologies / connectivity / Internet connection | Additional value, cloud services, AI/ML API's |

End-end IoT solution

# Example IoT Devices

# Applications of IoT

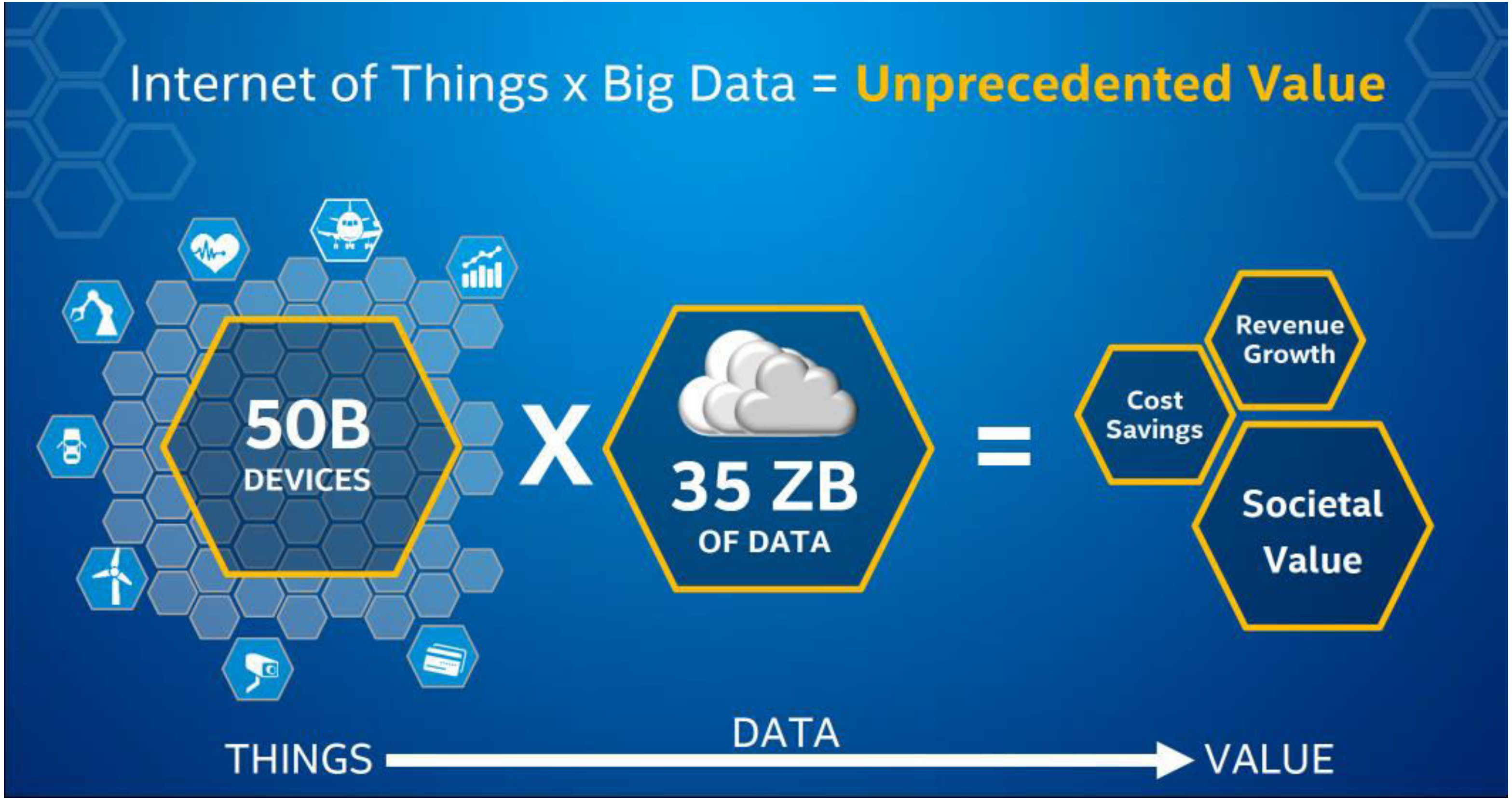
# Introduction to IoT

**9 billion** devices around the world are currently connected to the Internet, including computers and smartphones

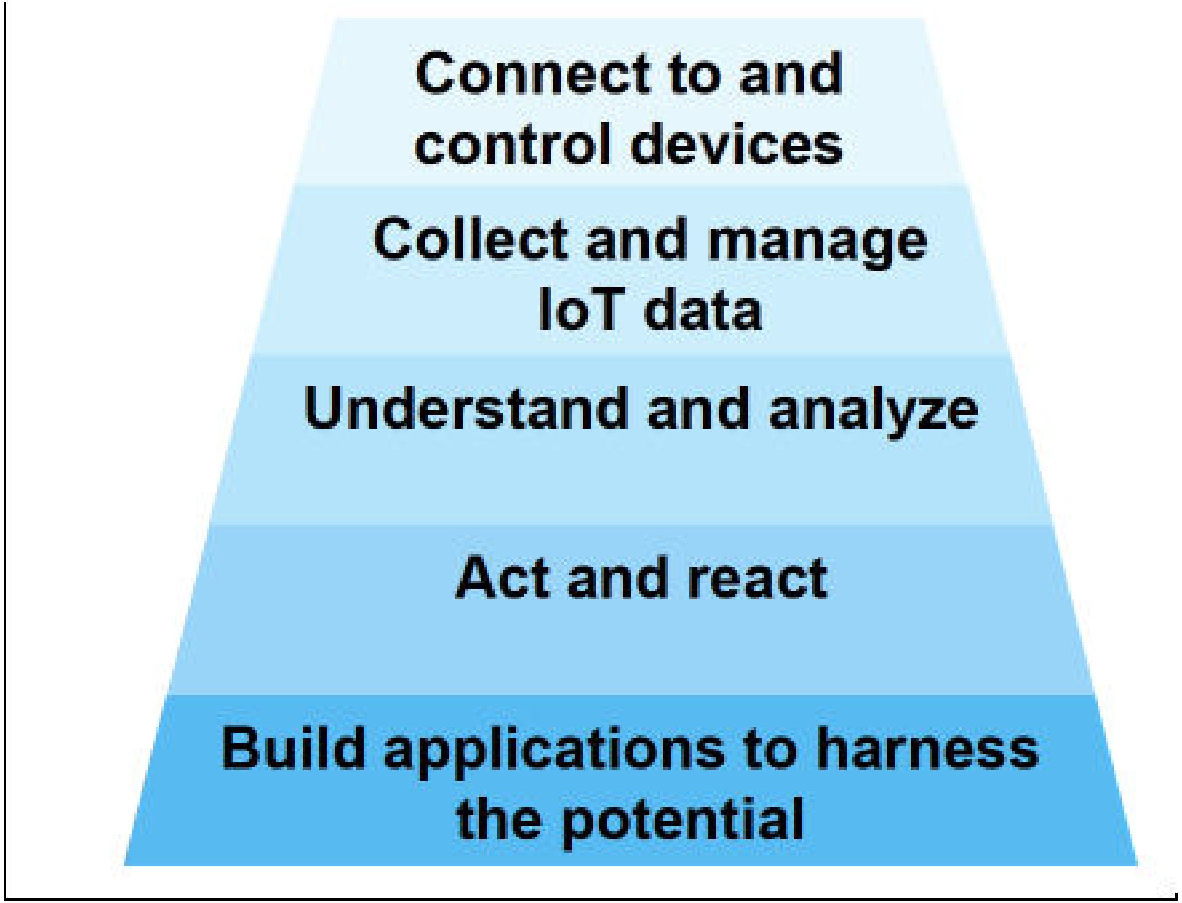
The number is expected to increase dramatically within the next decade, with estimates ranging from **50 Billion devices** to reaching **1 trillion**


The Internet of Things has the potential to create economic impact ***of $2.7 trillion to $6.2 trillion*** annually by 2025

# Value Proposition



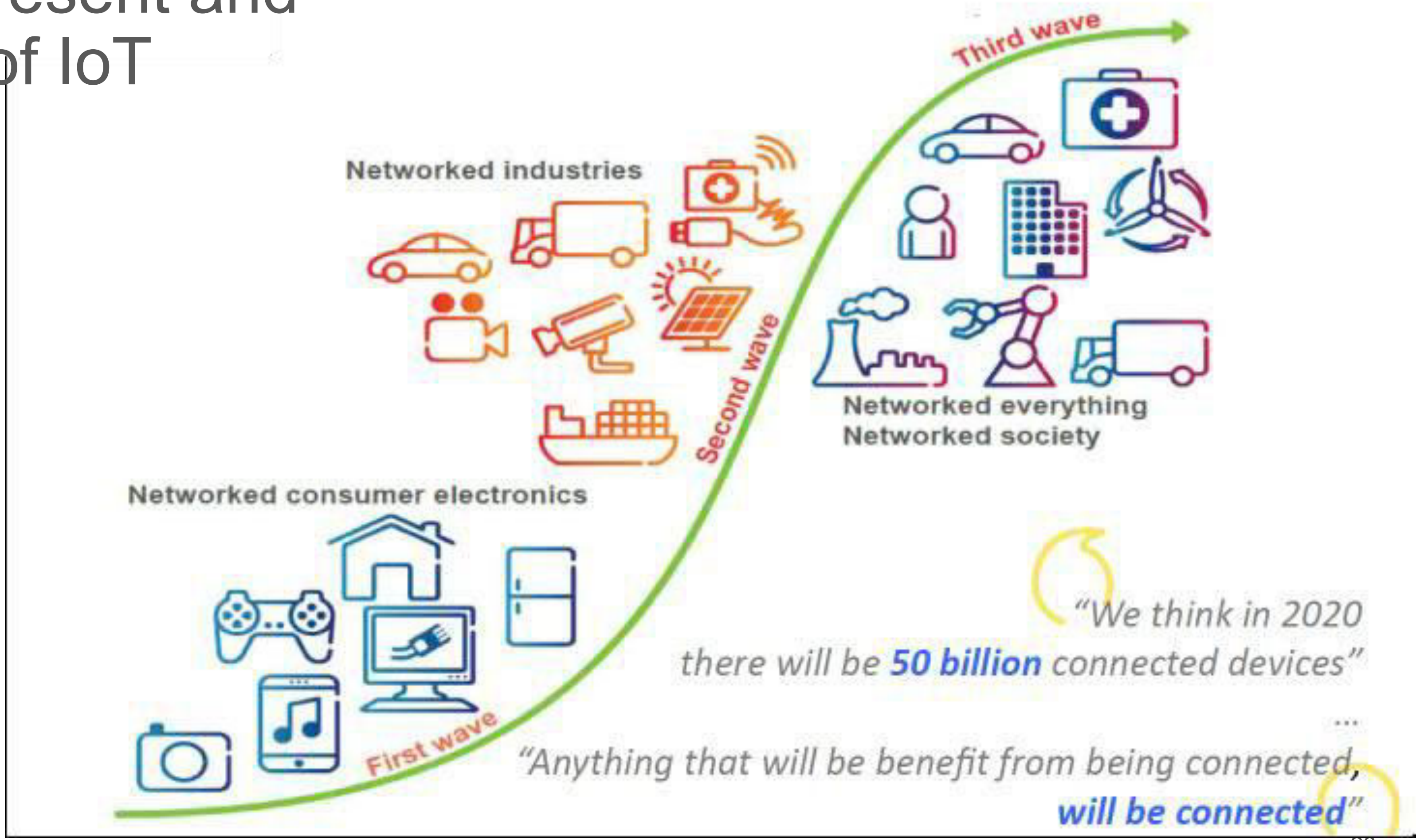
# Layers of IoT



# Challenges to IoT

- Security, Privacy, Compliance
- Market Fragmentation
- Legacy Infrastructure
- LAN/WAN Connectivity
- Underutilized Data
- Interoperability and Standards

# Past, Present and Future of IoT



# What are Embedded Systems?

- IoT devices are embedded systems
- Computer based Systems that do not appear to be computers - complexity is hidden from the users
- The complexity is embedded inside the device (that is where the name came from)
- IoT devices are always connected to the internet
- Embedded systems may have computational complexity but may or may not be connected to a network
- Things are moving from Embedded to IoT, a lot of thing were Embedded but are now IoT
- Sometime an Embedded System does not interact with the user but with another system, invisible to the user (Disk drive, anti lock braking system)

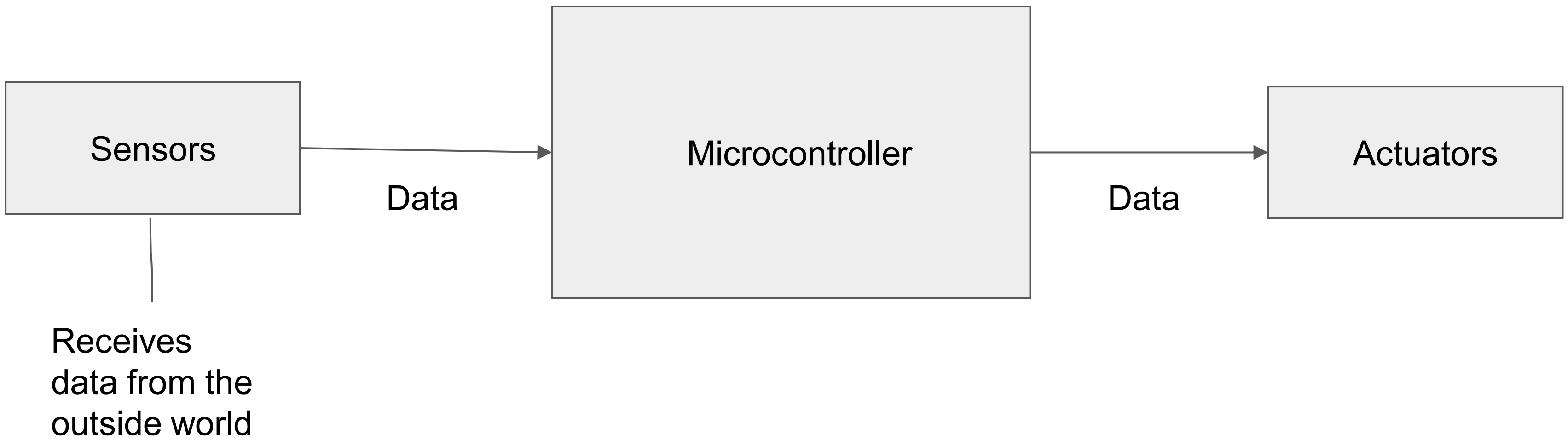
# Efficiency Rules in Embedded Systems

- Most embedded systems are in cost-critical markets (e.g. consumer products)
- Other Applications are in performance or power critical markets (e.g. military, medical)
- It not that we just want it to work but we want it to work under tight constraints
- Cannot depend on Moore’s Law to save you in the long run, it has to perform from day one

# Embedded Systems vs Regular Platform Design

- Embedded devices are generally application specific. Embedded systems are made to do one thing or one related set of things.
- Unlike desktop, laptop computers which can run any type of program or pretty good doing any type of program.
- When you know that the device is gonna do one thing, you design it for the one thing, you don't design it for everything.
- A general purpose machine is overpowered.
- But embedded systems are designed specifically and they let you change the way you do design, you can just put in the things that you need to put in. Spend money on what you need to put in. So, higher design efficiency is possible in Embedded System.
- In embedded system you have understand both the software and hardware, which makes it more difficult.

# Embedded Systems Structure



# Microcontrollers

Integrated circuits that executes a program

Microcontrollers vs Microprocessors

Slower, 16 MHz - 500 MHz

Less memory, fewer features

Much cheaper

You write your program on computer, compile it and upload it to the flash memory of the microcontroller. As soon as there is power it runs the program.

We will use C to program microcontrollers

# Sensors

Sensors just receive information from the environment.

Thermistor: Receives temperature information.

Photoresistor: It reports light intensity.

CMOS camera (digital camera): It captures images

# Actuators

Actuators cause events to occur in the environment.

LEDs (light emitting diodes): they turn lights off and on

LCDs (liquid crystal displays): like what's on my digital watch

Servo motor: motors

# Analog to Digital Conversion

- Converts Analog Data to Digital Data
- Used to interface with analog sensors
- Analog to digital is the same as the difference between real numbers and integers
- So the universe. The world in general to the perception of humans is analog.
- Digital phenomena is something that's either off or on, or at least has some discrete number of states.
- In order for our program on our microcontroller to be able to use information from sensors, that analog signal has to be converted to a digital value.
- Now on the output end, you usually need digital to analog conversion. So let's say I have a microcontroller and it's outputting some sound to some speakers. These speakers are analog devices, they need analog signal.

# Microcontroller Characteristics

Architecture (ARM, ESP32)

Datapath bitwidth (4 - 128 bits)

- Number of bits in each registry
- Determine accuracy and data throughput

Input/Output pins

- Need enough pins to support the application

Performance

- The clock rates are slower than desktops

# Other Microcontroller Characteristics

Timers

- Needed for real-time applications

Analog to Digital Convertors

- Used to read input from analog sensors

Low power modes

- Power saving is key

Communication protocol support

- Interface with other IC’s
- UART, I2C, SPI, etc.

# IoT Devices are a Window to Cloud Services

Google Assistant and Alexa (processing is done on the cloud)

Netflix (Movie is not sitting on your phone but are in the cloud)

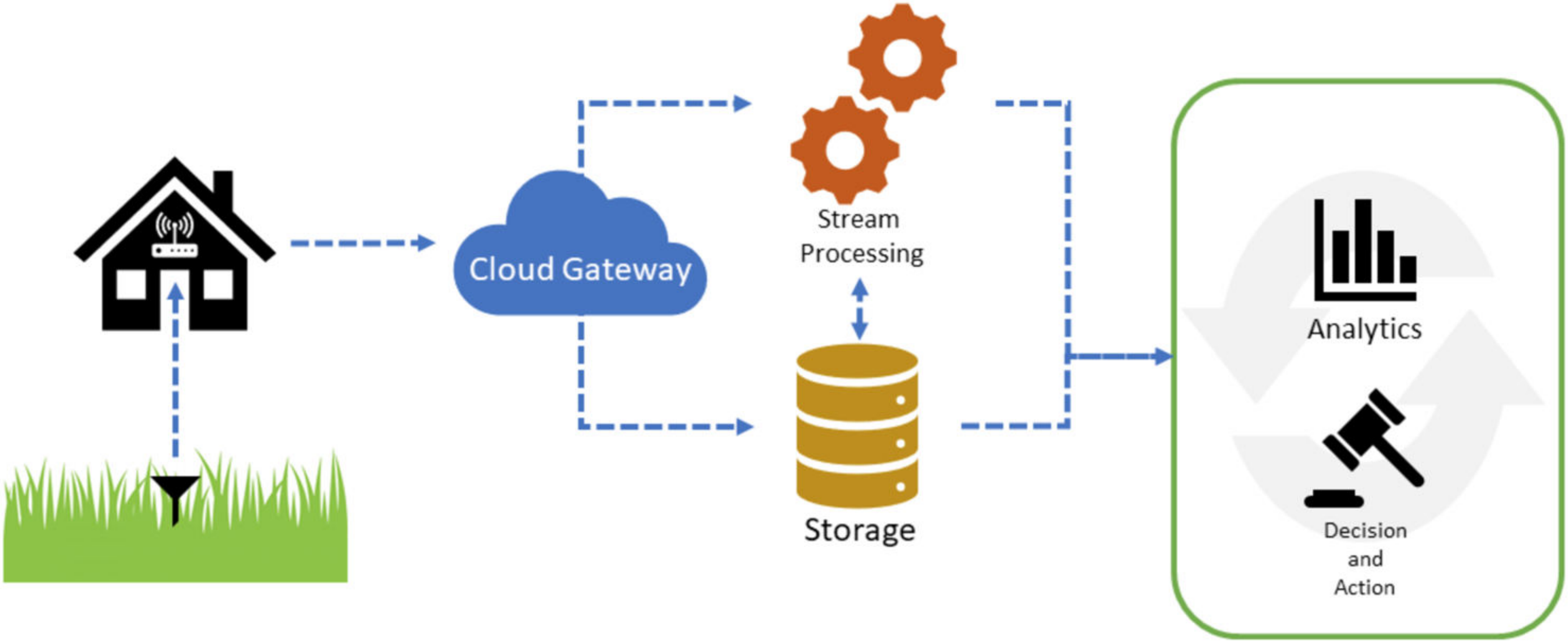
IoT devices give access to huge databases and computation resources on the cloud

# IoT involves two essential components

A device-side (made up of individual devices) that acts as a data source

A cloud-side that gathers data and provides resources for analyzing it

# Example: Water Pricing During Summer



# Categories of IoT devices and services: Maker IoT

The term "maker" has come to be equated with “hobbyist” and refers to those who like to build things to experiment or for personal use out of electronic components. When it comes to IoT, the idea of building unpolished but functional devices that collect data, using cloud services to gather and store that data, and maybe even doing analytics on the data collected all is a part of what is included in this category. But a commercial business may employ a maker's approach to experiment with ideas, create proof-of-concept devices, do costing, and other planning exercises. So "maker" need not be limited to hobbyists but describes an approach to development.

# Consumer IOT

It largely consists of commercial devices and associated services that are geared towards home or personal use such as connected thermostats or appliances. While the basic IoT concepts apply, the scope of what the devices collect, how they manage and store data, and how the data is used may be much more limited than what you'd find in an enterprise environment.

# Enterprise IoT

Whereas Consumer IoT is focused on “turnkey” device solutions that solve specific problems or enable new scenarios for individuals or homes, enterprise-class IoT is focused on solving specific business problems like efficiency, reducing waste, increasing speed to market or of production, and providing intelligence on how business systems are running. A single enterprise may deploy dozens of devices that work in concert to give a business a single view of a factory or fleet of planes or gas pipeline. Enterprises also may require real-time data and real-time analysis of those data in order to make just-in-time adjustments or prevent disastrous consequences from a failed system. Consumer-grade IoT products rarely require this so the type of architecture needed in an enterprise will be more involved and require more services than a consumer solution requires.

# IoBT, Software and Combat Clouds

**Internet of battlefield things (IoBT) -** Military planners envision a future battlefield defined by the internet of things, one in which smart devices, soldier-worn sensors and unmanned aircraft produce a nonstop torrent of actionable data.

**Software defined aircraft** - All revealed fifth-generation fighters use commercial off-the-shelf main processors to directly control all sensors to form a consolidated view of the battlespace with both onboard and networked sensors.

**Combat clouds** - Fifth-generation jet fighters will operate together in a "combat cloud" along with future unmanned combat aircraft.

# An IoT Device

1. Connected to the Internet
2. Secure
3. Smart Features
4. Communication Capabilities with other devices
5. Remotely Configurable
6. Programmable
7. Replaceable (Optional)
8. Environmentally Flexible (Optional)

# Consumer versus Business Goals for IoT

Individual consumers implement cloud connected devices (such as doorbells, thermostats, and even refrigerators) in order to make their life easier, more comfortable, or more secure. Consumer devices in the home are not typically being used for the same purpose as an IoT device implemented in a business scenario.

In a way, business goals for IoT are simple compared with consumer goals. Businesses tend to implement IoT solutions in order to be more profitable, to increase safety for their work force, and to more easily comply with government regulations in order to create a better business environment. Profitability can be realized either directly through cost reductions or indirectly through competitive advantage. A business could use IoT to provide customers with improved service, resulting in increased market share (and overall profits). In most cases both the business and their customer benefit.

# IoT Consumer Space Examples

- Connected Refrigerators
- Connected Doorbells and Cameras
- Connected Thermostats

# Business goals for IoT, improving:

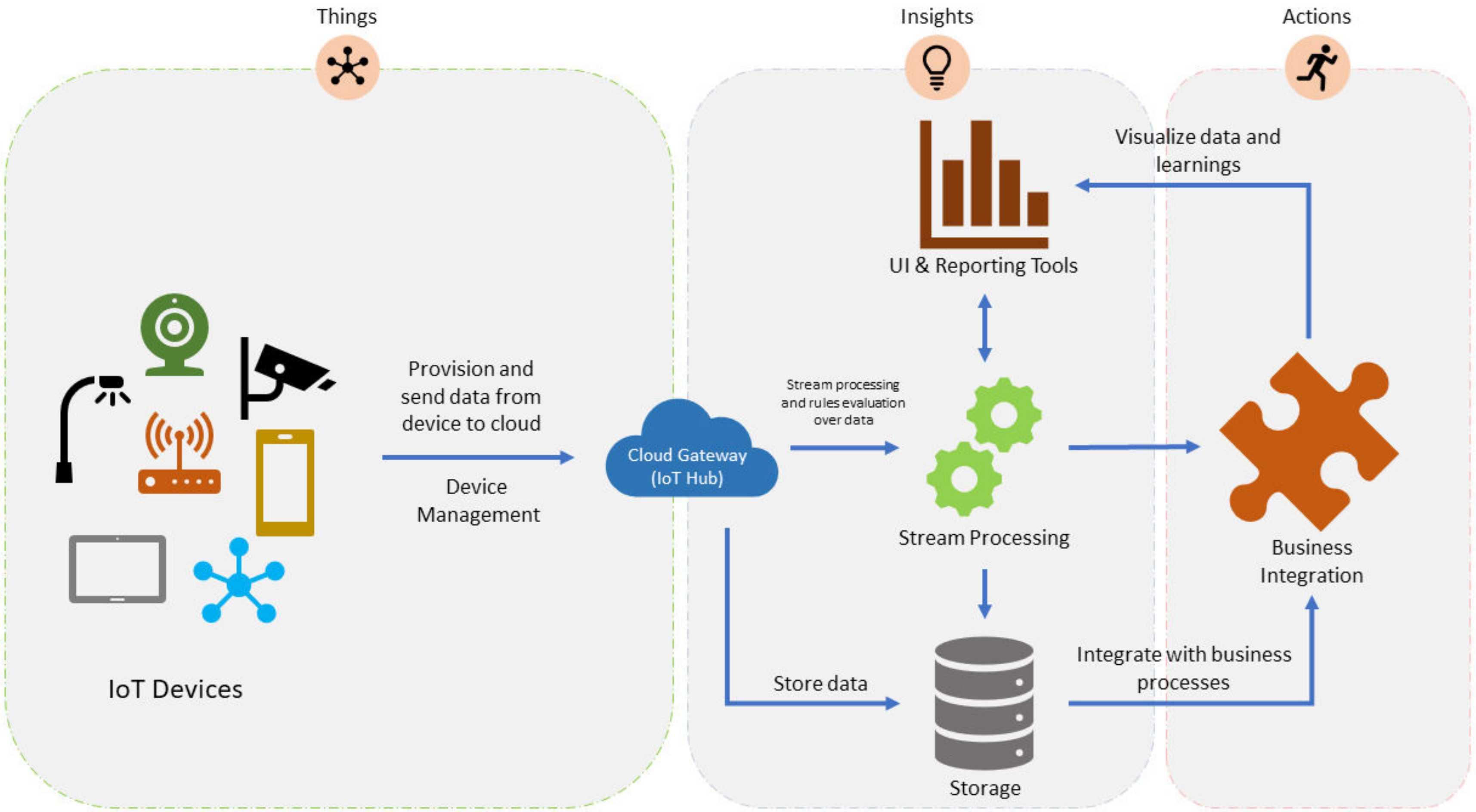
- Product Quality and Extended Product Lifetime
- Service Reliability and Uptime
- Operating Efficiency
- Workforce safety
- Governmental compliance

# IoT Verticals

- Manufacturing
- Smart City
- Smart Building
- Healthcare
- Energy
- Transportation and Smart Vehicles
- Logistics and Inventory Management
- Retail
- Agriculture
- Military

# IoT Sub-systems Description

1. **Cloud Gateway**: The Cloud Gateway provides a cloud hub for secure connectivity, telemetry and event ingestion and device management (including command and control) capabilities.
2. **Stream Processing**: Processes large streams of data records and evaluates rules for those streams.
3. **Business Process Integration**: Facilitates executing actions based on insights garnered from device telemetry data during stream processing. Integration could include storage of informational messages, alarms, sending email or SMS, integration with CRM, and more.
4. **Storage**: Storage can be divided into warm path (data that is required to be available for reporting and visualization immediately from devices), and cold path (data that is stored longer term and used for batch processing).
5. **User Interface**: The user interface for an IoT application can be delivered on a wide array of device types, in native applications, and browsers.


Things
Insights
Actions
Visualize data and learnings
UI & Reporting Tools
Provision and send data from device to cloud
Device Management
Cloud Gateway (IoT Hub)
Stream processing and rules evaluation over data
Stream Processing
Business Integration
IoT Devices
Store data
Storage
Integrate with business processes

# Example of Sensors Available

- Temperature
- Humidity
- Energy
- Compass
- Pressure
- Sonar
- Light and UV

# Edge Computing

- Edge computing is a distributed computing paradigm which brings computer data processing and storage closer to the location where it is needed. So, instead of having a centralized, remote cloud to do all the work, the data is handled and stored locally, i.e. on the IoT device itself or at the nearest network node.
- Computation is largely or completely performed on distributed device nodes.
- Edge computing pushes applications, data and computing power (services) away from centralized points to locations closer to the user.
- Edge computing does not need contact with any centralized cloud, although it may interact with one.
- Edge application services reduce the volumes of data that must be moved, the consequent traffic, and the distance the data must travel. That provides lower latency and reduces transmission costs.

# Why pure cloud computing isn’t the best option for IoT

Traditional cloud computing has a number of drawbacks when it comes to IoT:

- Data security threats. Data is constantly being transmitted back and forth between the cloud and a device, and as such, the risk of privacy violation is heightened.
- Performance issues. IoT applications rely heavily on real-time actions. Yet, the processing speed of your cloud-based app often depends on the actual distance between the device itself and the server location.
- Operational costs coincidentally grow as the amount of data produced and shared increases.

On top of that, most data sourced to the cloud often bears no practical value and is never used.

# How does edge computing work?

- Every IoT sensor produces tons of data every second. In the case of cloud computing, the data is instantly transferred to the central, unified cloud database where it's processed and stored.
- If there's any action required, the central server will send its response back to the device upon receiving and analyzing the acquired data.
- While the whole process typically takes less than a second to complete, there might be situations when the response may be delayed or interrupted. This can happen due to a network glitch, weak internet connection, or simply because the data center is located too far from the device.
- Now, in case of edge computing, you don't need to send the data acquired by the IoT sensors anywhere. The device itself or the nearest network node (e.g. the router) is responsible for data processing and can respond in a proper manner if action is required.

Edge Computing makes it possible that the IoT device is no longer dependent on the internet connection and can function as a standalone network node.

# The benefits for edge computing in IoT

1. Increased data security
2. Better app performance
3. Reduced operational costs
4. Improved business efficiency and reliability
5. Unlimited scalability

# Edge Computing Use Cases

McKinsey finds that the industries with the most edge computing use cases are:

- travel, transportation, and logistics
- energy
- retail
- healthcare
- utilities


Voice Revolution
LG

# Voice control is most suitable in the following IoT use cases

- Home automation
- Automobiles
- Health Care
- Entertainment

# Voice Assistants Are Taking Over Consumer IoT

No industry felt the heat of the voice assistant battle more than Consumer IoT (CIoT), in which voice assistant integrations became the primary focus for any CIoT product-centric company.

Imagine a future in which every command is at the tip of your tongue. When you wake up. your bathroom mirror can report your schedule for the day. During breakfast, you can ask the coffee machine for a latte, extra foam. On the train, your watch will tell you just how late you'll be to work. In the office, your printer will pipe up, asking for more ink, please.

# Entry point into the IoT’s has been Amazon and Google’s smart speakers

For many consumers, the entry point into the Internet of Things has been Amazon and Google’s smart speakers.

Voice control is one of the primary drivers of smart home market growth with the number of home voice devices projected to reach 275 million by 2023 in USA alone.

# Visions of dialogue from science fiction

- Hal  “2001:  A Space Odyssey” (1968)
  - Naturally conversing computer
- Star Trek (original 1966)
  - Natural language command and control
- Her  (2013)
  - A virtual partner with natural dialogue capabilities

# A NEW KIND OF UI: VUI

# A.I. Assistants/**Platform shift**

*"From mobile first to AI-first"*

Sundar Pichai

October 4th, 2016

THE WALL STREET JOURNAL.



Dyn Says Cyberattack Has Ended, Investigation Continues

Visa Taps Blockchain for Cross-Border Payment Plan

Airbnb Revises New York Rules Amid Possible Legislation

DIGITS

# Speech Recognition Gets Conversational

# Five Ways Conversational Bots Will Change The Way We Do Business

**Forbes Technology Council**

*Elite CIOs, CTOs & execs offer firsthand insights on tech & business.* FULL BIO

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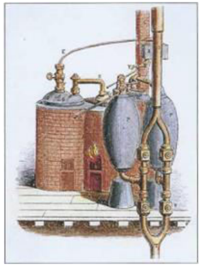
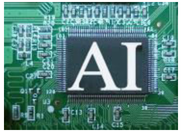
# GOOGLE'S NEW CHATBOT WON'T SHUT UP—AND THAT'S A GOOD THING

WIRED

# Technology revolutions






amazon web services™

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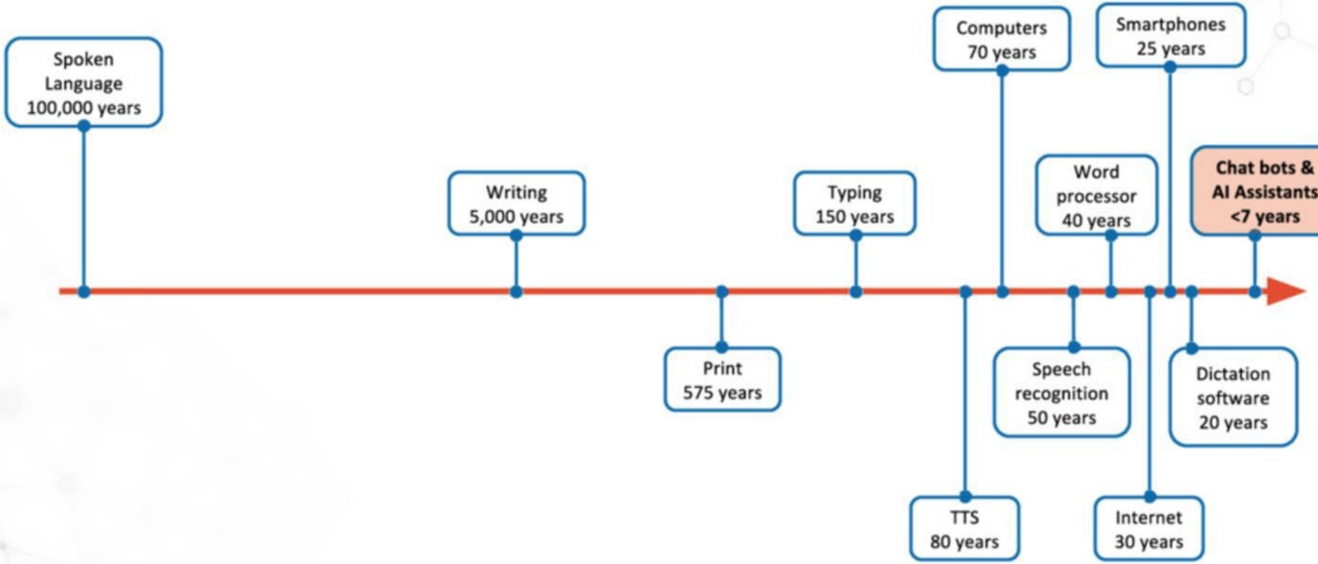
# VUI/Human to human vs. Human to computer



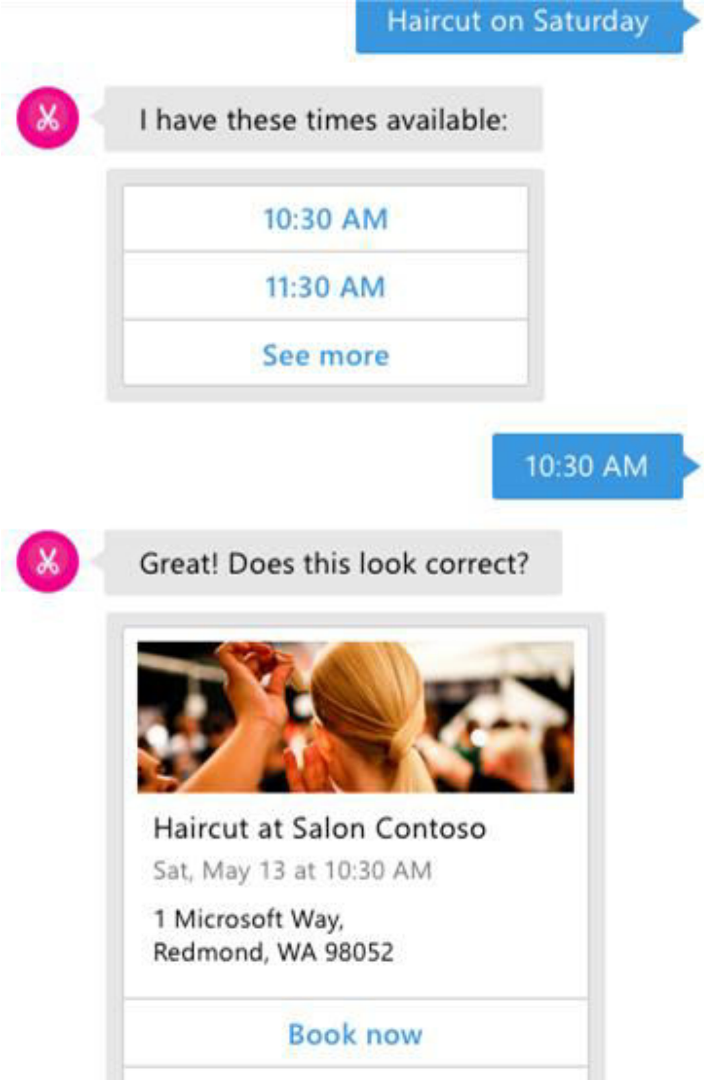
# A.I. Assistants/**Some examples**

| Apple's Siri | Microsoft's Cortana | Amazon's Alexa | Google's Assistant | Samsung's Bixby |
|---|---|---|---|---|
| 2011 | 2014 | 2014 | 2016 | 2017 |

# What is a Bot?

- A Bot is a conversation based UI
- Conversation is based on language
- Conversation takes place on a general canvas

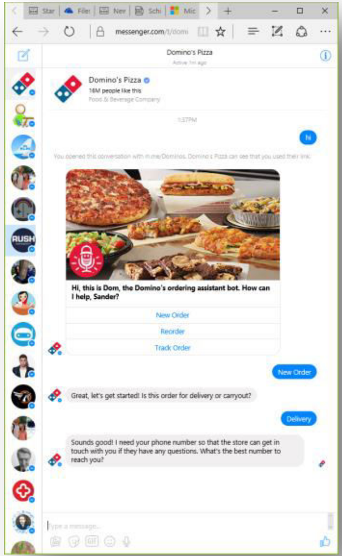
- Canvas can be:
  Chat Client: Skype, Team, Slack, Messenger
  Voice: Echo, Cortana Skills, Siri, Google Now
  App: Website, App

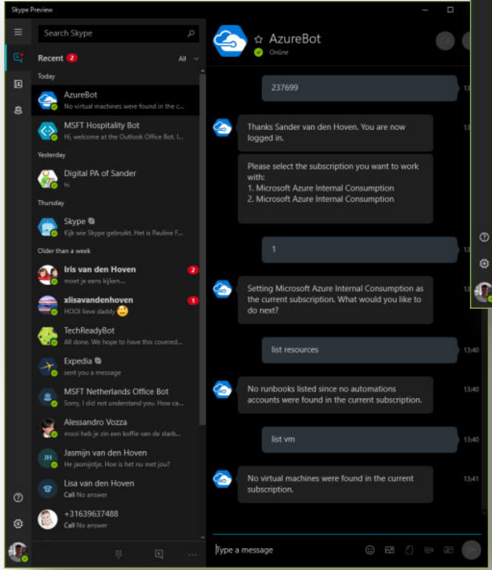


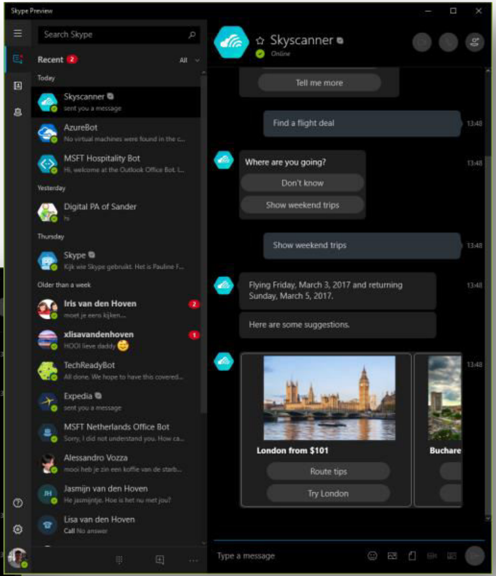
# Scenario's for Bots

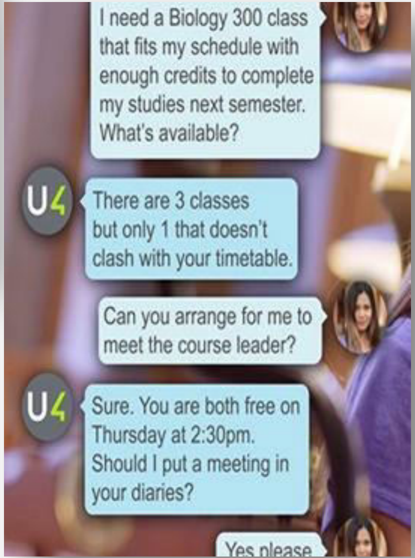
1. Question and Answers
2. Automate Helpdesk, Handoff to human if too complex
3. Product selection and ordering
4. Task Automation
5. Proactive Assistance & Monitoring
6. Expert Systems

# Bot Examples



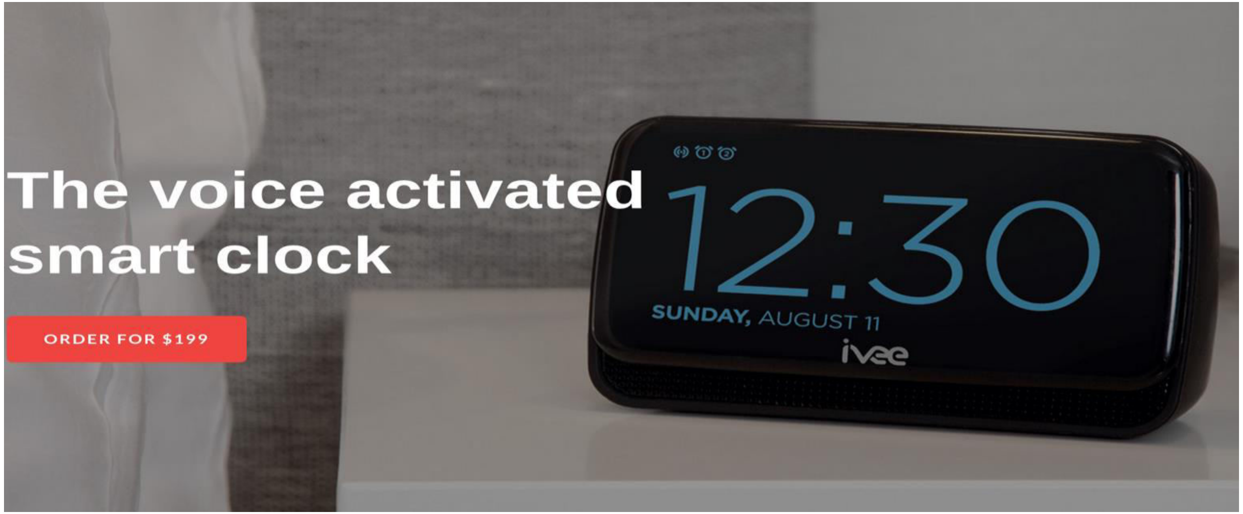
# Embedded devices with dialogue capabilities

- Amazon Echo (2014) – home assistant device
    - Plays music
        - With voice commands
    - Question answering
        - Get weather, news
        - More complex questions, like
            - “how many spoons are in a cup?”
    - Setting timer
    - Manages TODO lists

# Embedded devices with dialogue capabilities

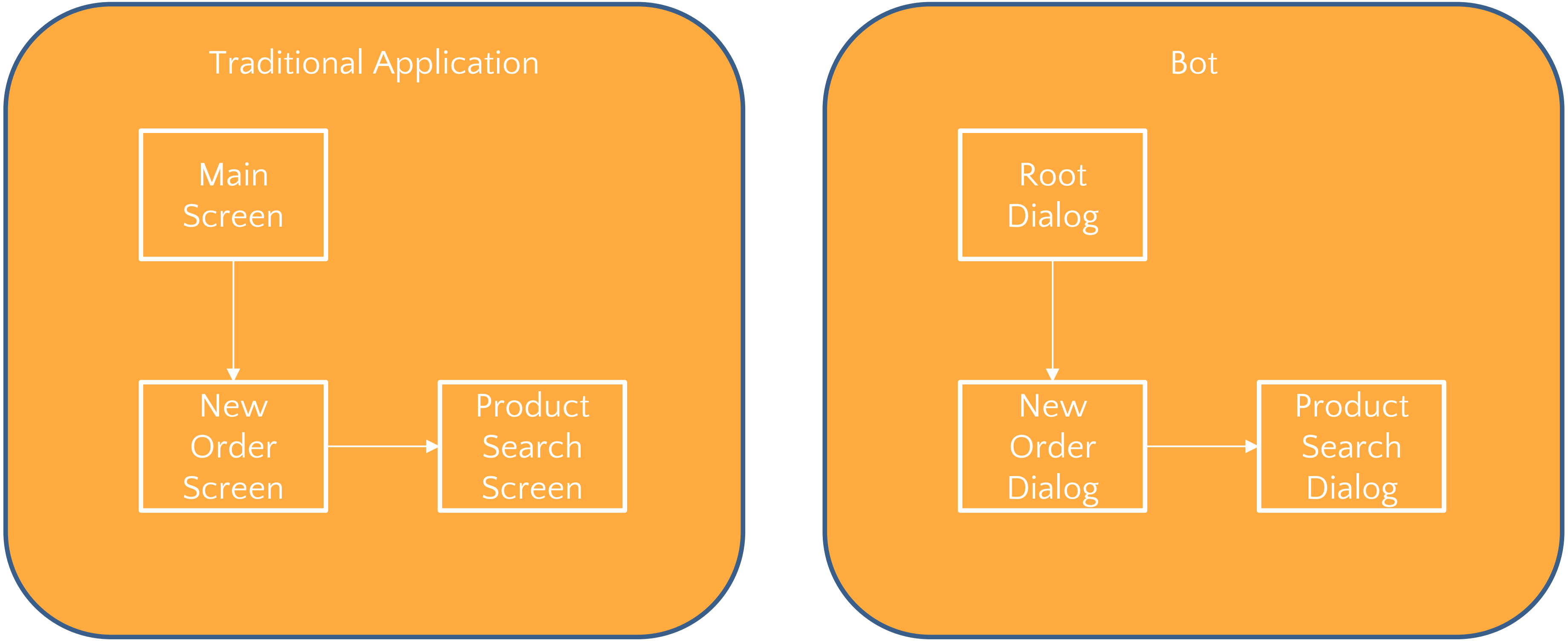
Answers questions
Sets time
Device control and queries.

Thermostat Etc.



# Dialogs are for bots like screens are for apps

They separate concerns and organize flows, exactly the same way:

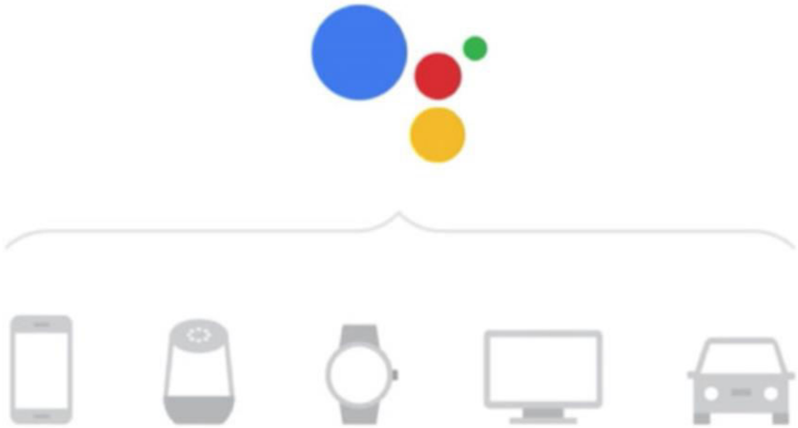


Google

ASSISTANT

Hi, how can I help?

# G. Home & G. Assistant/**Device compatibility**



# Google Assistant coming soon to more speakers, appliances and other devices

- Google is putting its Assistant on a wide range of third-party hardware. Google has announced that it’s going to be putting the Assistant on partner speakers, appliances, connected cameras, and much more.
- It is already on the iPhone.

# Google wants to ‘see’ as well as ‘hear’ your surroundings

Google Lens

# How to develop for the Google Assistant platform

# Actions on Google
# https://developers.google.com/actions/

Actions on Google is a developer platform that lets you create software to extend the functionality of the Google Assistant, Google's virtual personal assistant, across more than 500 million devices, including smart speakers, phones, cars, TVs, headphones, watches, and more.

You can build smart home Actions that let users control Internet of Things (IoT) devices through the Google Assistant. Building smart home Actions lets you connect, query, and control devices through your existing cloud infrastructure.

# Messaging Protocols: Kafka and MQTT

- MQTT is a publish/subscribe protocol particularly suited to IoT applications thanks to its small footprint, real-time guarantees, and suitability for use in high-latency, low-throughput, and unreliable networks. It is designed for connections with remote locations where a "small code footprint" is required or the network bandwidth is limited. The publish-subscribe messaging pattern requires a message broker.
- Based on a publish/subscribe model, Kafka is one of the most widely used platforms to process and distribute real-time data streams. It is used for building real-time data pipelines and streaming apps. It is horizontally scalable, fault-tolerant, wicked fast, and runs in production in thousands of companies.
- Both, MQTT and Apache Kafka have great benefits for their own use cases. But, none of them are the single allrounder for everything. The combination of both makes them very powerful and a great solution to build IoT end-to-end scenarios from the edge to data center and back.

# The future of IoT is AI

As IoT devices will generate vast amounts of data, then AI will be functionally necessary to deal with these huge volumes if we’re to have any chance of making sense of the data.

Data is only useful if it creates an action. To make data actionable, it needs to be supplemented with context and creativity. IoT and AI together is this context, i.e. ‘connected intelligence’ and not just connected devices.

Traditional methods of analysing structured data and creating action are not designed to efficiently process the vast amounts of real-time data that stream from IoT devices. This is where AI-based analysis and response becomes critical for extracting optimal value from that data.

# Blockchain in the Internet of Things?

- Traditional IoT systems are dependent on a centralized architecture. Information is sent from the device to the cloud where the data is processed using analytics and then sent back to the IoT devices.
- With billions of devices set to join IoT networks in the coming years, this type of centralized system has very limited scalability, exposes billions of weak points that compromise network security and will become incredibly expensive and slow if third-parties have to constantly check and authenticate each and every micro-transaction between devices.
- **Smart contracts** in blockchain networks will allow devices to function securely and autonomously by creating agreements that are only executed upon completion of specific requirements. It not only allows for greater automation, scalability and cheaper transfers (no third-party needed to oversee transactions).
- With traditional centralized networks, the risk of a single point of failure disabling an entire network is a very real possibility. A **decentralized blockchain** network mitigates this risk with millions of individual nodes that transfer data on a peer-to-peer (p2p) basis to keep the rest of the IoT network running smoothly.

# IoT and Blockchain Complement Each Other

Blockchain technology can be used in tracking billions of connected devices, enable the processing of transactions and coordination between devices; allow for significant savings to IoT industry manufacturers. ... In an IoT network, the blockchain can keep an immutable record of the history of smart devices.

## IoT + Cloud and Edge Computing + AI + Blockchain: The Fourth Industrial Revolution has Begun

The combination of IoT, Cloud and Edge Computing, AI and Blockchain technologies allow machines in the Internet of Things to be able to lease themselves out, schedule and pay for their own maintenance, purchase their own replacement parts and keep their own transactional records, using blockchain.