CSIE52400/CSIEM0140 Distributed Systems

Lecture 10: Introduction to Artificial Intelligence of Things (AIoT)

Shiow-yang Wu (吳秀陽)
Department of Computer Science and Information Engineering
National Dong Hwa University

What is Internet of Things

- The term Internet of Things(IoT) was first suggested by Kevin Ashton in 2009.
- It is used to refer to uniquely identifiable objects and their virtual representations in an internet-like structure.
- If all the objects and people have identifiers, they could be managed and inventoried by computers.
- The world where all objects and people have identifiers and are connected by an internet-like structure is called the Internet of Things.

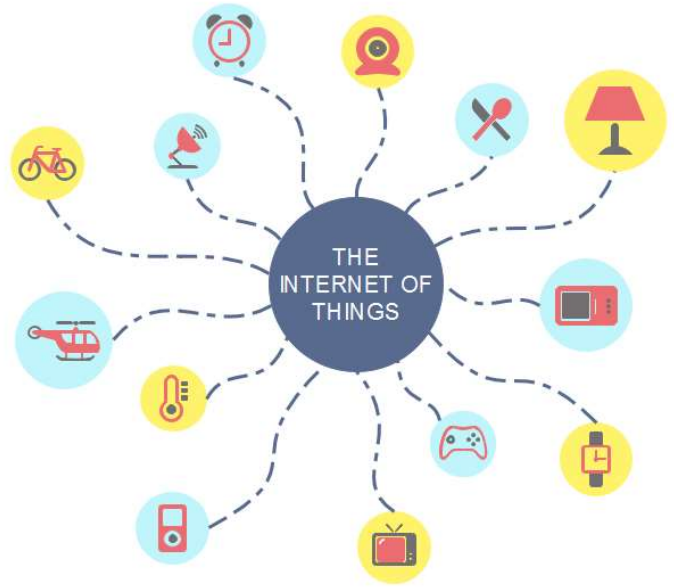
What is AIoT?

- The Artificial Intelligence of Things (**AIoT**) is the combination of artificial intelligence (AI) with IoT infrastructure to
  - achieve more efficient IoT operations
  - improve human-machine interactions
  - enhance data management and analytics
- A key feature of AIoT is to have AI on IoT devices, i.e. at the edge or edge computing, with no need for external connections.
- AIoT promise to unlock unrealized customer value in wide areas such as edge analytics, autonomous vehicles, personalized fitness, remote healthcare, precision agriculture, smart retail, predictive maintenance, and industrial automation.
- We will discuss IoT first and then AIoT.

Major Subject of 5G (2020-2030)

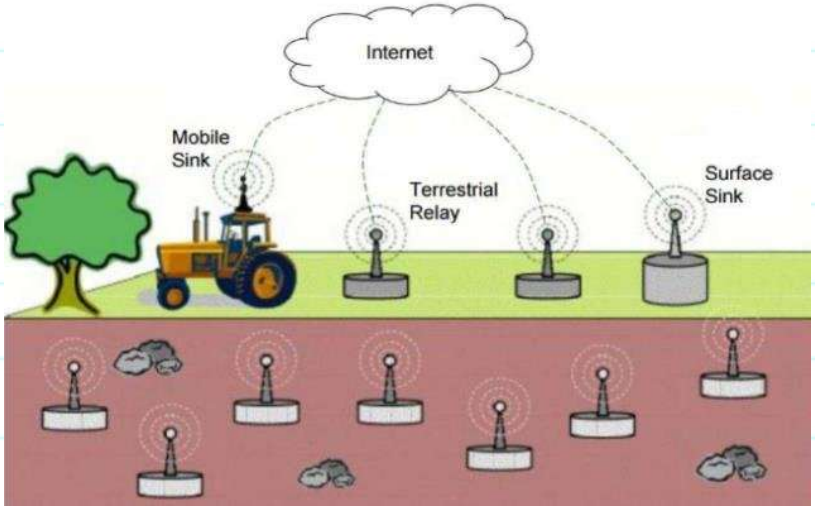
Connection of
7 Billion of People and
7 Trillion Things

Will have Internet of Things



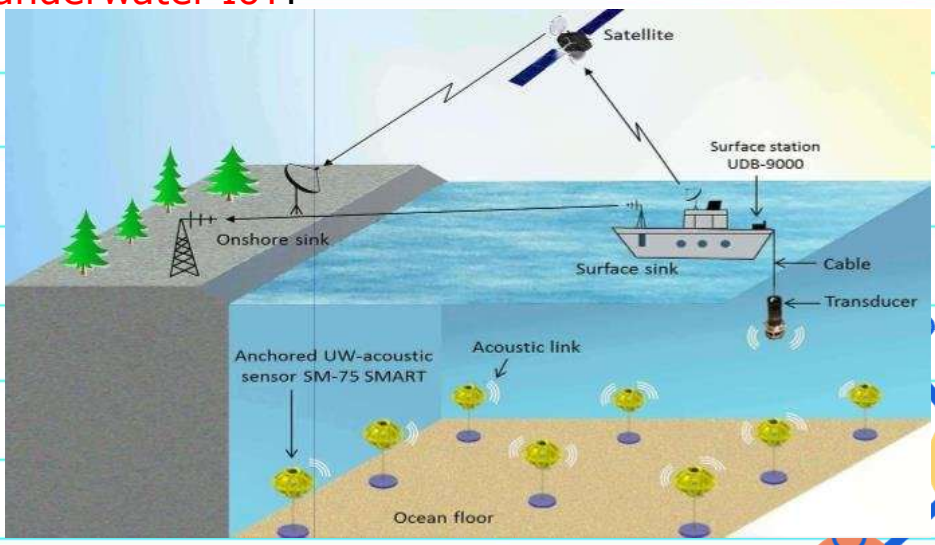
# of Underground Things

- Yes! IoT is underground now!

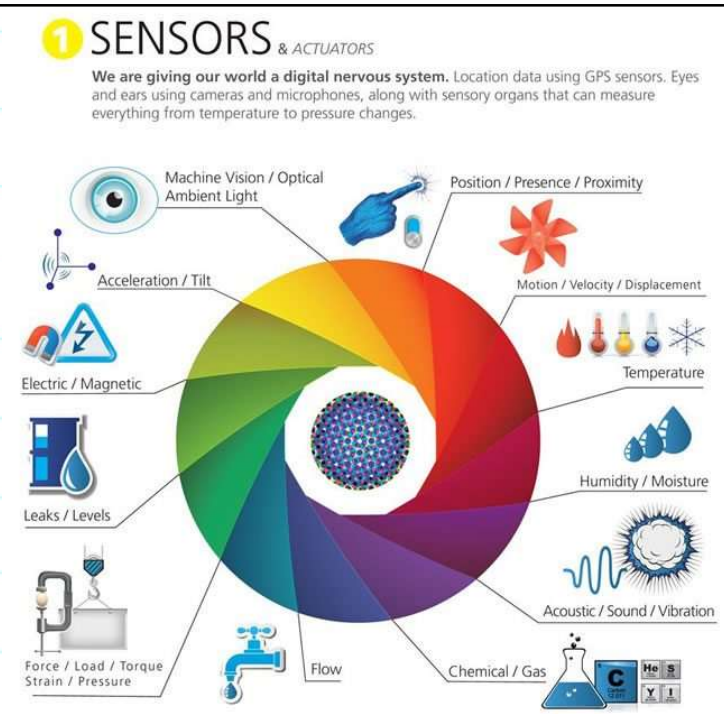


even Underwater Things

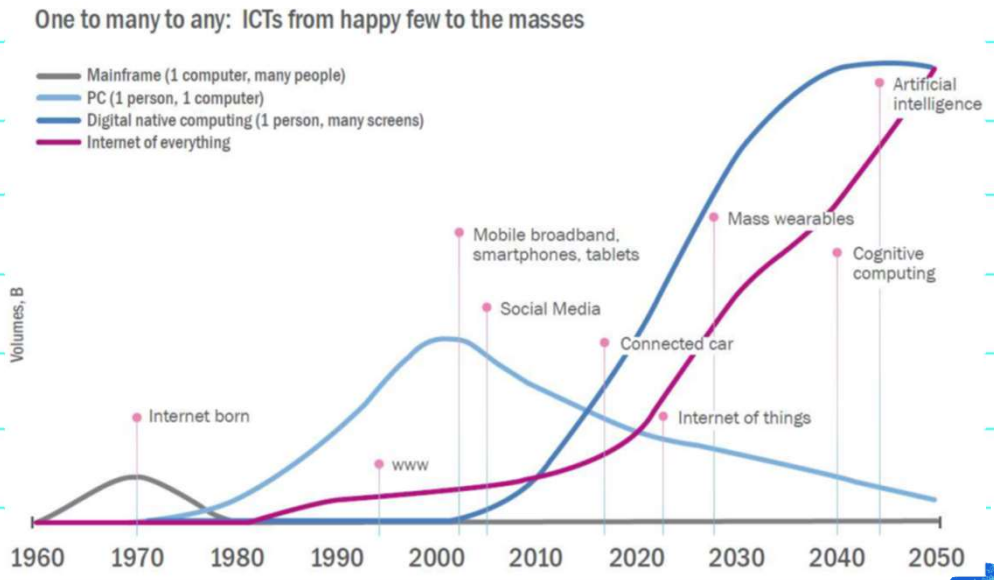
- Even underwater IoT!



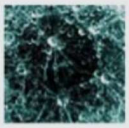
IoT as Digital Nervous System

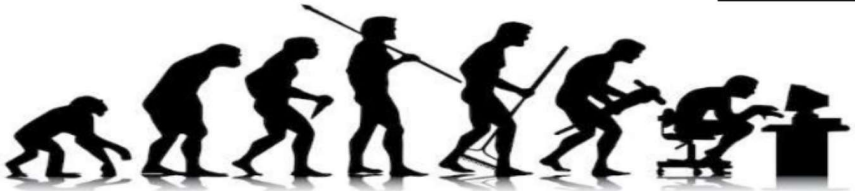


One to Many to Any



Evolution of Internet

Internet of boffins	Internet of geeks	Internet of masses	Mobile Internet	Internet of things
				
1969 - 1995	1995 - 2000	2000 - 2007	2007 - 2011	2012 & beyond



Internet of Boffins(專家)

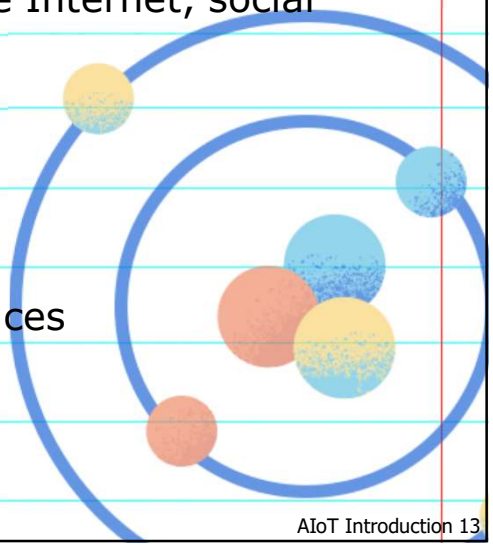
- 1969: ARPANET carried its first data packet. It was the first network to use TCP/IP.
- 1970: Mark I Network by Davis (a packet switched network)
- 1973: Mark II Network
- 1974: Telenet (an American commercial packet-switched network)
- 1980: Ethernet
- 1990: GOSIP(Government Open Systems Interconnection Profile)
- 1994: first full text Web search engine
- A stage of early evolution and research.

Internet of Geeks(極客)

- 1995: IPv6 proposed (makes IoT possible)
- 1995: Amazon started its 1st online retail service
- 1995: eBay provided online auction and shopping services
- 1996: Hotmail offered free Web based email service
- 1998: Google Search engine officially launched
- 1998: PayPal started 1st Internet payment service
- Internet penetration was low until 2000.

Internet of Masses

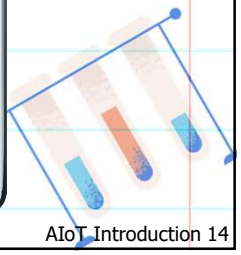
- 2000: Dot-com bubble burst, high growth in stock markets, people across the globe started using the Internet, social networking sites emerged
- 2001: Wikipedia started
- 2004: Facebook started
- 2005: YouTube started
- 2006: Twitter started, WikiLeaks started
- The era with high growth and mass services
- The era of social network/media



Mobile Internet

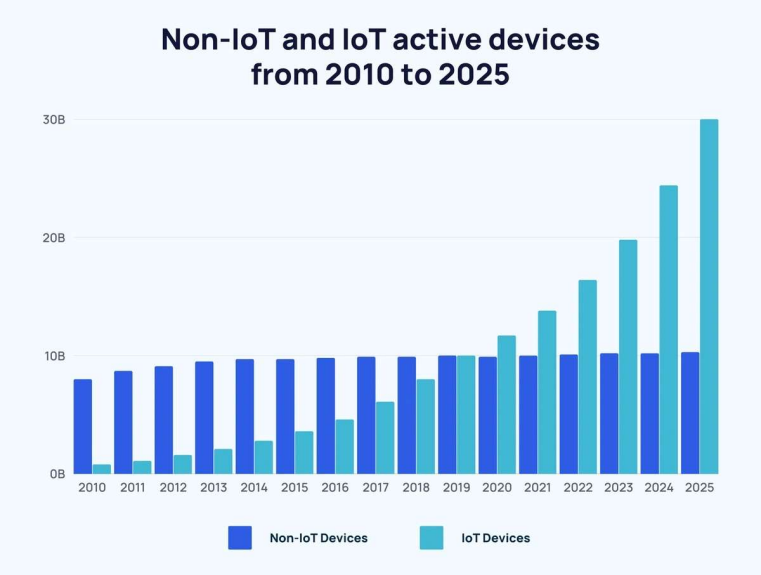
- The first mobile phone call was made on April 3, 1973 with a phone weighed 1.1kg (2.5 pounds) and sized 228.6x127x44.4mm.
- 1996: Nokia 900 Communicator was the 1st commercial mobile phone with internet connection
- Mobile internet was available in 2007 when Apple released the 1st gen iPhone.
- 2007~2011 was the era of mobile internet.

Nokia 9000 Communicator



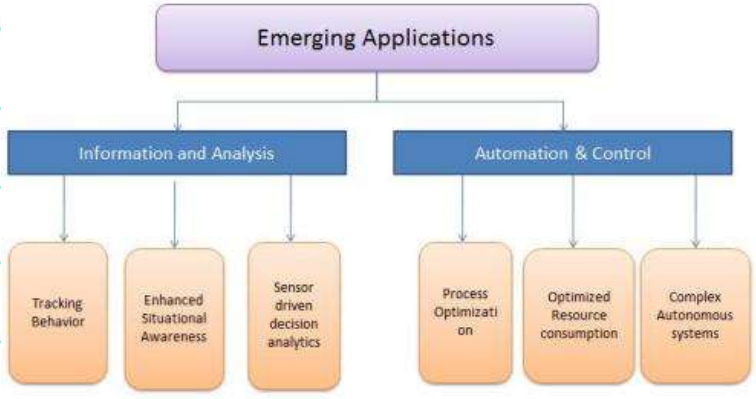
IoT Devices Growth

- Since 2010, the number of IoT devices has been increasing each and every day.
- There will be 25+ billion IoT devices within the next 6 years (Finance Online)
- By 2030, 75% of all devices will be IoT.



IoT Application Trends

- The emerging applications of IoT:
  - Informaton & Analytics
  - Automation & Control



Applications Domains

- IoT has been used in many application domains.

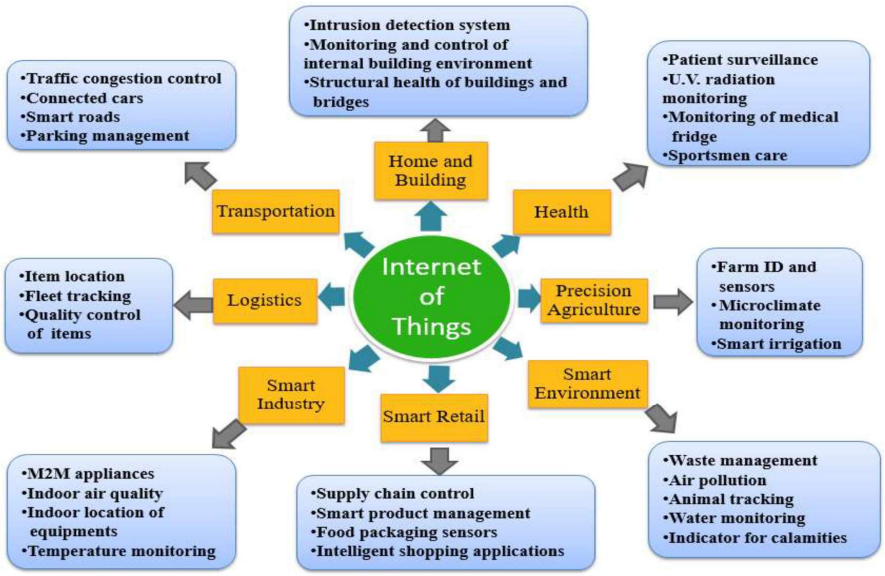
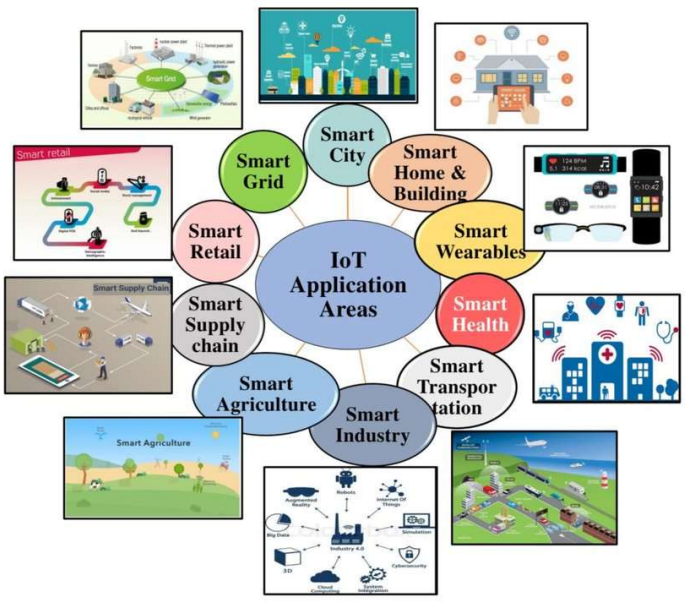


Figure 1. Application Domains of IoT

IoT Application Areas

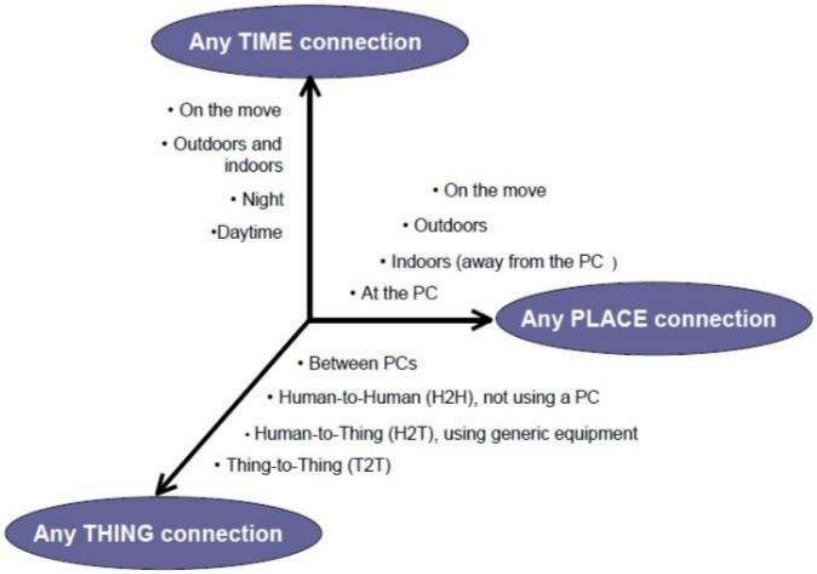
- Another nice picture of IoT application areas.
- All requires IoT devices and applications through
  - Collection phase
  - Transmission phase
  - Processing phase
  - Management phase
  - Utilization phase



3 Dimensions of IoT

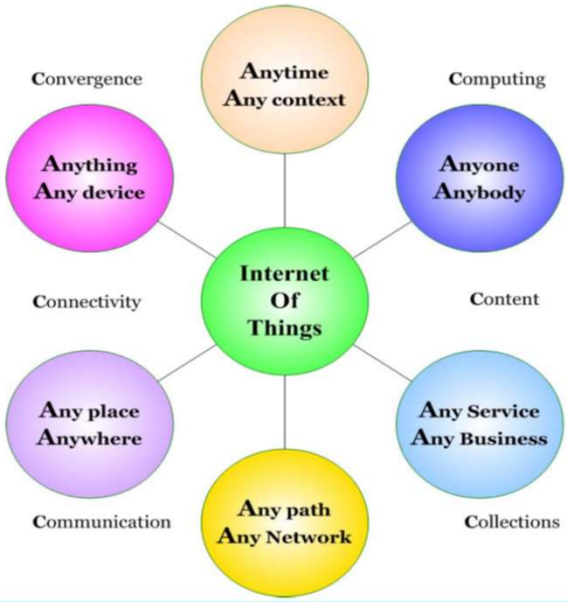
- IoT is to provide
  - ➢ Any TIME
  - ➢ Any PLACE
  - ➢ Any THING

connections and services.



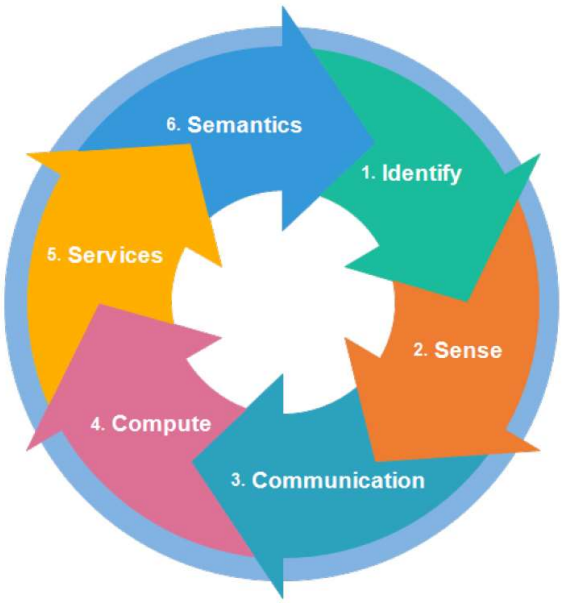
More Dimensions and 6Cs

- More dimensions and the 6Cs



IoT Elements

- Several elements are required to deliver the functionality of IoT.

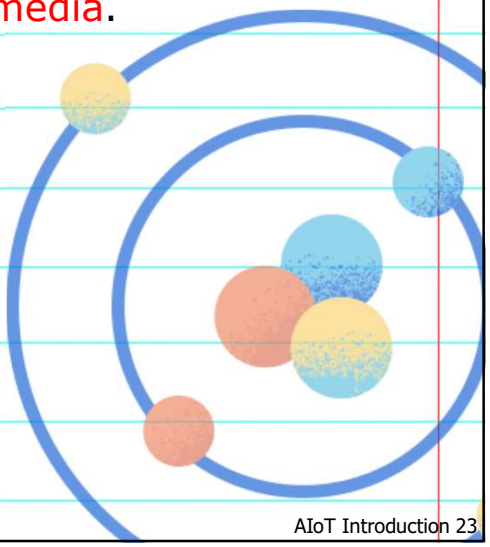


IoT Elements - Identification

- Need to offer explicit identity for each object.
- Two processes in identification: naming and addressing.
- Naming provides names of objects for referencing
- Addressing offers unique address of specific obj
- Two ore more objects may have same name but always different and unique address.
- Naming methods: Electron Products Codes(EPC), Bar codes, QR codes, Digital watermarking, …
- Unique addressing is assigned by IPv6.

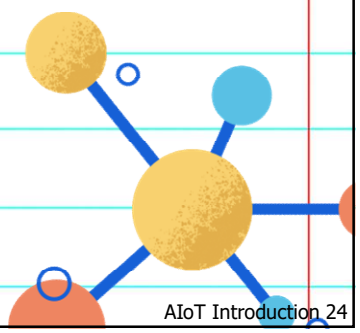
IoT Elements - Sensing

- Sensing is the process of collecting information from objects.
- The collected info is sent to the storage media.
- There are many sensing devices:
  - RFID tags
  - Smart sensors
  - Wearable sensing devices
  - Actuators
  - …



IoT Elements - Communication

- Communication is essential for different objects to be connected to each other and communicate.
- In communication, objects may send and receive messages, files, and other information.
- Many technologies to facilitate communication:
  - RFID (Radio Frequency Identification)
  - NFC (Near Field Communication)
  - Bluetooth
  - Wi-Fi
  - LTE (Long Term Evolution)



IoT Elements - Computation

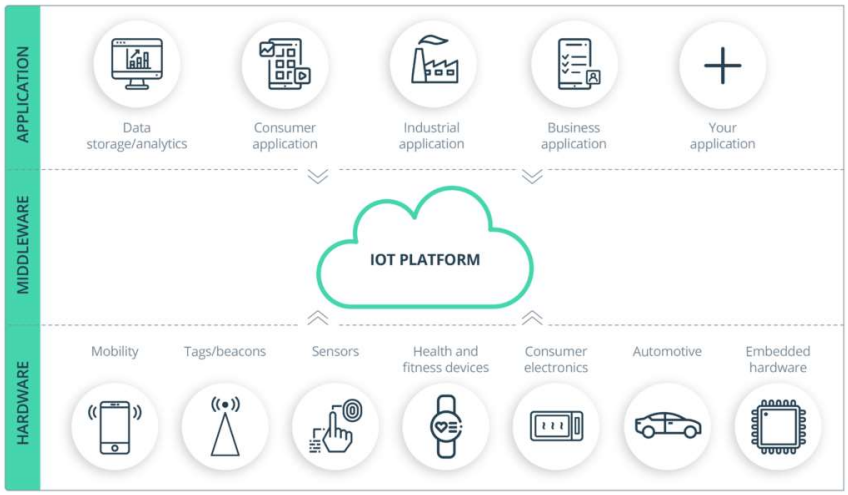
- Computation is performed on the collected information.
- Provide processing power for IoT applications.
- Many HW/SW platforms are available.
- Hardware platforms: Audrino, Rasperry Pi, Intel Galileo, Nvidia Jetson Nano, …
- Software platforms: Android, Tiny OS, Lite OS, ROS (Robot Operating System), …
- Stream processing platforms: Kafka, Flume, Spark, Storm, S4, Google Cloud IoT, AWS IoT, Azure IoT, IBM Watson IoT, Salesforce IoT, …

IoT Elements - Services

- Identity-related services: get identity of objects
- Information aggregation: collect info from objects
- Collaborative services: integrate info sources, make decisions, send appropriate responses, …
- Ubiquitous services: offer immediate responses without rigidity of time and place.
- IoT platforms: platforms for hosting, connecting, and integrating IoT services. (next slide)

IoT Platforms

- IoT platforms play the role of middleware between hardware/devices and applications.

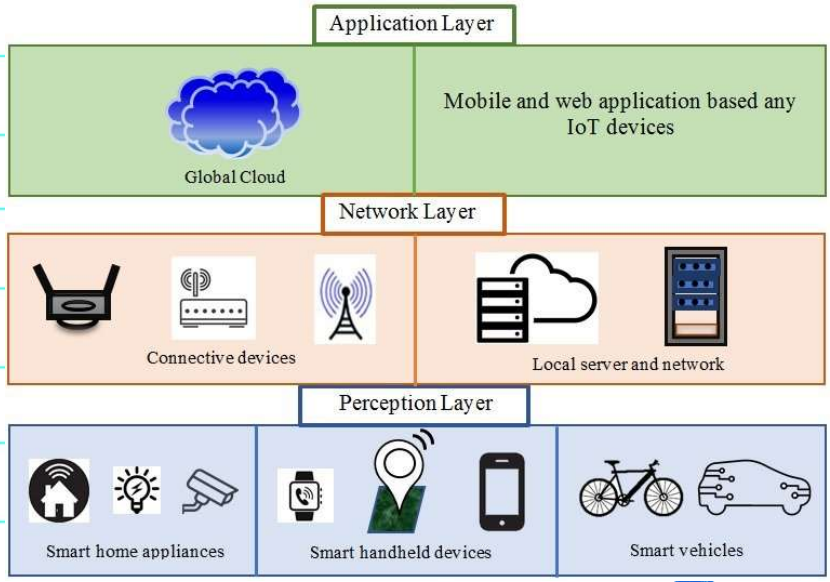


IoT Elements - Semantics

- The brain of IoT
- Coordinating all other elements to facilitate users
- Collect and integrate all information
- Determine the meaning of the data
- Make appropriate decisions
- Send responses to the devices
- Record and evaluation
- Improve effectiveness by machine learning
- Adjust/personalize to individual user

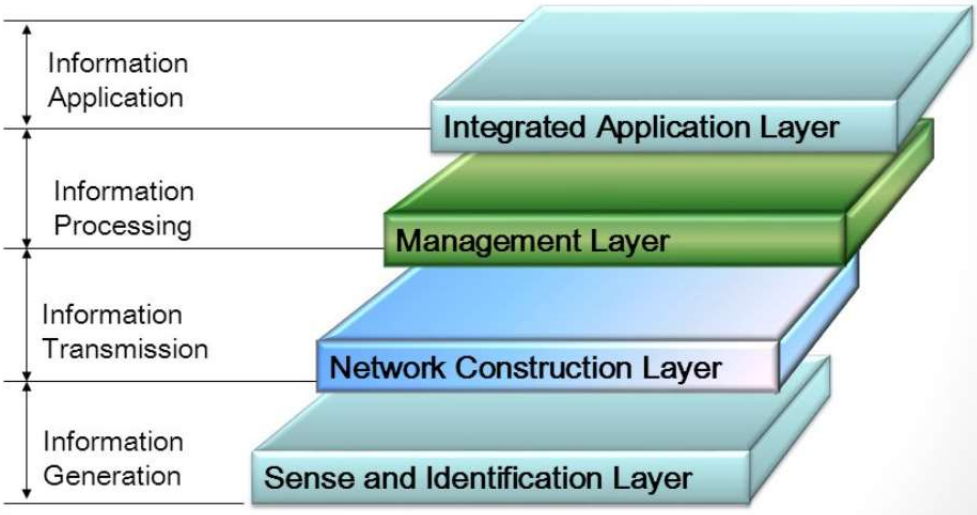
Layered Architecture of IoT

- The most fundamental architecture of IoT consists of three layers.



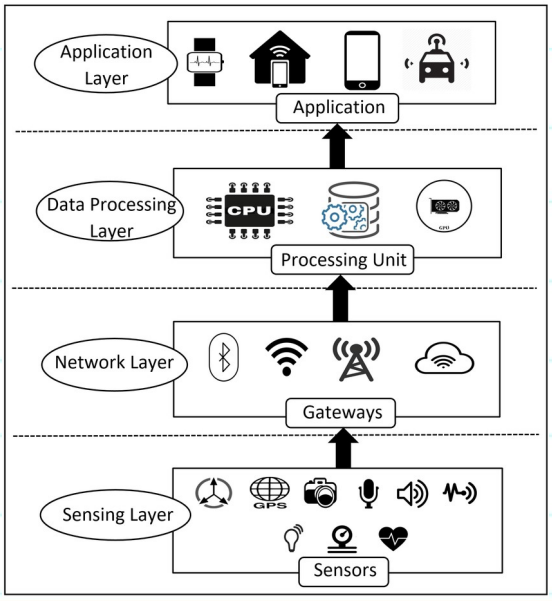
4 Layers Model of IoT

- We also have 4 layers model.



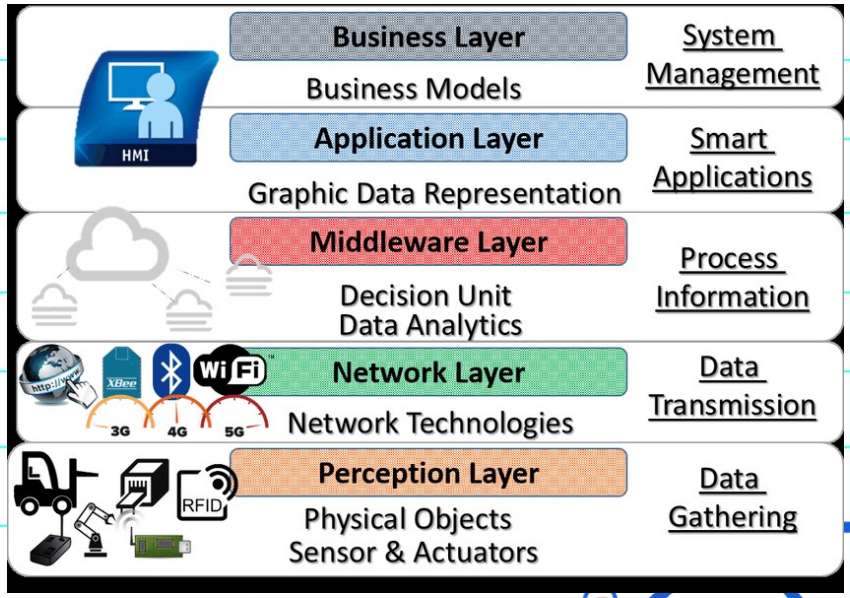
Another 4 Layers Model

- They are more or less the same



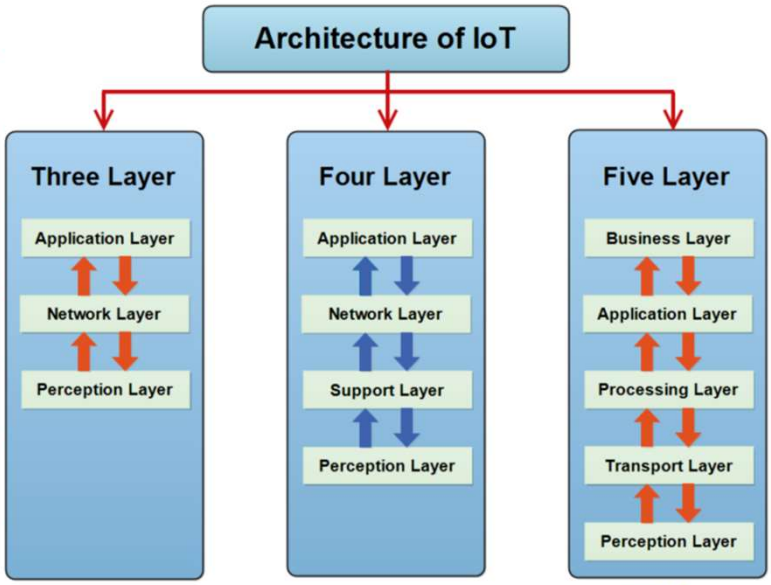
5 Layers Model !

- Yes. We even have 5 layers model.



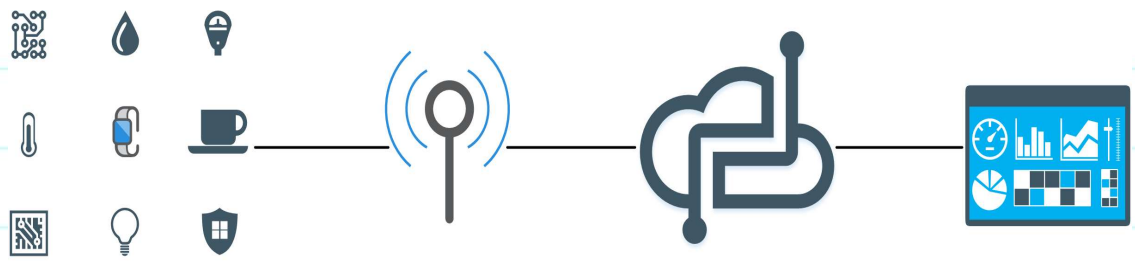
Compare Layered Models

- There are 3, 4, even 5 layers models.
- By comparing the models, the essential parts should be clear.



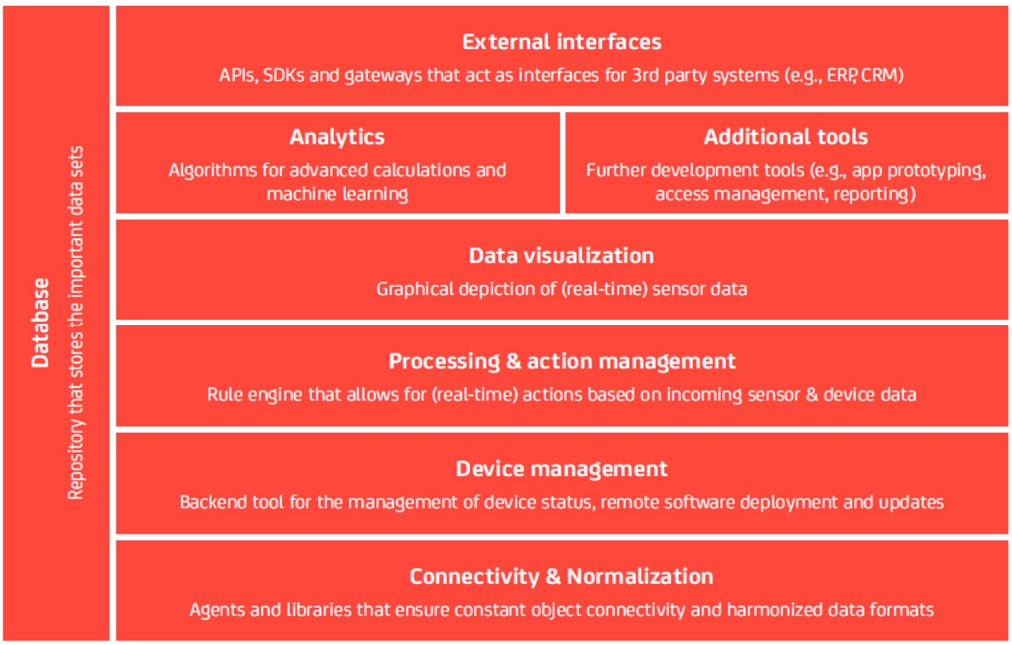
IoT Technology Stack

- The IoT technology stack covers all required technologies from connecting IoT devices, producing data, to an actual purpose.



Devices	Gateway	IoT Platform	Applications
Sensors & Actuators	Connecting devices to platform	End-to-end IoT services	Smart IoT applications

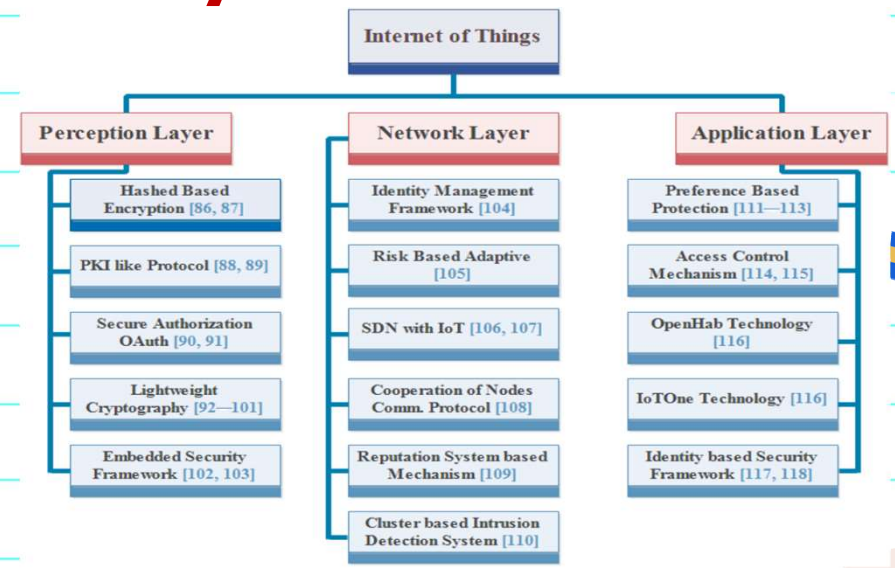
IoT Platform Components



Security in IoT

- IoT devices are much closer to people's every day life than any other devices.
- Security/privacy issues are much more important in IoT since it may affect personal health or even life.
- No benefits of IoT can be provided without proper management of security and privacy.
- Different mechanisms are proposed for different layers of the IoT architecture

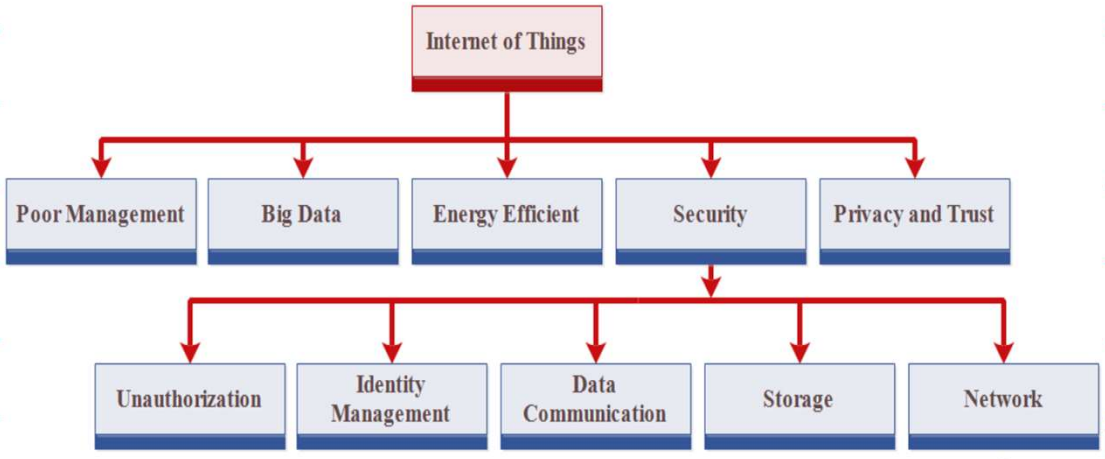
Security Mechanisms in IoT



(https://www.researchgate.net/publication/327272757_IoT_Elements_Layered_Architectures_and_Security_Issues_A_Comprehensive_Survey)

Challenges of IoT

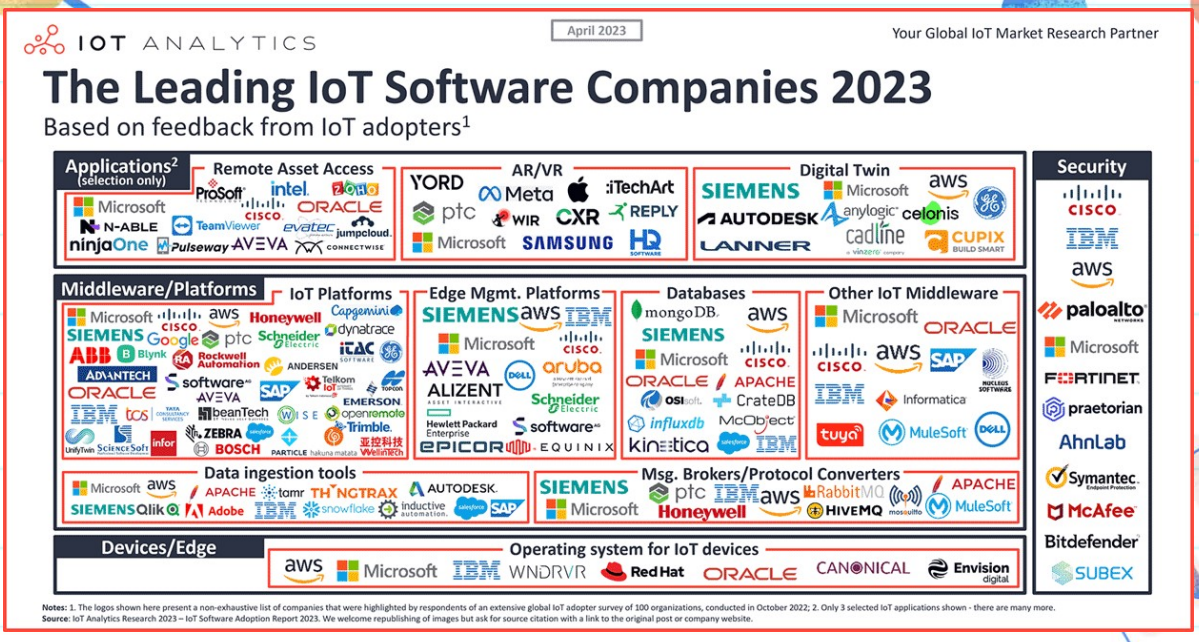
- There are many research challenges ahead.



Concluding Remarks On IoT

- The IoT era is here!
- Expected to greatly enhance the quality of life.
- In general, IoT would allow for the automation of everything around us.
- Many issues and challenges are still ahead of us.
- Extensive research and industrial efforts have been devoted into IoT.
- Tons of opportunities and jobs are waiting for capable graduates.

IoT Landscape 2023



How to combine AI and IoT

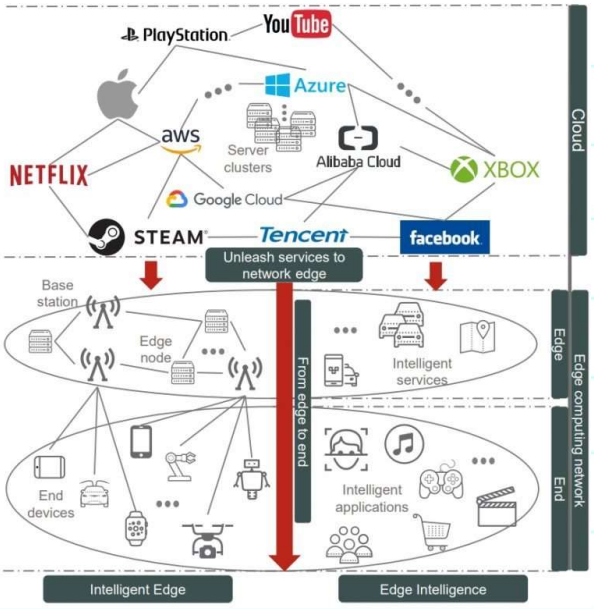
- Edge Artificial Intelligence (edge AI) refers to processing data where it's generated rather than sending it to cloud via the net.
- Edge AI involves deploying AI&ML models directly to the network's edge.
- The integration of edge AI and IoT exemplifies AIoT technology.
- However, AIoT is the fusion of AI and IoT in general.
- While IoT is the digital nervous system, AI becomes an advanced brain that makes the decisions to control the overall system.
- True potential of IoT will only be achieved through the introduction of AIoT. (by IBM)

Cloud AI vs Edge AI

- Two main ways of implementing AIoT are cloud AI and edge AI.
- Cloud AI is to send all IoT data to the centralized cloud that processes all impulses and makes decisions.
- Edge AI is to process data and make decisions in the periphery, close to the source where data was originated.
- Edge AI is like the reflexes of the nervous system that can make autonomous decisions w/o the need to send all info to the brain (centralized cloud).
- Cloud AI has been shown to be very useful but lack real-time responsiveness.
- Edge AI brings intelligence, real-time decision making and responsiveness to all kinds of IoT devices.

Edge AI & AIoT

- Edge AI based AIoT is the most promising fusion of AI and IoT.
- It provides solutions to overcome the bottlenecks, latency, and privacy issues of cloud-based AI applications.

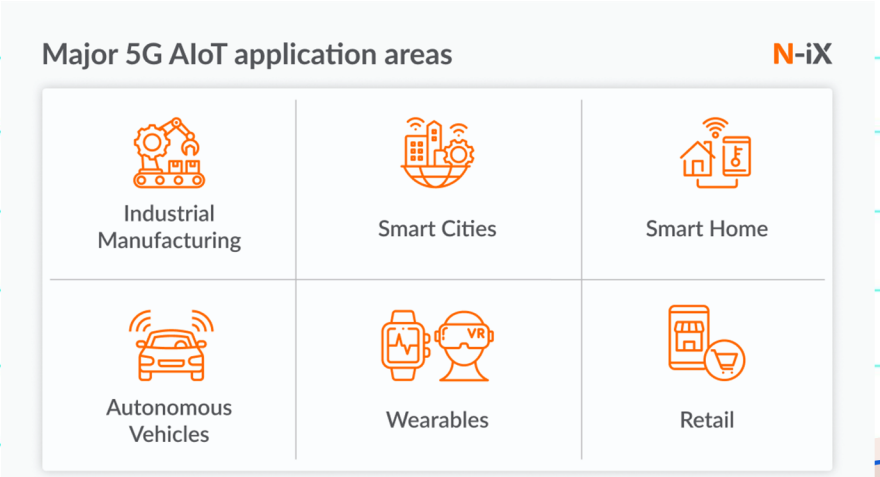


Benefits of AIoT

- Enhancing connectivity and data insights
- Boosts operational efficiency
- Real-time monitoring
- Improved decision-making
- Smart and flexible automation
- Reduces operational costs
- Predictive maintenance
- Increased scalability
- Reduced human error
- Helps in risk management
- Greater customization and personalized user experiences
- Increased security and privacy

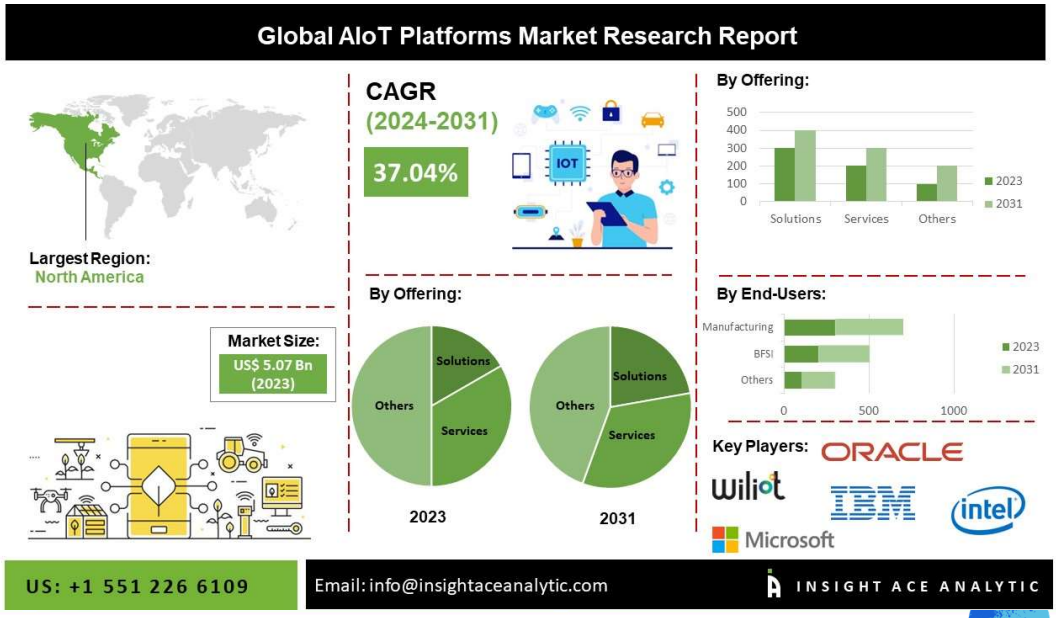
Major AIoT Application Areas

- 5G, AI/ML and IoT facilitate 6 hottest areas of applications



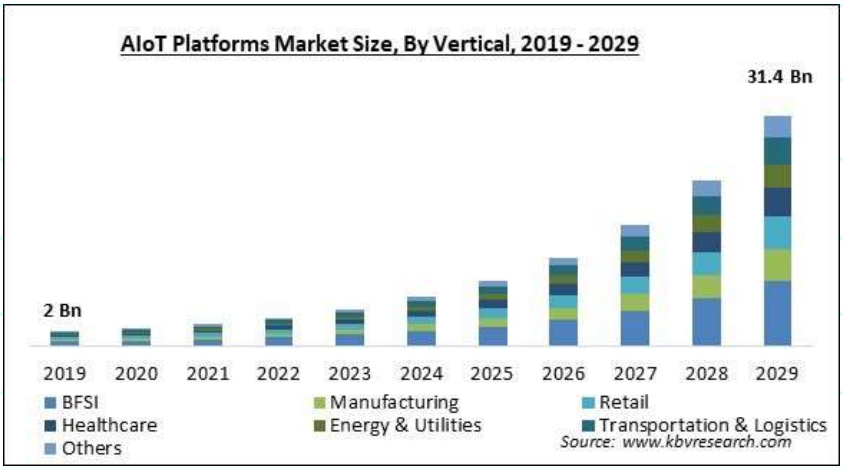
Global AIoT Market Analysis

Global AIoT Platforms Market



AIoT Platforms Market Size

- The global AIoT platforms market size is expected to reach $31.4 billion by 2029. (KBV reseaarch)



Concluding Remarks On AIoT

- The AIoT is always on the hottest IoT trends!!
- So hot that IoT is now often directly referred to as AIoT.
- AIoT also brings unprecedented attention to network security and privacy protection.
- One analogy to AIoT might be water: it is practically everywhere, it is about everything and it is essential to life as we know it, or as we ask it to be.
- The main challenge is to integrate data.