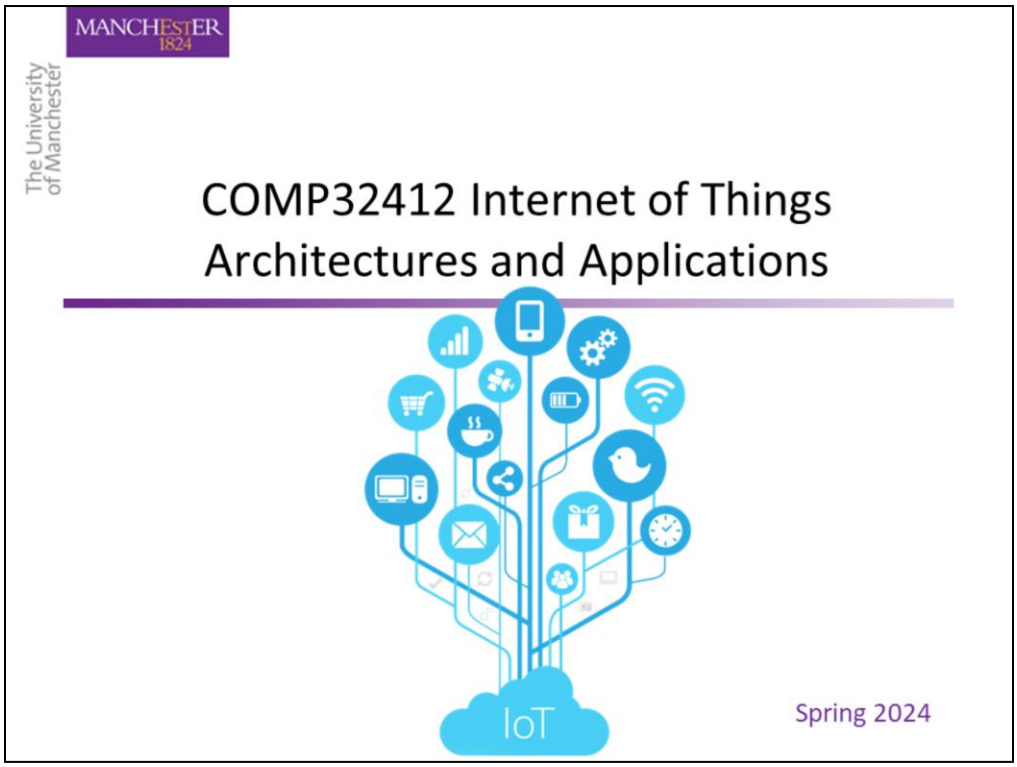

Image source: http://www.interprit.com/integration/internet-of-things-iot

Course Instructors

- Course leader: Dr Vasilis Pavlidis
  - pavlidis@cs.man.ac.uk
  - Office location – IT 414
  - Office hours: Fridays 14:00-15:00
- Course instructor: Dr Mustafa Mustafa
  - mustafa.mustafa@manchester.ac.uk
  - Office location – KB 2.93
  - Office hours: Thursdays 09:00am-10:00am

Course Structure

- Face to face lectures
- Primarily synchronous lectures
  - There will be sporadic asynchronous lectures
- Assessment: 100% exam (online closed book exam)
  - Formative quizzes will be available periodically

Course Content

- Emphasis on networking for IoT systems
- Part I (Vasilis)
  - IoT architecture and related design methodology
  - Physical mechanisms, models, and techniques for wireless communications
  - IoT application and PHY protocols
    - HTTP, CoAP, MQTT, etc.
    - WiFi, Bluetooth
- Part II (Mustafa)
  - Security requirements and challenges in IoT
  - Understanding botnets and DDoS attacks in IoT
  - Countermeasures and techniques to secure IoT

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What is the "Internet of Things (IoT)?"

- The vision[1]
  - *Specialized elements of hardware and software, connected by wires, radio waves, and infrared, will be so ubiquitous that no one will notice their presence.*
- A definition[2]
  - *A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) **things** based on existing and evolving interoperable information and communication technologies.*

[1]M. Weiser, "The computer for the 21st Century," *Scientific American*, Vol. 265, No. 3, pp. 94-104, September 1991.
[2]International Telecommunication Union, *Overview of the Internet of Things*, June 2012.

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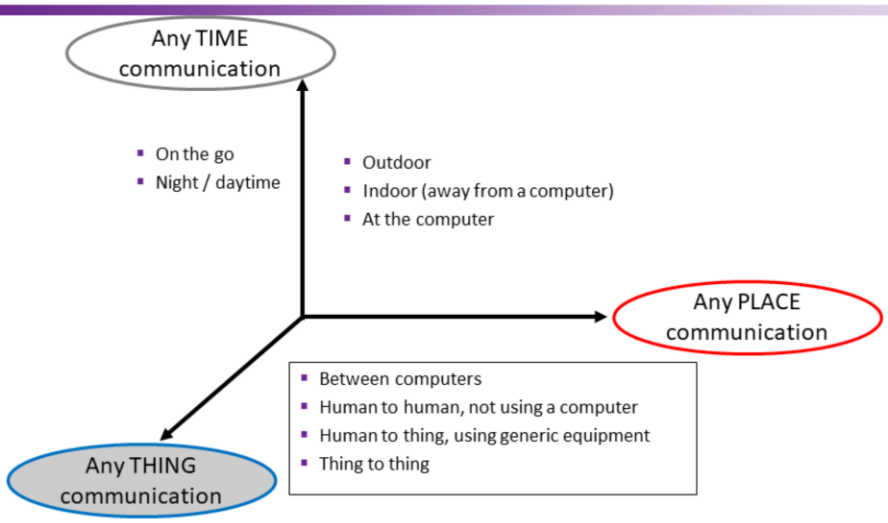
IoT – An Added Dimension for ICT



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*International Telecommunication Union, *Overview of the Internet of Things*, June 2012.

The IoT Connected World

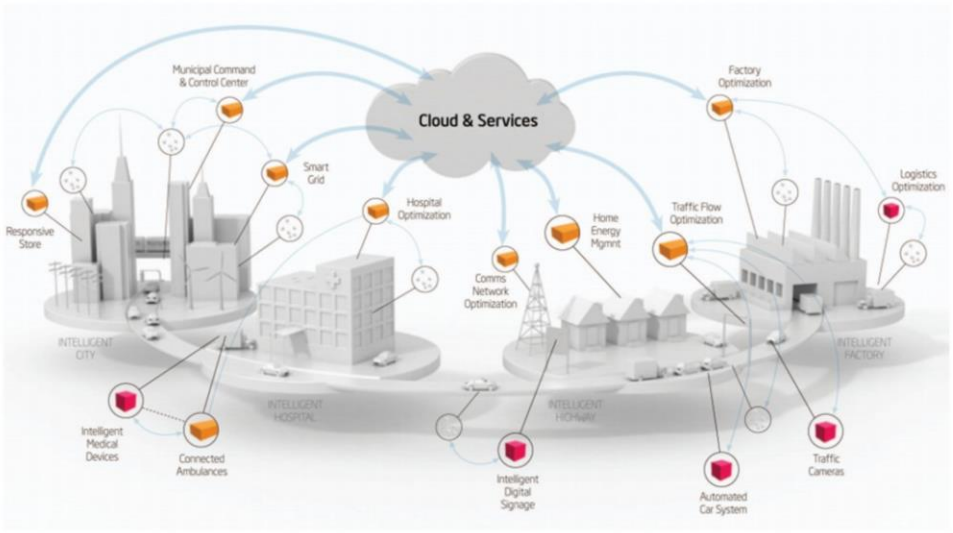

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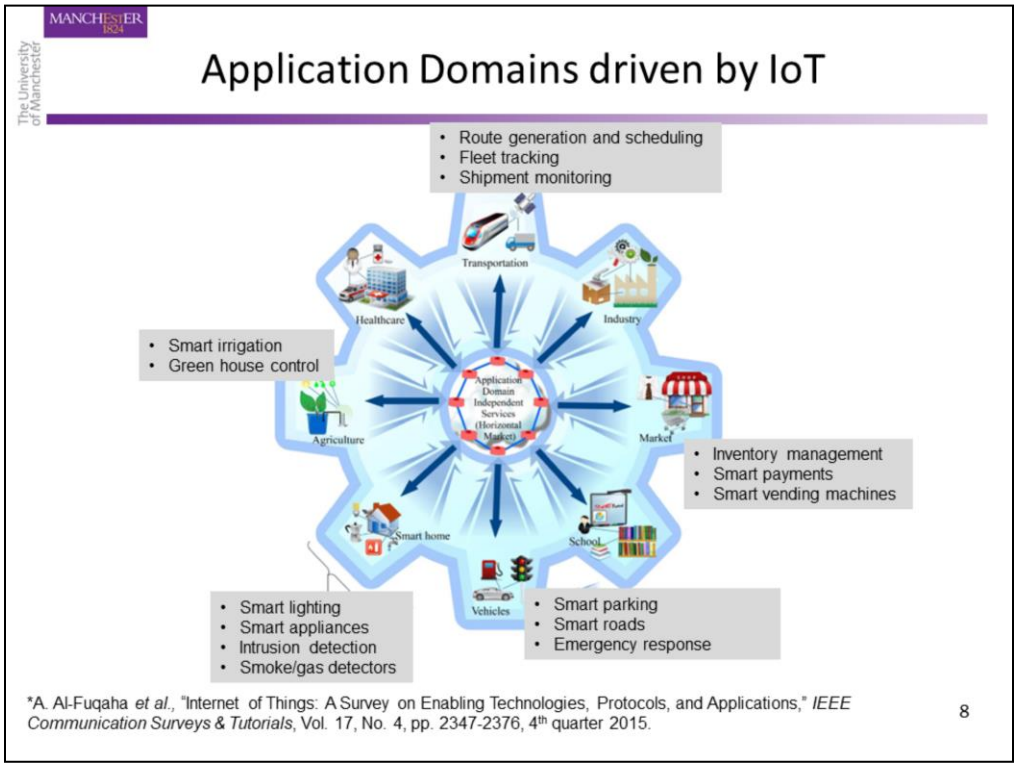
Image source: https://hutgrip.com/2013/06/24/market-opportunity-for-the-next-big-thing/



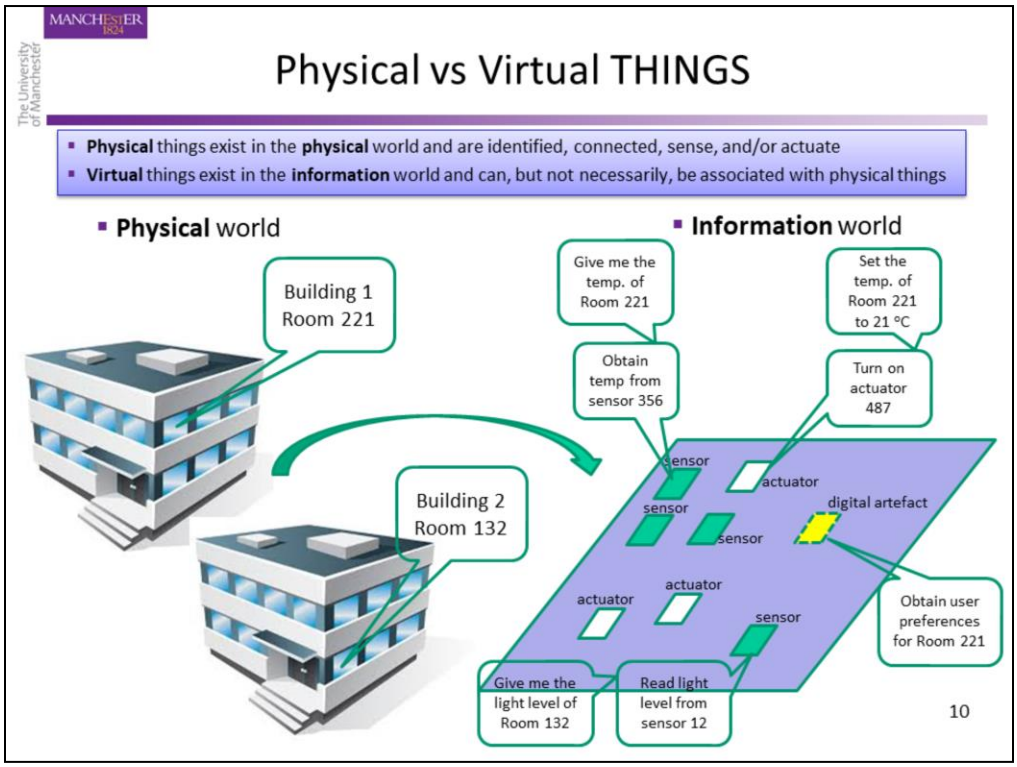
Other IoT applications include:

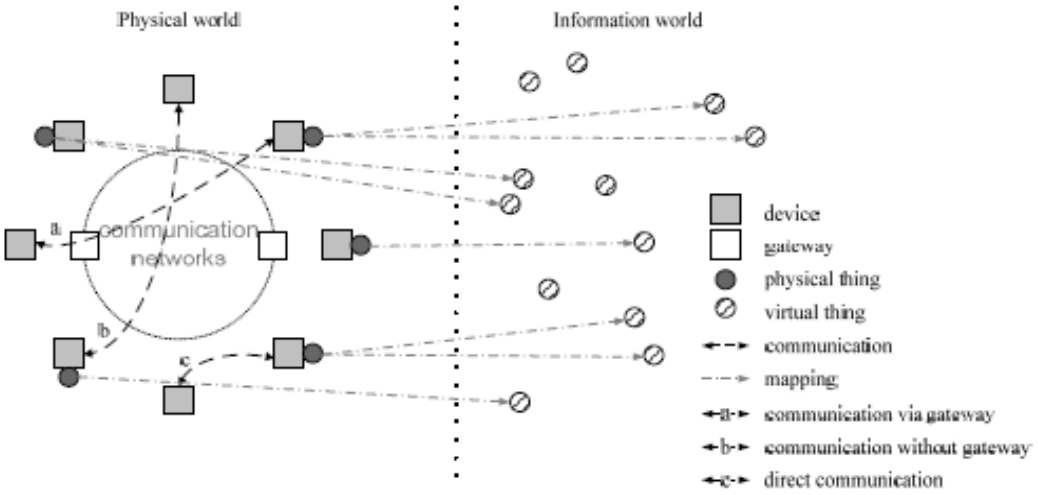
- Industry
  - Machine diagnosis and prognosis
  - Indoor air quality monitoring
  - Gas/fire sensors
  - Monitoring of industrial processes
- Health and lifestyle
  - Health & fitness monitoring
  - Wearable electronics

How was IoT Enabled?

- Technology push was the driver for rise of IoT
  - In the past 10 yrs (2008-2017), networking, computing, and storage advanced immensely
  - Bandwidth improved by more than 1000× while the cost has decreased 40×
  - Cost of computing ICs has reduced 60×
  - The capacity of a single disk increased by more than 10,000× while the cost reduced by 17×

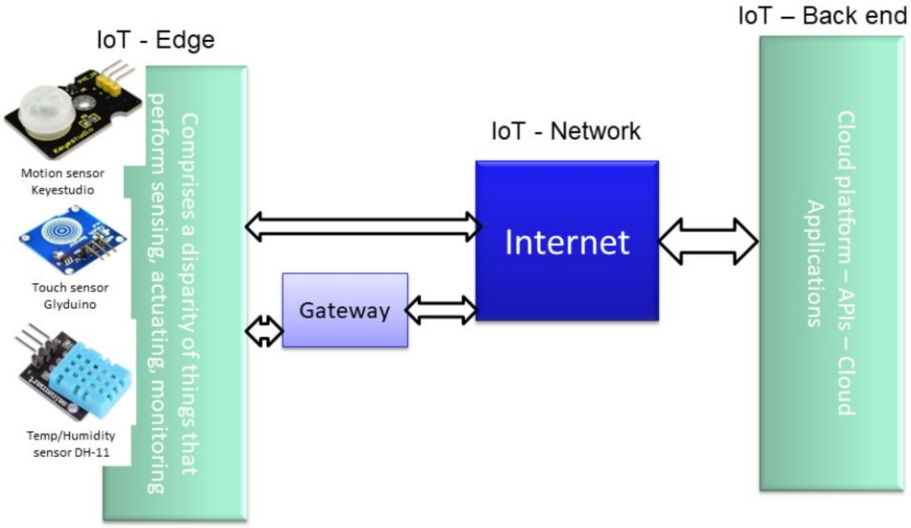
*Edge Computing Reference Architecture 2.0, *Edge Computing Consortium (ECC) and Alliance of Industrial Internet (AII)*, November 2017





A physical thing may be represented in the information world via one or more virtual things (mapping), but a virtual thing can also exist without any associated physical thing.

IoT System Basic Infrastructure



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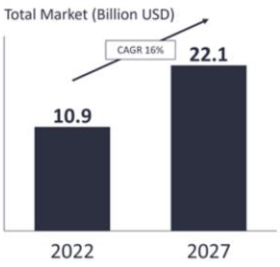
IoT Sensor Market 2022

Market Size



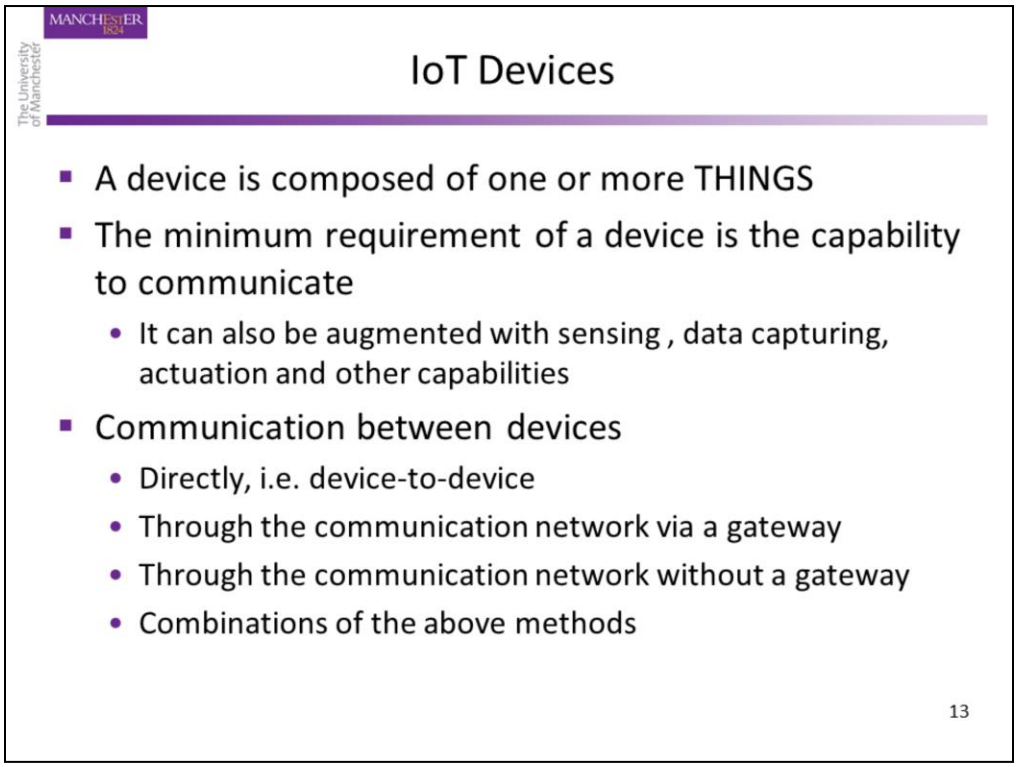
Leading vendors (selection)

SONY, BOSCH, ams, ST, Teledyne Technologies, OMNIVISION, Infineon + CYPRESS, SENSIRION, Sensata Technologies, Honeywell, TE, muRata, knowles, NXP, TDK, ANALOG DEVICES, Amphenol, BROADCOM, Texas Instruments, RENESAS, AKM, SMARTSENS

5 trending technologies

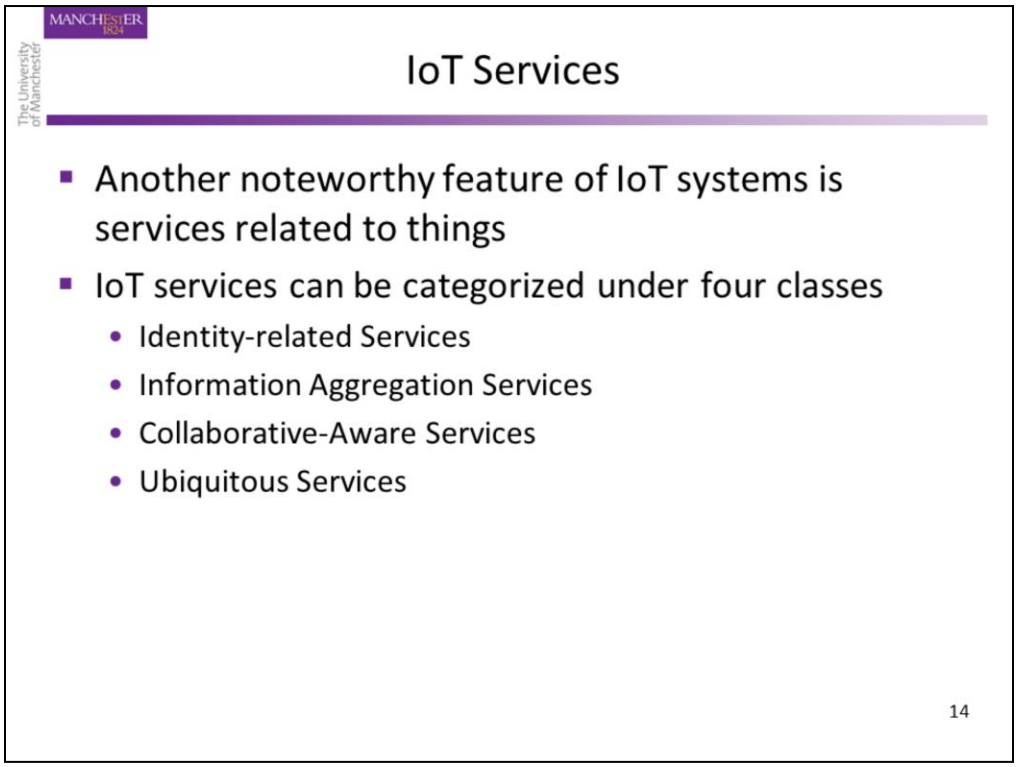
1. Smart sensors
2. Power-efficient sensors
3. Soft & Virtual sensors
4. Sensor fusion
5. Biosensors

*Source: IoT Analytics Research 2022 (https://iot-analytics.com/).



Combinations include for example the case where devices can communicate with other devices using a network providing local connectivity between devices and between devices and a gateway, and then communication through the communication network via a local network gateway, effectively combining all cases mentioned above.

The IoT network infrastructure may be realized via existing networks, such as conventional TCP/IP-based networks, and/or evolving network protocols such as 6LoWPAN.



- Identity-related services are the most basic and important services that are used in other types of services. Every application that needs to bring real world objects to the virtual world has to identify those objects.
- Information Aggregation Services collect and summarize raw sensory measurements that need to be processed and reported to the IoT application.
- Collaborative-Aware Services act on top of Information Aggregation Services and use the obtained data to make decision and react accordingly.
- Ubiquitous Services, however, aim to provide Collaborative-Aware Services *anytime* they are needed to *anyone* who needs them *anywhere*.

To offer such services there should be a shift in the technologies both in the physical (hardware) and information (software) world. These services should be provided while complying with the constraints of the things, for example, privacy protection and security.

Source:

X. Xiaojiang, W. Jianli, and L. Mingdong, “Services and key technologies of the Internet of Things,” ZTE Commun., Shenzhen, China, vol. 2, p. 011, 2010.

M. Gigli and S. Koo, “Internet of Things: Services and applications categorization,” *Adv. Internet Things*, vol. 1, no. 2, pp. 27–31, Jul. 2011

Primary Characteristics of IoT Systems

- Interconnectivity
  - Anything is connected virtually to “any THING”
- Heterogeneity
  - Different hardware platforms and networks
- Dynamic changes
  - Devices have many more power states compared to state-of-art-devices (sleep, wake-up, connected, disconnected)
  - Location and speed of the device
- Scale and complexity
  - Several billions(!) of devices connected. These devices should be managed and communicate with each other

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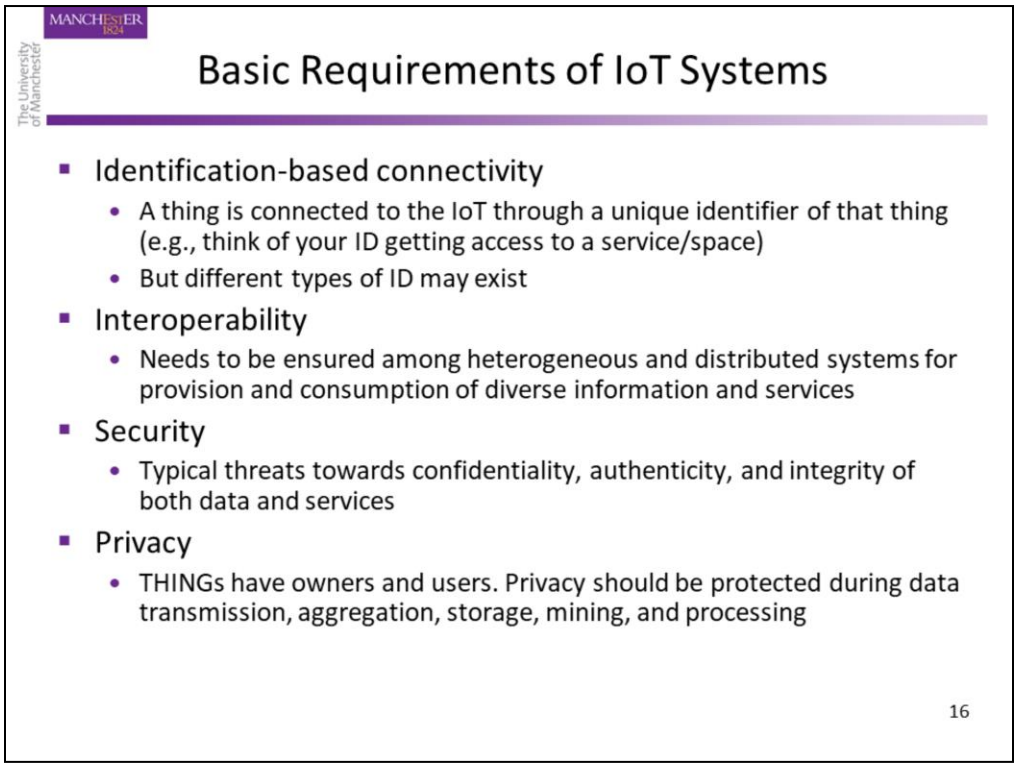


Other requirements for IoT systems include:

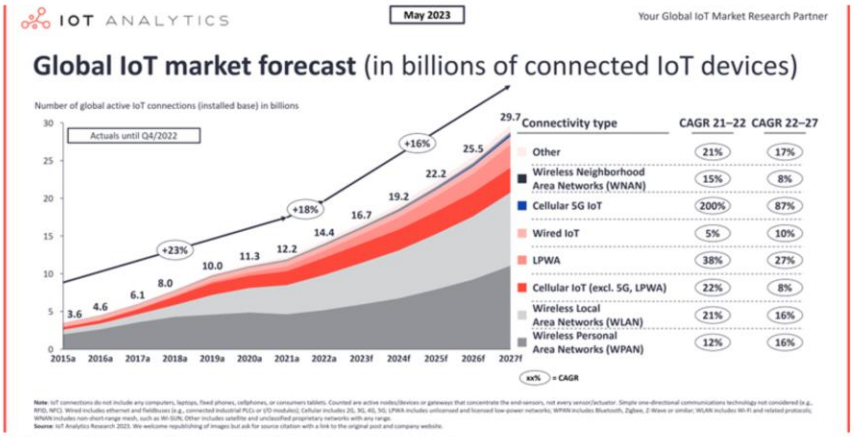
- **Networking should be autonomic*** (involuntary) including self-management, self-configuring, self-healing, self-optimizing and self-protecting techniques and/or mechanisms. Autonomy should be supported in the networking control functions of the system to ensure adaptation to different application domains, different communication environments, and large numbers (scale) and types of devices.
- Autonomic service provisioning should be provided by capturing, communicating, and processing automatically the data of things based on the rules configured by operators or customized by subscribers. These services may depend on the techniques of automatic data fusion and data mining.
- **Location-based capabilities** must be supported in the IoT. Something-related communications and services will depend on the location information of things and/or users. For example, think of weather conditions information, which is not that useful without related location information. Location-based communications and services may be constrained by laws and regulations, and should comply with security requirements.
- **High quality and highly secure human body related services.** Different countries have different laws and regulations on these services.
- **Plug and play** capability which will enable on-the-fly generation, composition or acquisition of semantic-based configurations for seamless integration and cooperation of interconnected things with applications and responsiveness to application requirements.
- **Manageability** will ensure normal network operations. IoT applications usually work automatically without the participation of people (see autonomic networking above), but their whole operation process should be manageable by the relevant parties.

*Not be confused with “autonomous” (self-governing).

IoT Connected Devices

- The IoT smart objects are expected to reach 212 billion entities deployed globally by the end of 2020.

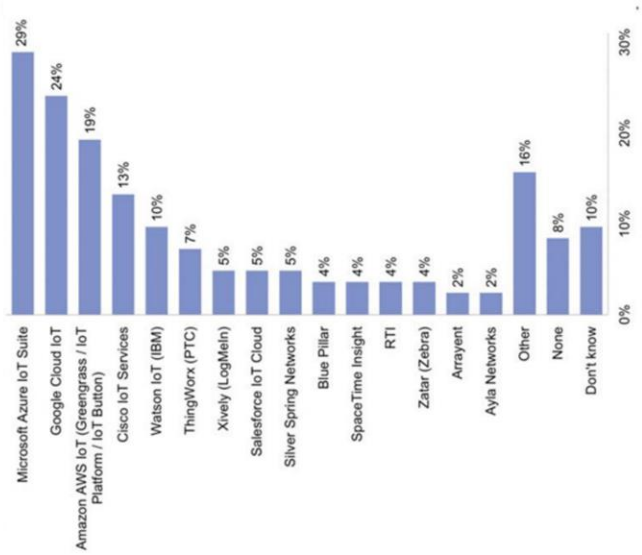
*J. Gantz and D. Reinsel, "The digital universe in 2020: Big data, bigger digital shadows, and biggest growth in the far east," *IDC iView: IDC Anal. Future*, vol. 2007, pp. 1–16, Dec. 2012.



*Source: IoT Analytics Research 2022 (https://iot-analytics.com/).

IoT Development Platforms

- Technologies used to run connected devices in your software products



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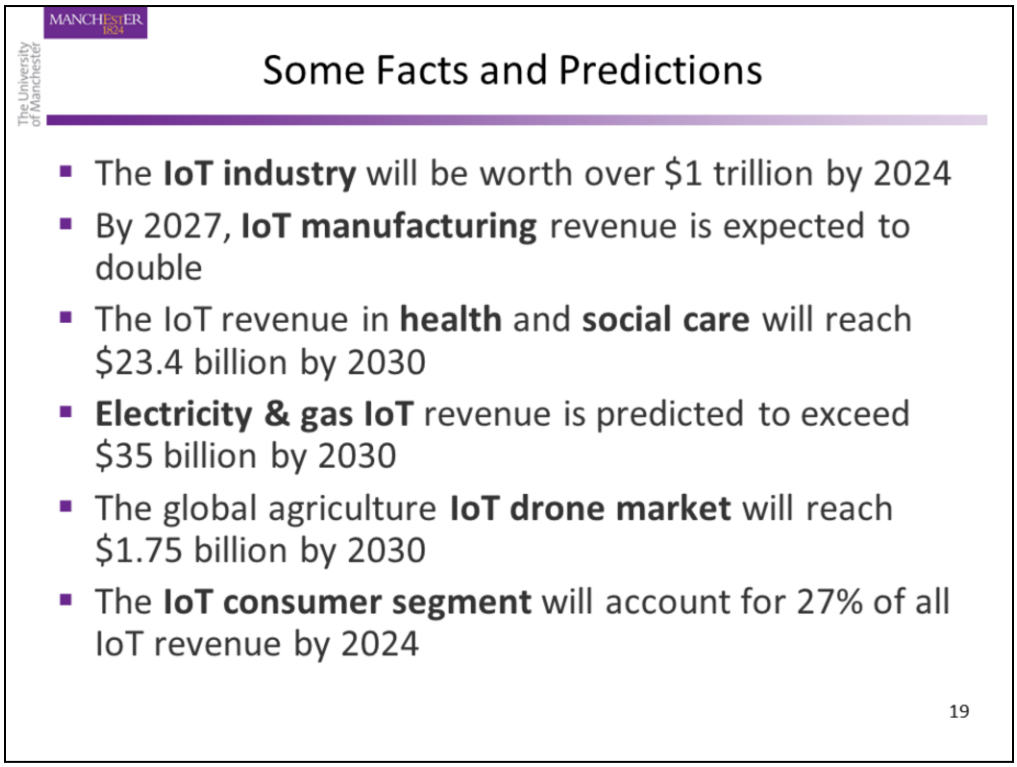
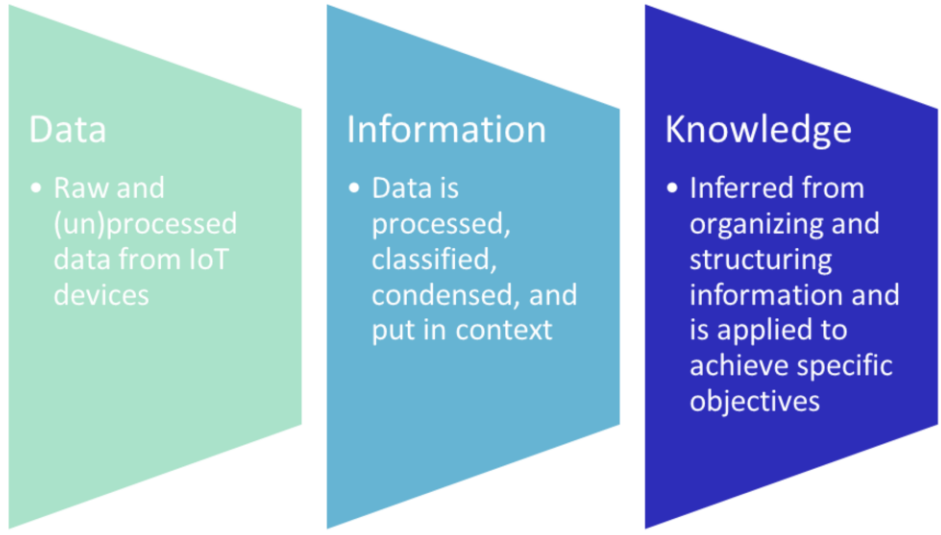


Source: https://vpnalert.com/resources/iot-statistics/

From Data to Information and Knowledge



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*A. Bahga and V. Madisetti, *Internet of Things: A Hands-On Approach*, 2014