Introduction to Internet of Things

Instructor: Deepak Gangadharan
Assistant Professor, Computer Systems Group
PhD (National University of Singapore)

General Information

- Office: Vindhya A5-303
- Email: deepak.g@iiit.ac.in
- Course Grading

Component	Marks
2 Quizzes	15
End Sem exam	30
Labs	30
Project	25

Reference Material

- Lea, P., 2018. Internet of Things for Architects: Architecting IoT solutions by implementing sensors, communication infrastructure, edge computing, analytics, and security. Packt Publishing Ltd.

Research Areas

- **Real-Time System Design/Analysis:**

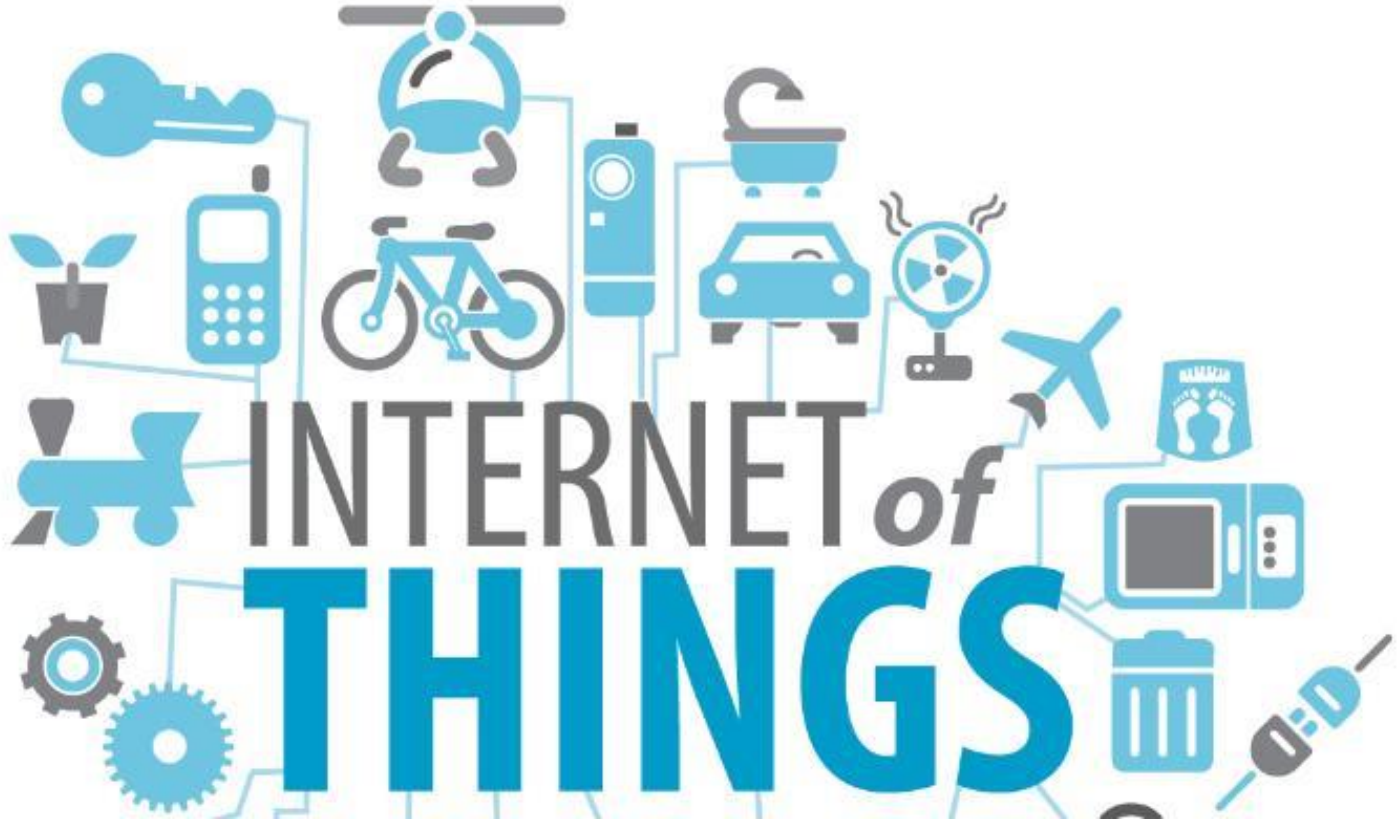
1) Scheduling in Multicore Real-Time Embedded Systems considering Thermal and Security Constraints
2) Embedded system-based fault tolerant control and autonomous navigation of an unmanned aerial vehicle
3) Secure Drones: Analyze, Deploy, and Decide Cryptographic Modules in UAVs

- **Edge Computing for ITS:**

1) IIIT-H BikeSafety Project
2) Design, development, and deployment of energy-efficient smart EDGE devices for real-time traffic flow prediction and control
3) Mobility and QoS aware Service Delivery in Vehicular Edge Computing

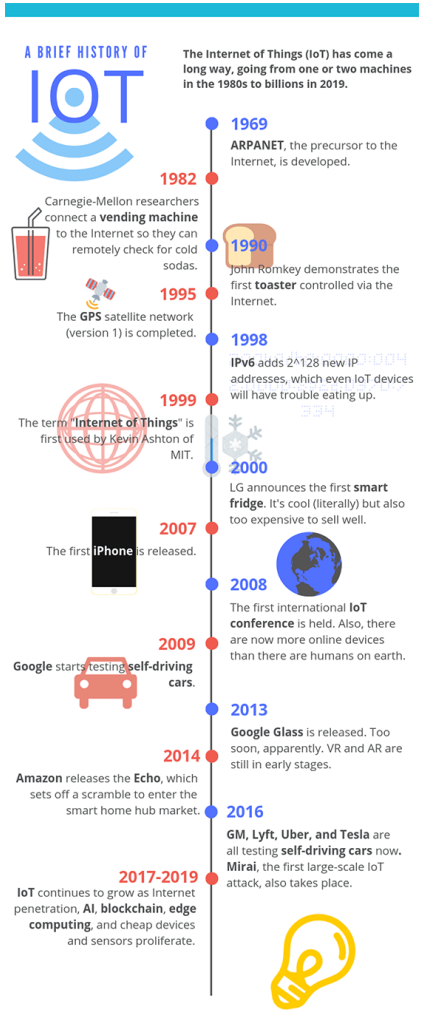
Outline

- History of IoT
- What is IoT?
- IoT Applications
- M2M vs IoT
- Importance of IoT
- Challenges/Impediments
- Case Study



Source: https://www.groundreport.com/

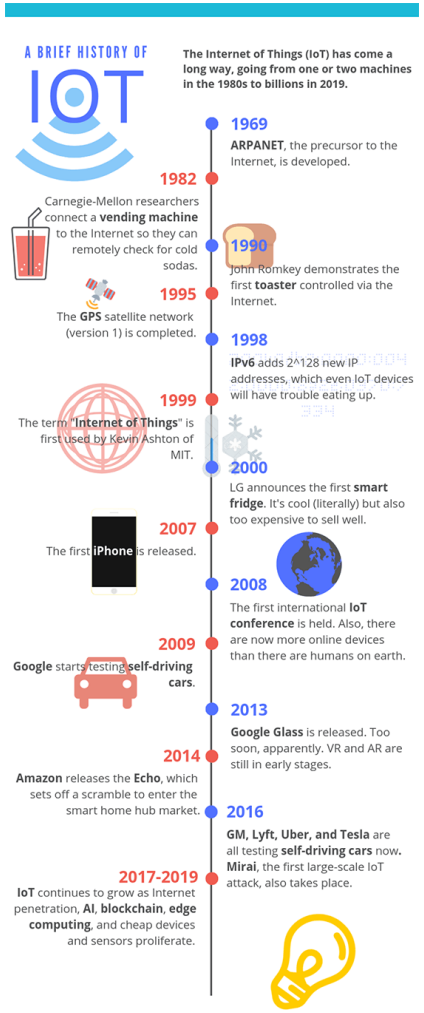
History of IoT



Source: https://www.iottechtrends.com/history-of-iot/

- 1969 – ARPANET was put into service by DARPA, which paved way for the "Internet"
- 1982 – A Coca-Cola vending machine is connected to the Internet by researchers at CMU to check availability of cold sodas. Often cited as one of the first IoT devices.
- 1990 – John Romkey, an Internet pioneer connected a smart toaster to the Internet and controlled it.
- 1995 – The first GPS satellite program of US government is completed making it possible to get location information required for many IoT devices
- 1998 – 128-bit IPv6 becomes a draft standard allowing more devices to be addressed than IPv4 could (32-bit).
- 1999 – A big year for IoT as the term was used for the first time by Kevin Ashton, a cofounder of Auto-ID center at MIT

History of IoT (continued)



Source: https://www.iottechtrends.com/history-of-iot/

- 2000 – LG introduced the Internet refrigerator with screens and trackers to keep track of the food that was there in the fridge. It was expensive.
- 2007 – The first iPhone is released allowing people to interact with the world and internet connected devices in a whole new way.
- 2008 – The first international IoT conference was held in Zurich and also the number of Internet connected devices surpassed the number of humans.
- 2009 – Google starts self-driving car tests
- 2014 – Amazon Echo is released which paves way for the Smart Home Hub market
- 2016 – GM, Lyft, Tesla and Uber all start testing self-driving cars

What is IoT?

Source: https://www.gartner.com/en/information-technology/glossary/internet-of-things

- Definition

The Internet of Things (IoT) is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment. – By Gartner Research

Source: https://www.groundreport.com/

What is IoT?

- Alternate definitions

- 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.

Source: https://www.itu.int/rec/T-REC-Y.2060-201206-I

- The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

Source: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT

What is IoT?

- Alternate Definition (From Wikipedia)

- The Internet of things (IoT) is the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data.

What is IoT?

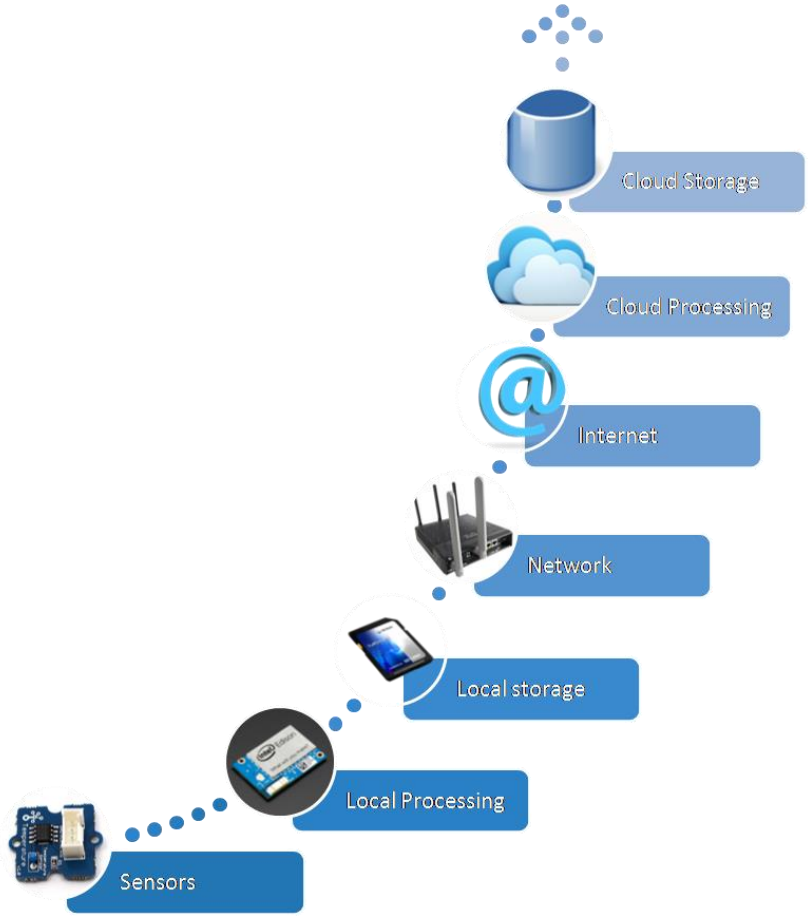
- Simple Definition

Internet of Things (IoT) is a simple concept which means taking all the things in the world and connecting them to the internet.

But is connecting everything to Internet enough for IoT?

The true potential of IoT is realized when the connected things can sense the environment and send data or receive data and trigger some action or do both.

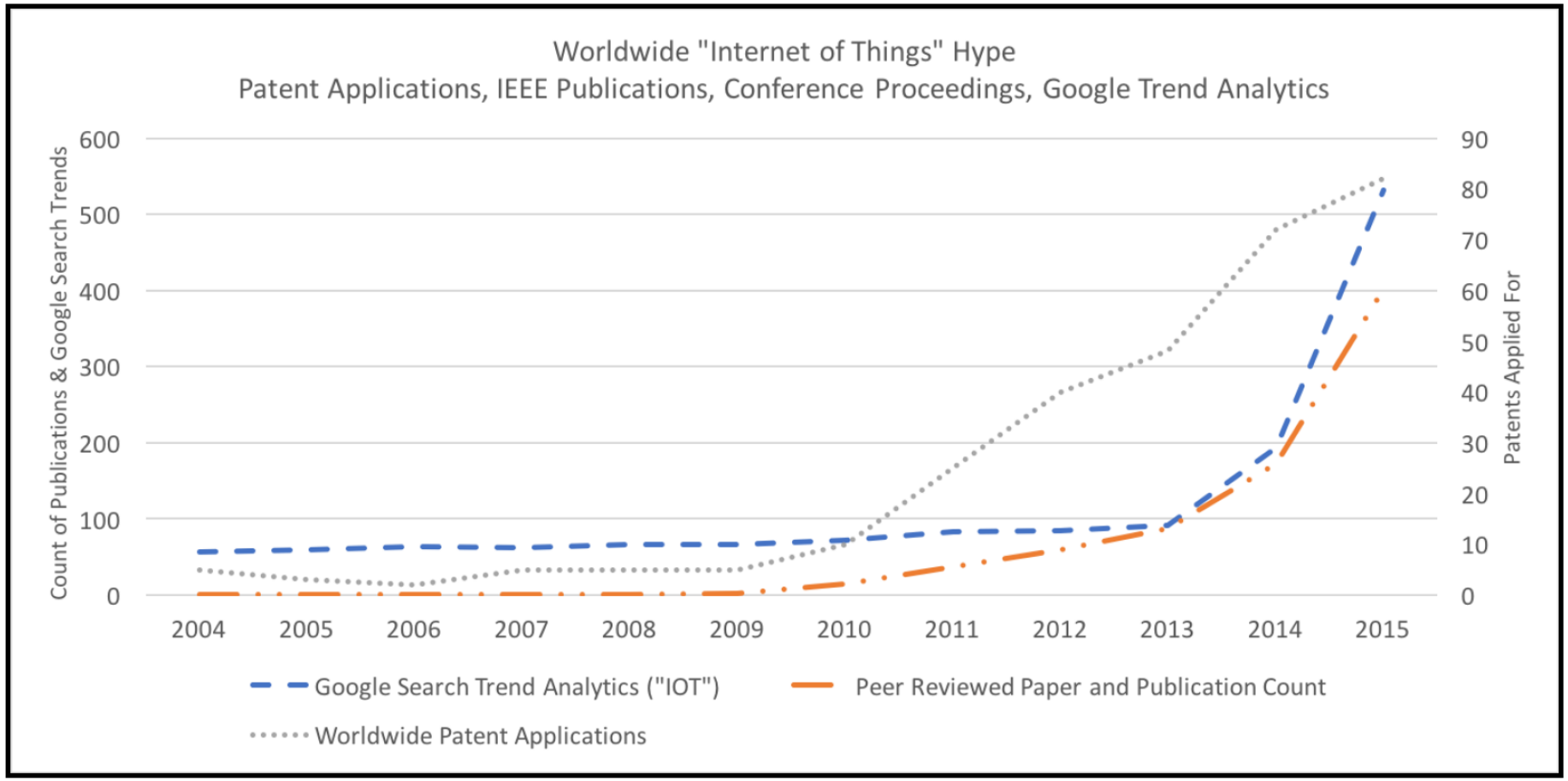
Upstream Information Flow in IoT



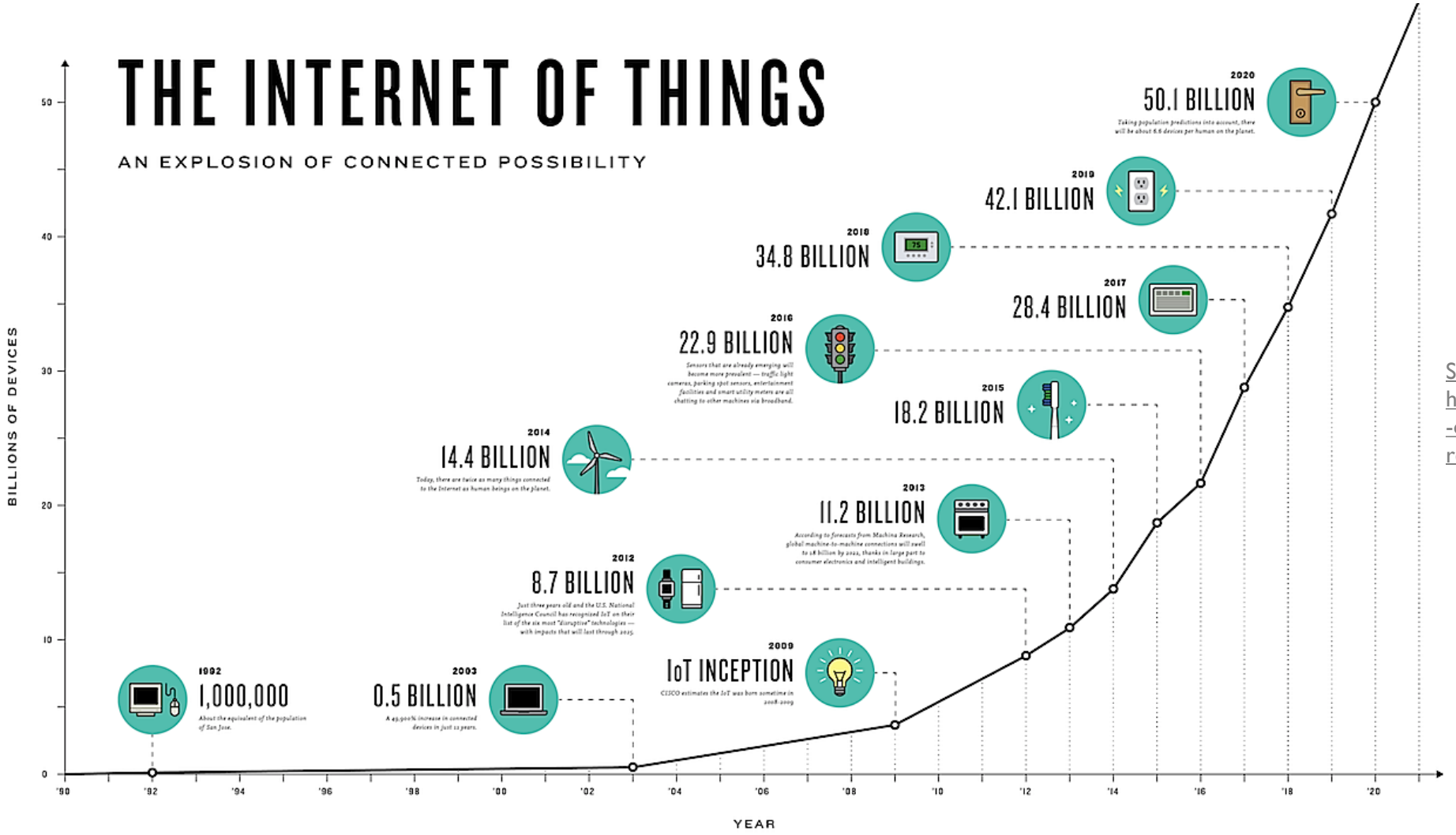
- The initial information flow did not encompass the local storage and the local processing – Purely cloud based processing
- Currently *edge computing* is a concept that is gaining prominence whereby there is availability of some local processing and storage

Source: http://ocw.cs.pub.ro/courses/_media/iot2015/courses/picture11.png?w=450&tok=584430

Rise of IoT

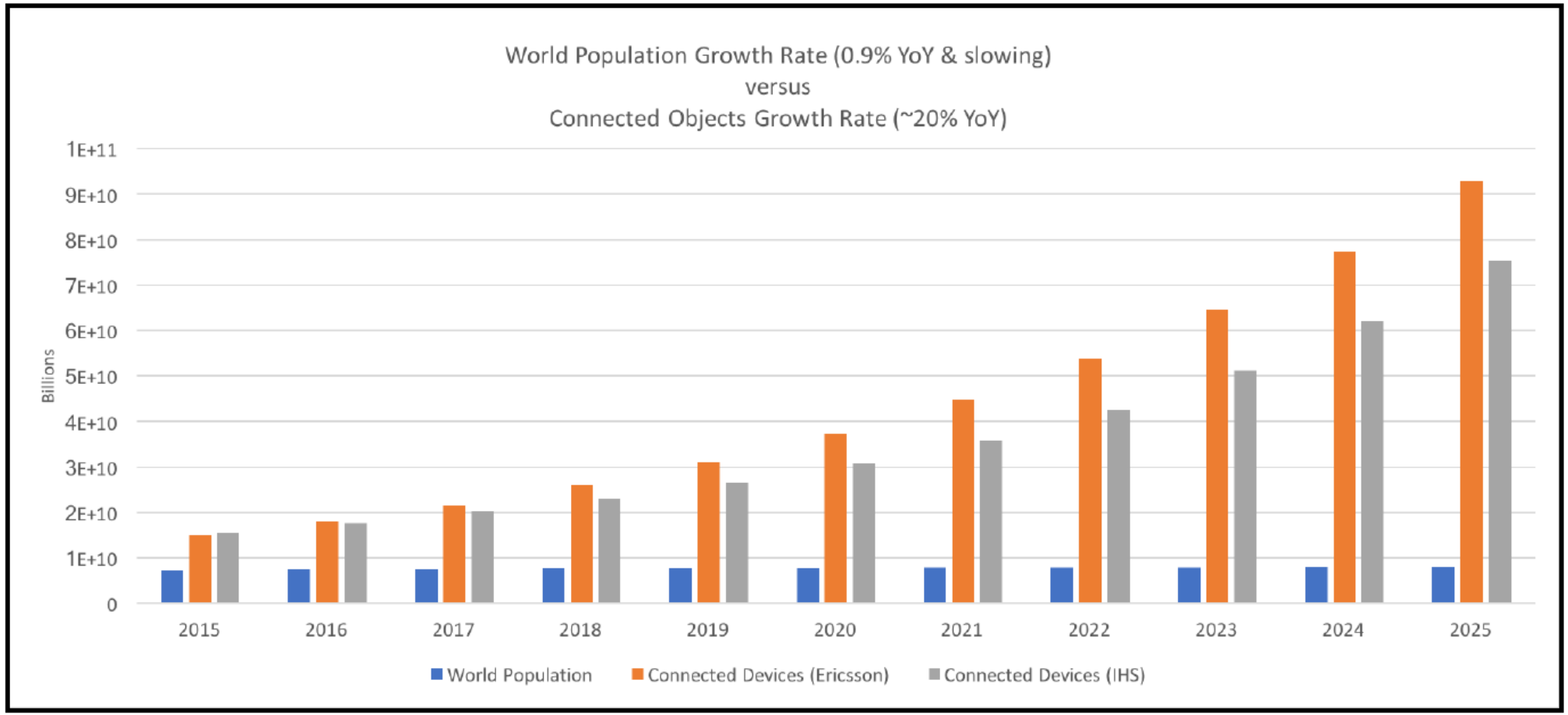

Worldwide "Internet of Things" Hype
Patent Applications, IEEE Publications, Conference Proceedings, Google Trend Analytics
Count of Publications & Google Search Trends
Patents Applied For
600
500
400
300
200
100
0
90
80
70
60
50
40
30
20
10
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Google Search Trend Analytics ("IOT")
Peer Reviewed Paper and Publication Count
Worldwide Patent Applications

Rise of IoT



Source: https://www.weforum.org/agenda/2017/06/internet-of-things-will-power-the-fourth-industrial-revolution/

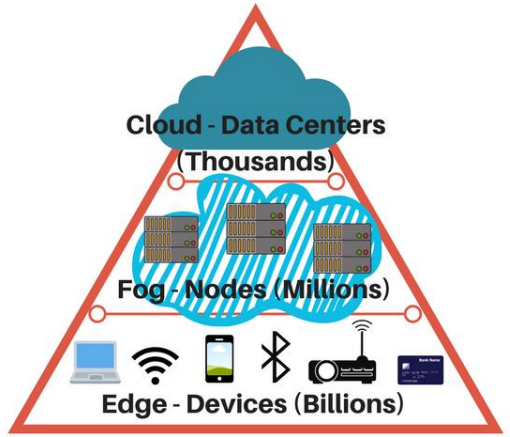
Rise of IoT


World Population Growth Rate (0.9% YoY & slowing)
versus
Connected Objects Growth Rate (~20% YoY)
Billions
1E+11
9E+10
8E+10
7E+10
6E+10
5E+10
4E+10
3E+10
2E+10
1E+10
0
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
World Population
Connected Devices (Ericsson)
Connected Devices (IHS)

Why is IoT buzz word now?

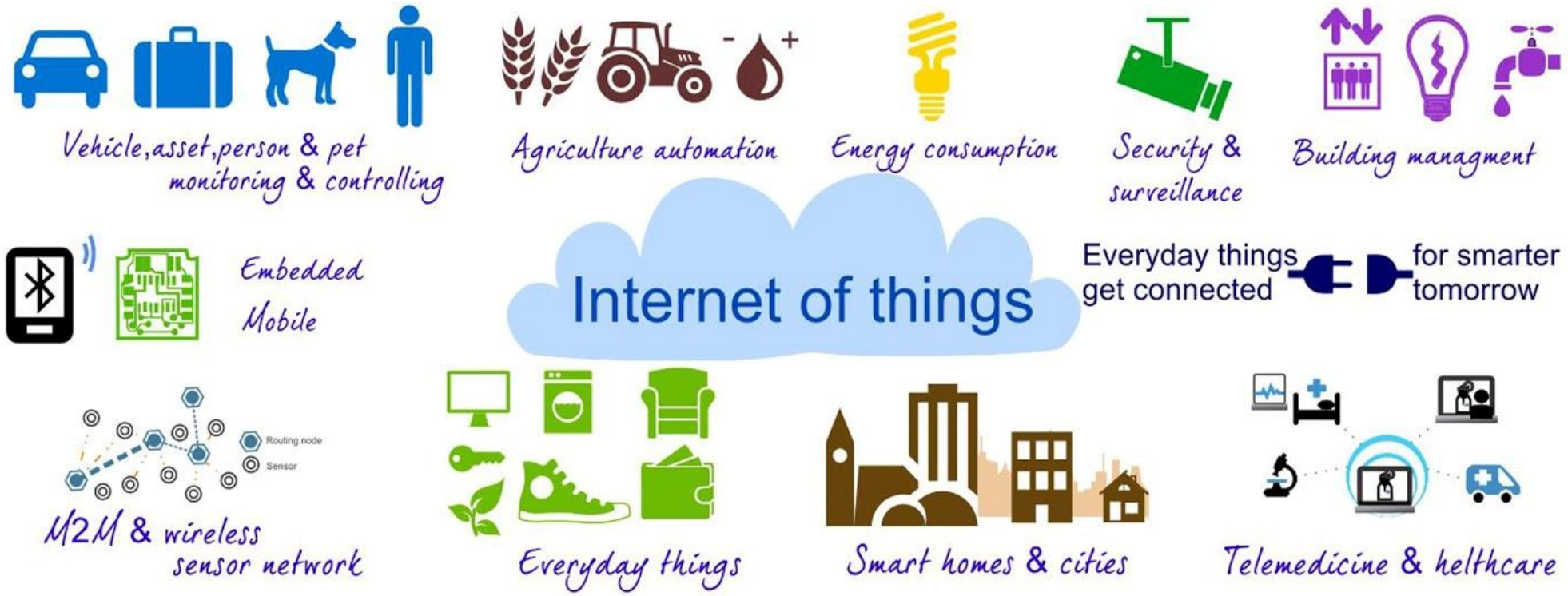
- Embedded chips are becoming cheaper, smaller and low power devices
- Emergence of faster communication technologies
- Flexibility of IPv6 to address more IoT devices
- Emergence of fog/edge computing
- Advances in Big Data, Deep Learning and AI understanding

Source: https://timestech.in/gartner-say-worldwide-5g-network-infrastructure-revenue-will-reach-4-billion-in-2020/

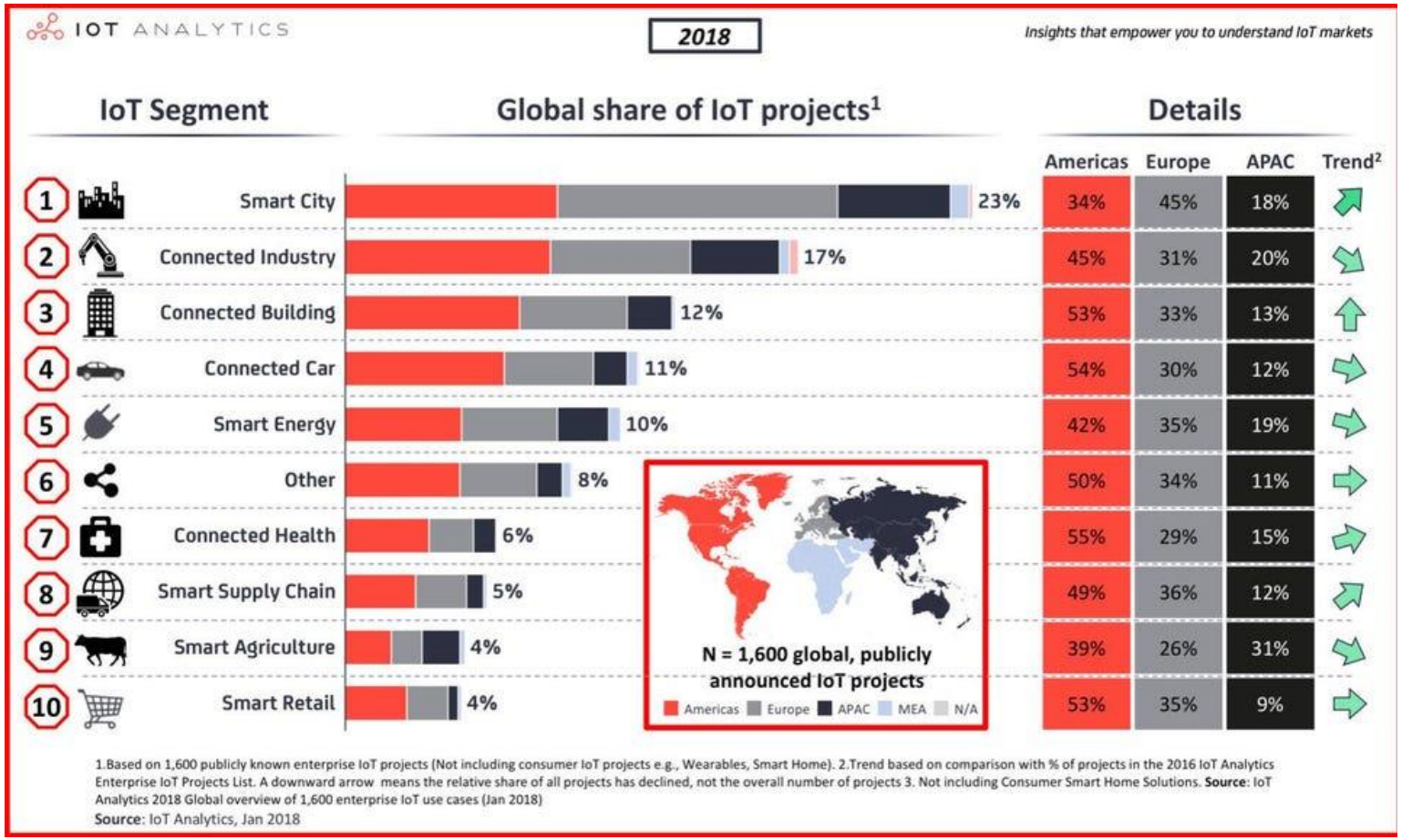


Source: https://www.power-solutions.com/industry-trends-best-practices/industry-trends/fog-computing-and-edge-computing-what-you-need-to-know

IoT Applications



Source: https://iotworm.com/internet-of-things-applications-area/



Source: https://www.forbes.com/sites/louiscolumbus/2018/06/06/10-charts-that-will-challenge-your-perspective-of-iots-growth/?sh=42f59eed3ecc

M2M vs IoT

- M2M – An autonomous device communicating directly with another autonomous device
  - Uses Non-IP based channels
- IoT – Incorporates M2M nodes but aggregates data at an edge router or gateway
  - Uses IP based protocols for communication

Importance of IoT

- **Gathers useful data**: Significant information gathered helps in making the right decision. If something malfunctions in the system, it can be maintained because the information is gathered.
- **Focuses on Automation and Control:** Connectivity of physical objects and their control using wireless support enables significant control and automation without the need of human intervention, which makes execution faster leading to timely output.
- **Useful in Monitoring:** Helps knowing things in advance, i.e., collects information on quantity of supplies, water distribution and consumption, intelligent energy management, which also allows taking necessary actions.
- **Increases efficiency and saves time**
- **Improves quality of life**

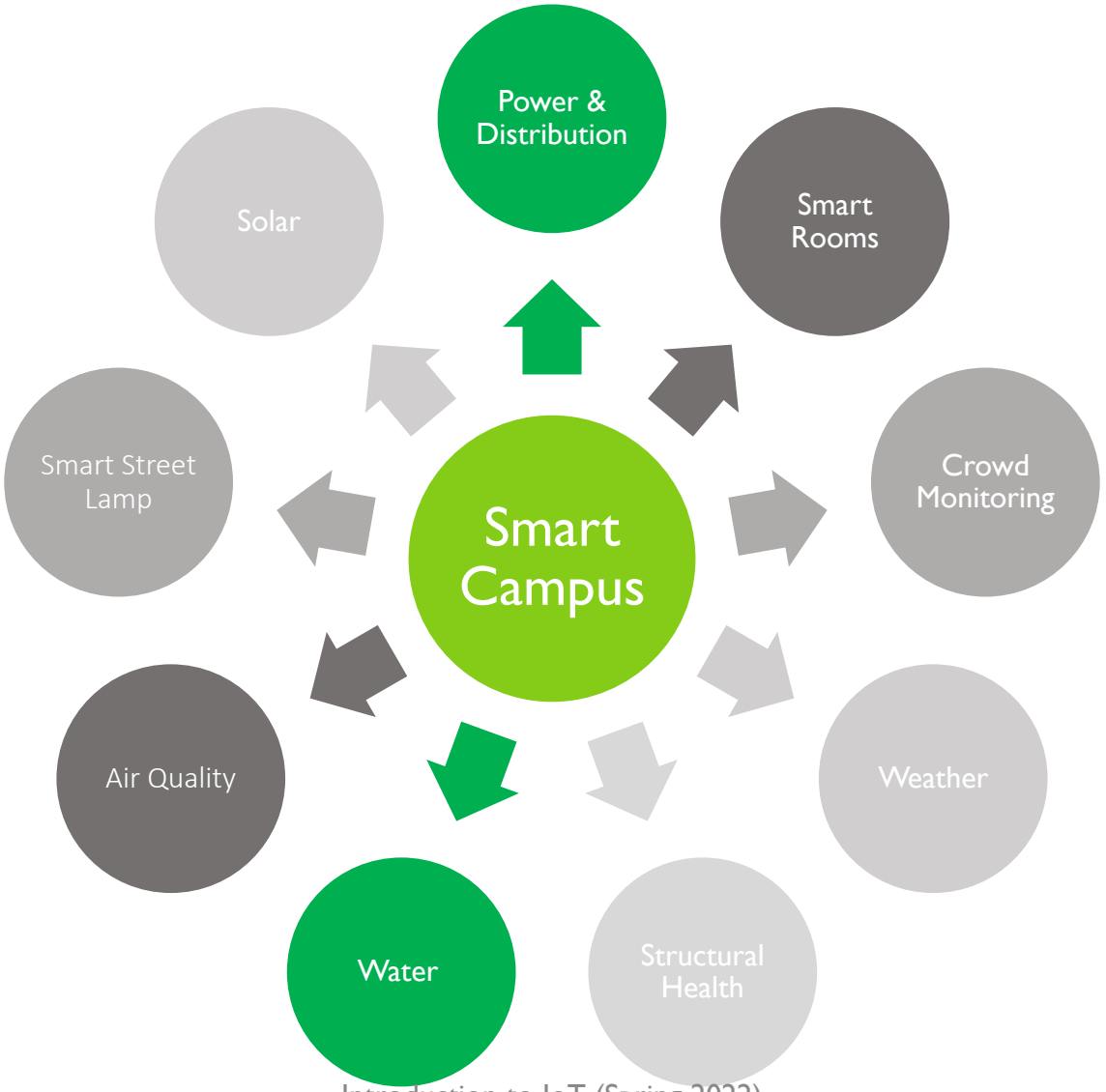
Challenges/Impediments

- **Privacy and Security**: Connectivity brings vulnerability to leakage of user identity and confidential data
- **Huge Volume of Data**: With increasing number of connected devices, the amount of data generated will be huge, which will need advancements in storage technology and processing infrastructure
- **Complexity**: The increasing complexity of IoT systems with increasing number of connected devices makes it difficult to verify such a system for safety and correctness
- **Intermittent Connectivity**: A mobile node may experience lack of connectivity on its path which reduces the quality of user experience

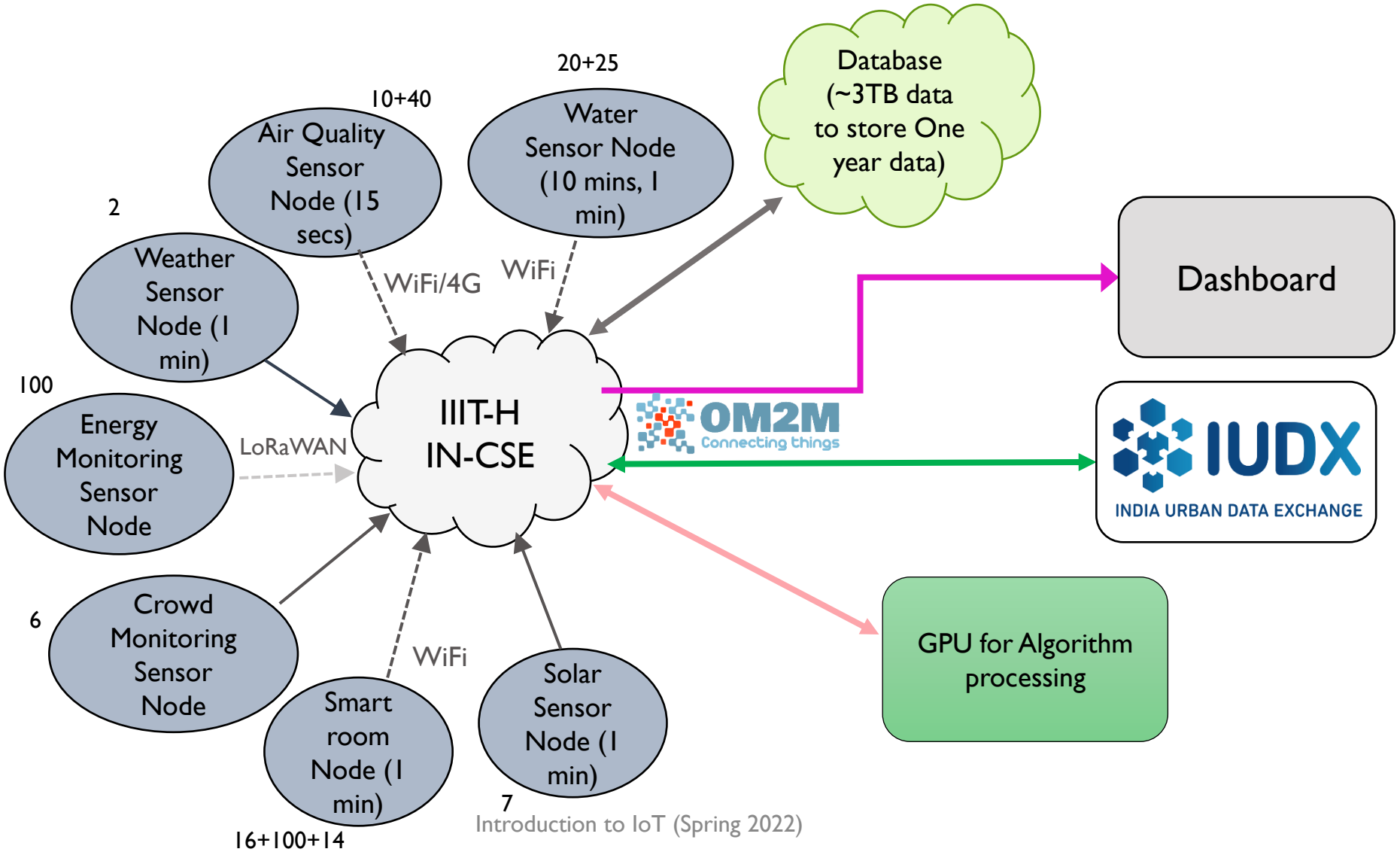
IoT Use Cases

- Industrial and Manufacturing
- Consumer
- Retail
- Healthcare
- Transportation and Logistics
- Agriculture
- Energy
- Smart City

Smart City Living Lab



Smart City Living Lab – General Architecture



IIIT-H BikeSafety Project

- Developed a prototype hardware node to capture the accelerometer and gyroscope data
- Showed a very preliminary set of raw data captured by the node
- Data collection process has been ongoing
- Currently have data from test rides across campus conducted over several days
- Identified some classes and evaluated few classifier algorithms

IoT Case Study

IoT in connected vehicles

Thank you