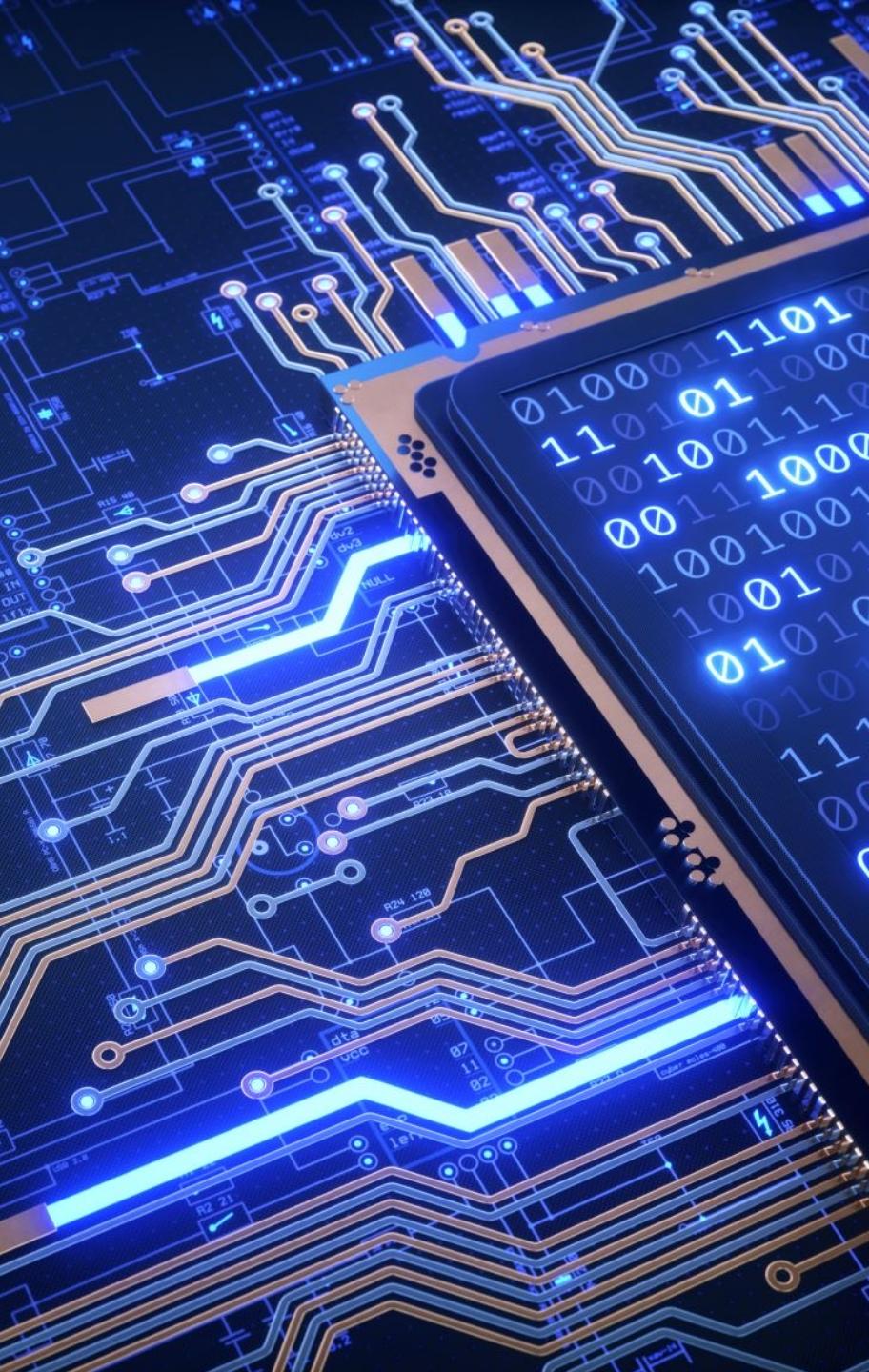




# CSCE 438/838: Internet of Things

# COORDINATES

- **M. C. Vuran**  
Dale M. Jensen Professor  
214 Schorr Center
  
- Phone: (402) 472-5019, Fax: (402) 472-7767
- E-mail: [mcv@unl.edu](mailto:mcv@unl.edu)
- URL: <http://www.cse.unl.edu/~mcvuran>
- Cyber-Physical Networking Lab:  
<http://cpn.unl.edu>



Sensor Networks →  
Internet of Things (IoT)

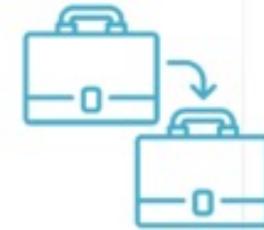
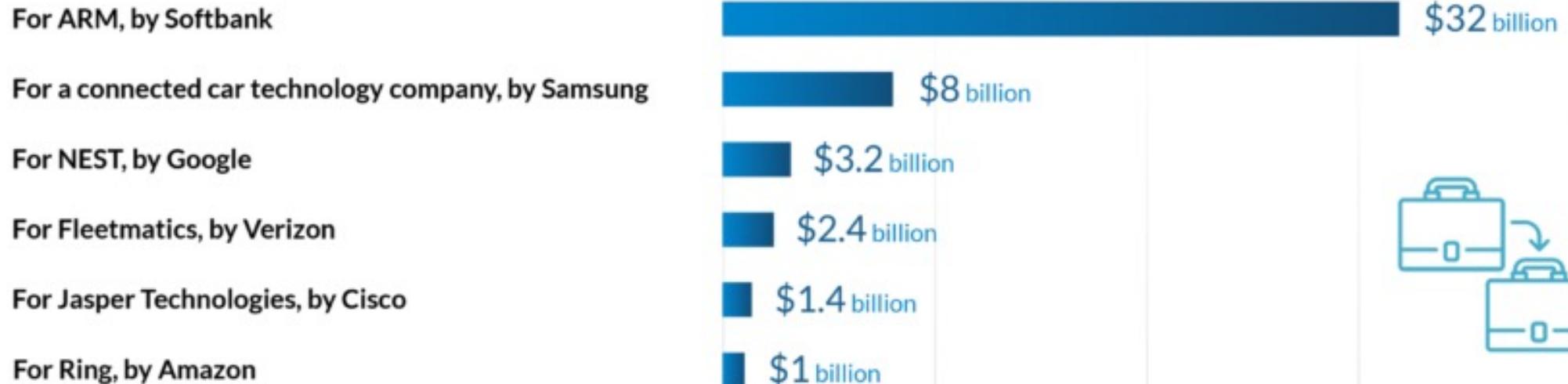
# Wireless Sensor Networks

“One of the 10 technologies that will change the world”,

MIT Technology Review, 2003

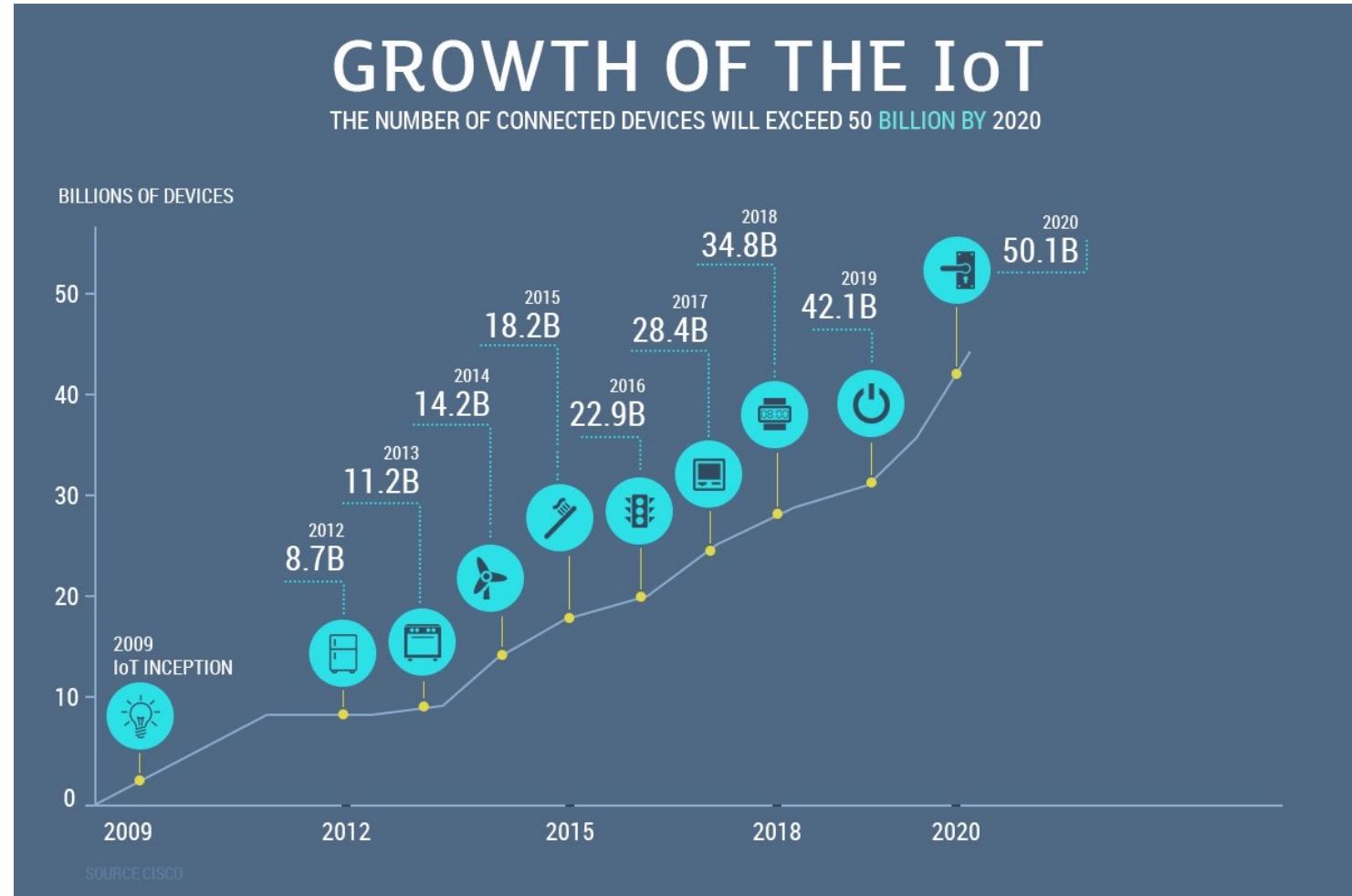
# Biggest IoT acquisitions

Sources: SDxCentral, CRN, VCCircle, IoT World Today, Adweek



## Why IoT?

# Why IoT?



# Why IoT?

Number of global active IoT Connections (installed base) in Bn

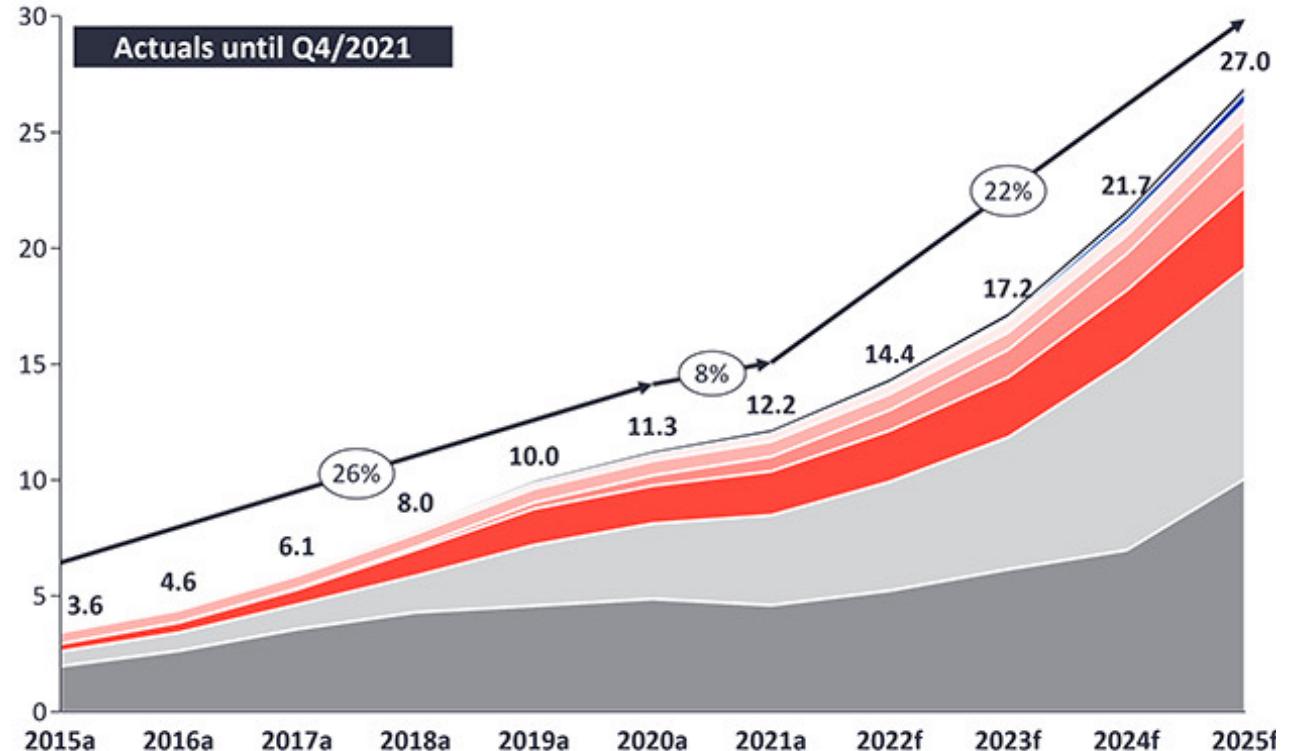
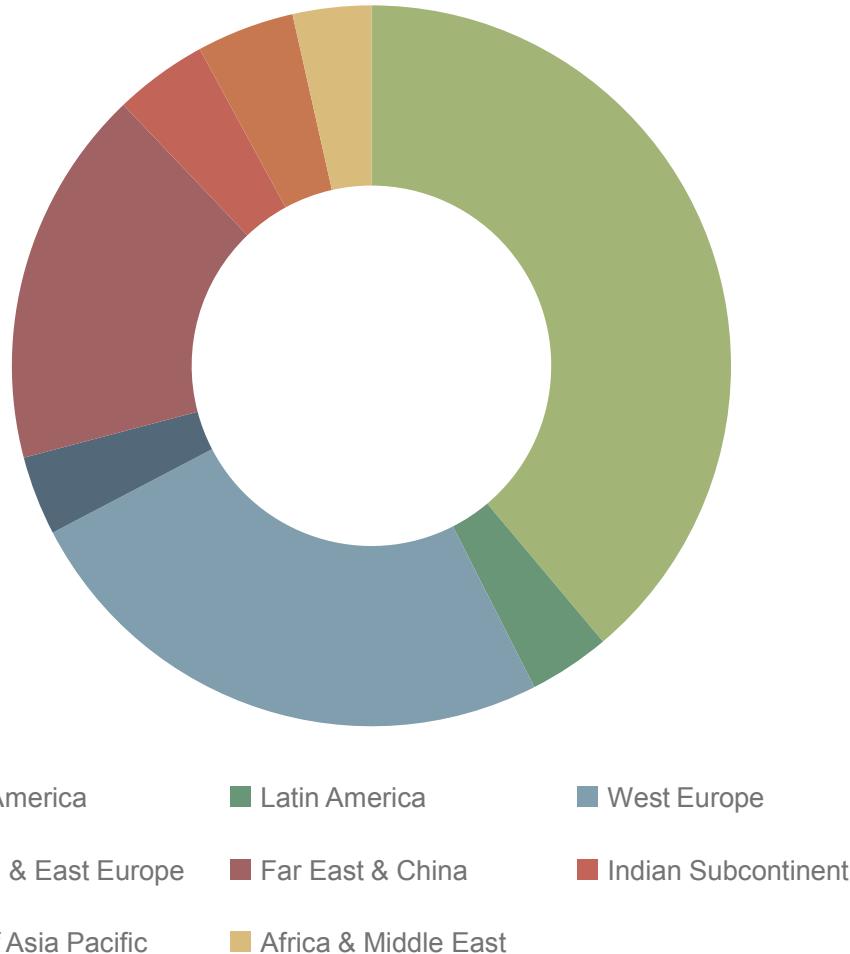
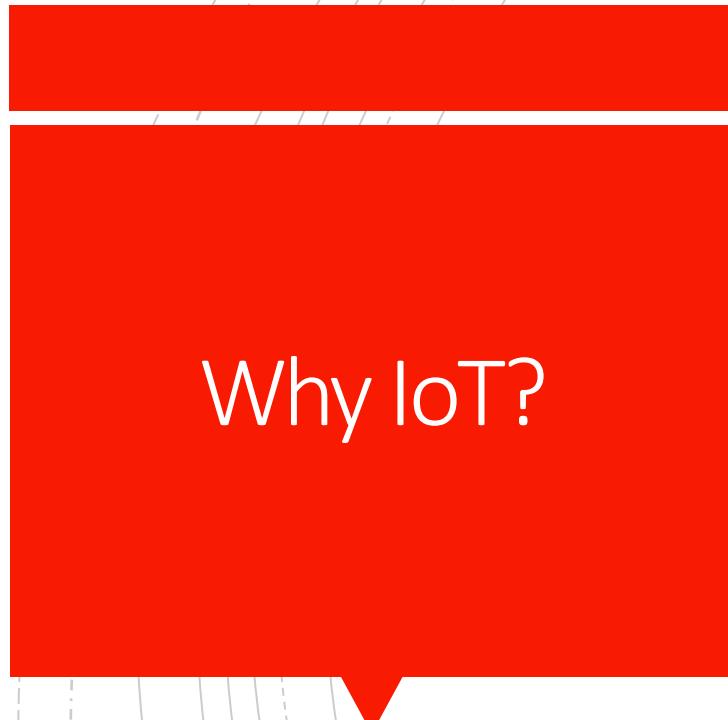
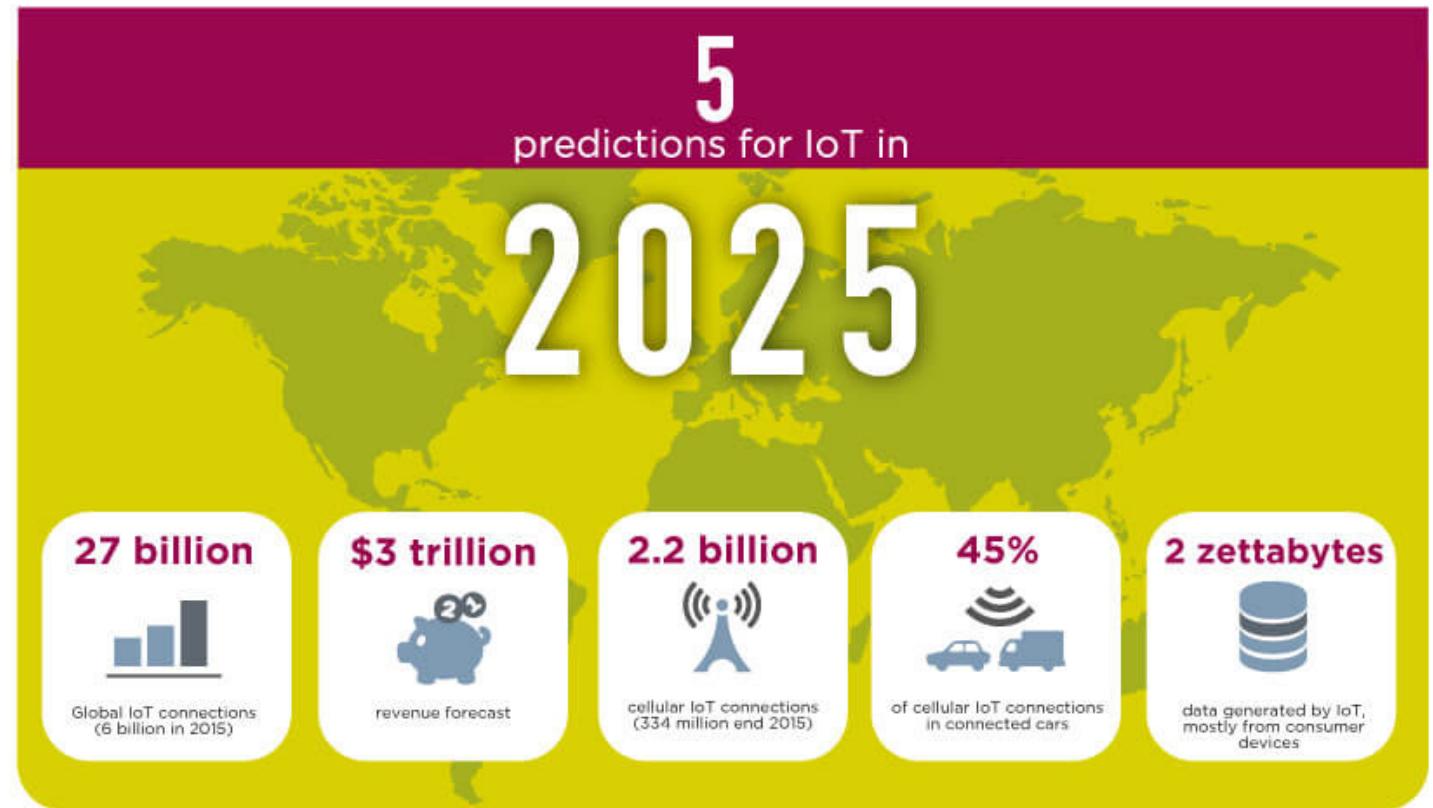


Figure 1: Global Number of Connected IoT Units (m), Split by 8 Key Regions in 2019: 35.7 billion



Source: Juniper Research

# Why IoT?

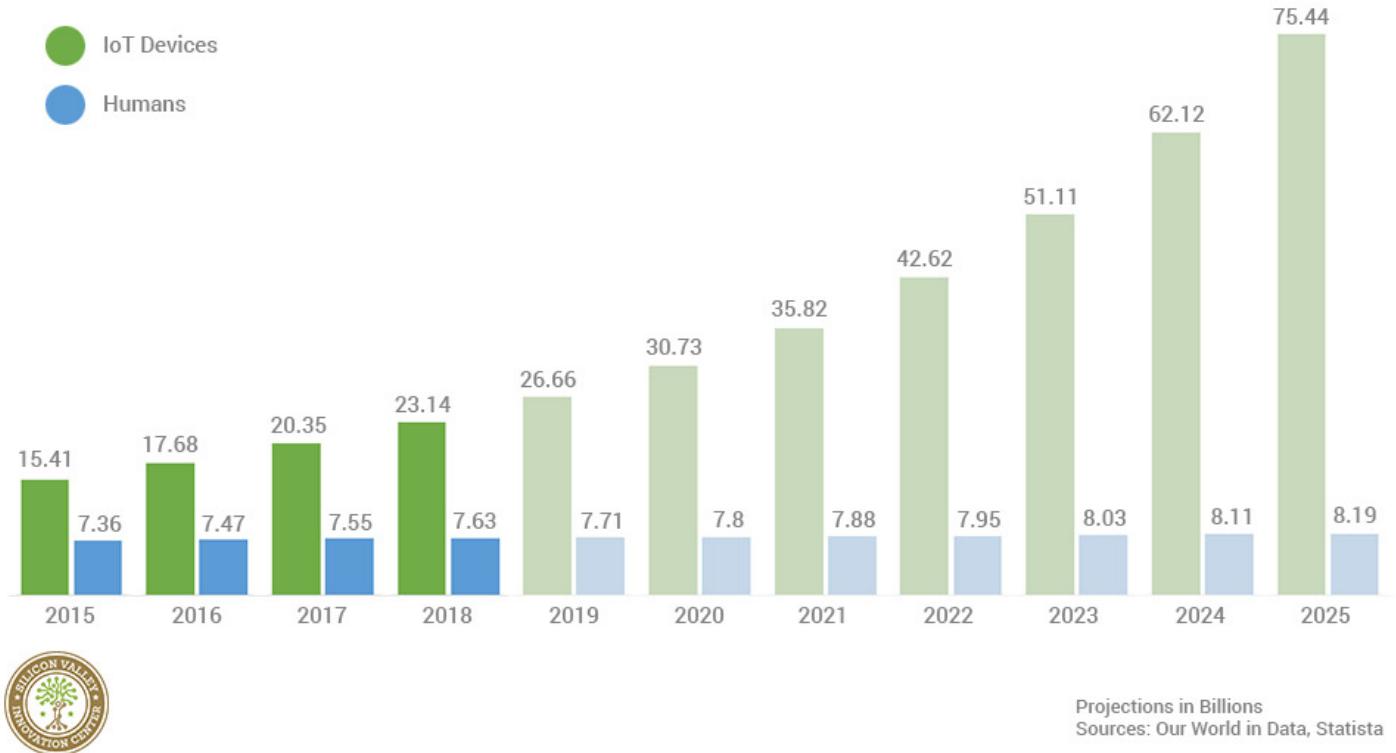


# Why IoT?

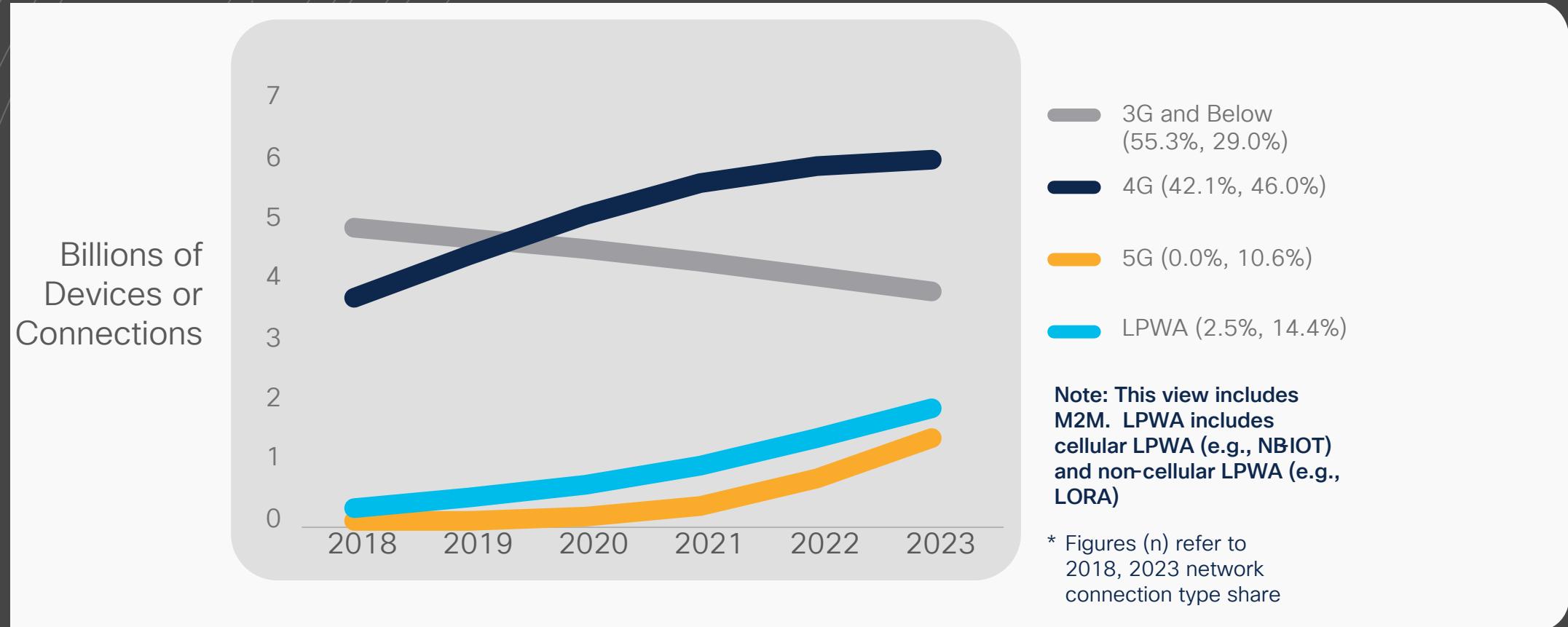
## IoT Devices Outnumber Humans on Earth

By 2025 there will be ~8 connected devices per human on earth

- IoT Devices
- Humans



Projections in Billions  
Sources: Our World in Data, Statista



Source: Cisco Annual Internet Report, 2018–2023

# 2018 This Is What Happens In An Internet Minute

Why IoT?



# 2020 This Is What Happens In An Internet Minute

Why IoT?



# 2021 This Is What Happens In An Internet Minute

Why IoT?

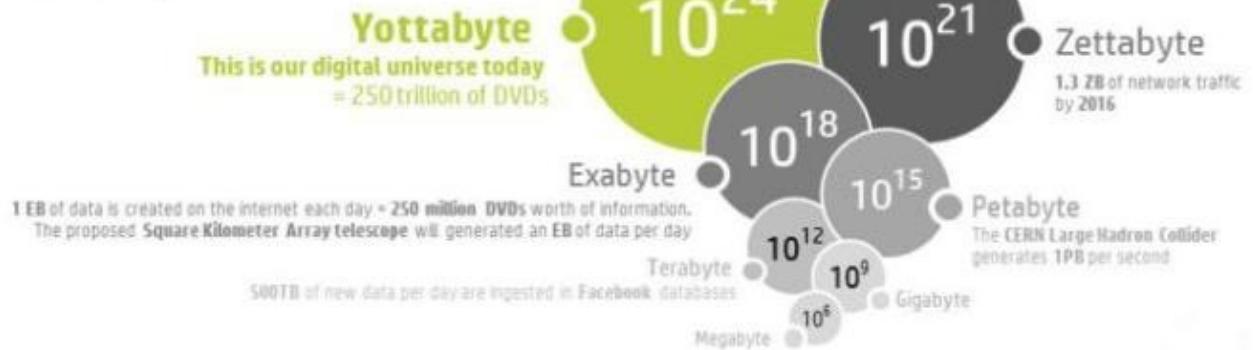


# Why IoT?

## Information from the Internet of Things: We have gone beyond the decimal system

Today data scientist uses **Yottabytes** to describe how much government data the NSA or FBI have on people altogether.

In the near future, **Brontobyte** will be the measurement to describe the type of sensor data that will be generated from the IoT (Internet of Things)



# What is IoT?



# What is your favorite IoT device (that you own)?

pi smart-water-tap  
electric google  
plug smartlights  
clock phone smart-tv  
3dprinter home raspberry  
fire-stick mini watch homepod  
tv smart outlet  
voice-assistant



Powered by  Poll Everywhere

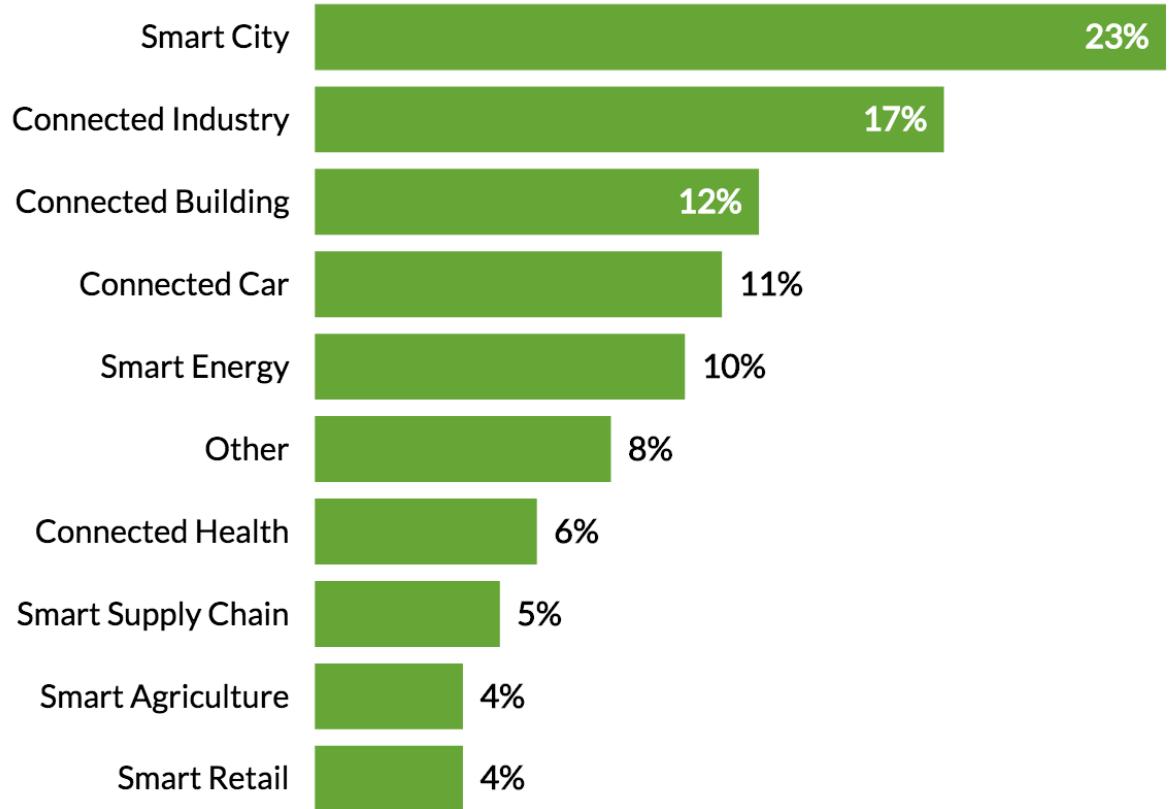
Start the presentation to see live content. For screen share software, share the entire screen. Get help at [pollev.com/app](http://pollev.com/app)



# Where is IoT?

## Large-Scale Uses of Internet of Things

Global share of IoT projects by category



Data source: IoT Analytics database of projects

**splunk>**

## TOP 5 REASONS FOR IoT ADOPTION BY INDUSTRY

19



### Manufacturing

Production flow monitoring	47%
Industrial automation	44%
Production planning and scheduling	44%
Quality and compliance	41%
Process optimization	39%



### Power & Utilities

Grid asset maintenance	46%
Smart metering	41%
Generation optimization & load balancing	41%
Smart grid automation	40%
IT security	40%



### Retail

Supply chain optimization	42%
Surveillance and security	40%
Inventory optimization	39%
Connected logistics	36%
Digital distribution center	35%



### Oil & Gas

IT security	48%
Asset and predictive maintenance	46%
Emissions monitoring and reduction	42%
Home or building energy management	38%
Remote infrastructure maintenance	37%



### Healthcare

Tracking inventory	49%
Tracking staff	45%
IT security	44%
Compliance	41%
Facilities management	40%





# What is IoT?

physical system plus internet connection



Seamless connectivity and communication



Keeping track of the data



Essential Hardware



Connection of devices to gather data and make decisions to control.



convenient and easy ways to do things



Devices That communicate with each other



Data Capture and Data based Automation



Connected-Devices



Connecting and communicating multiple devices.



Smart-devices



Devices that makes our daily life easy



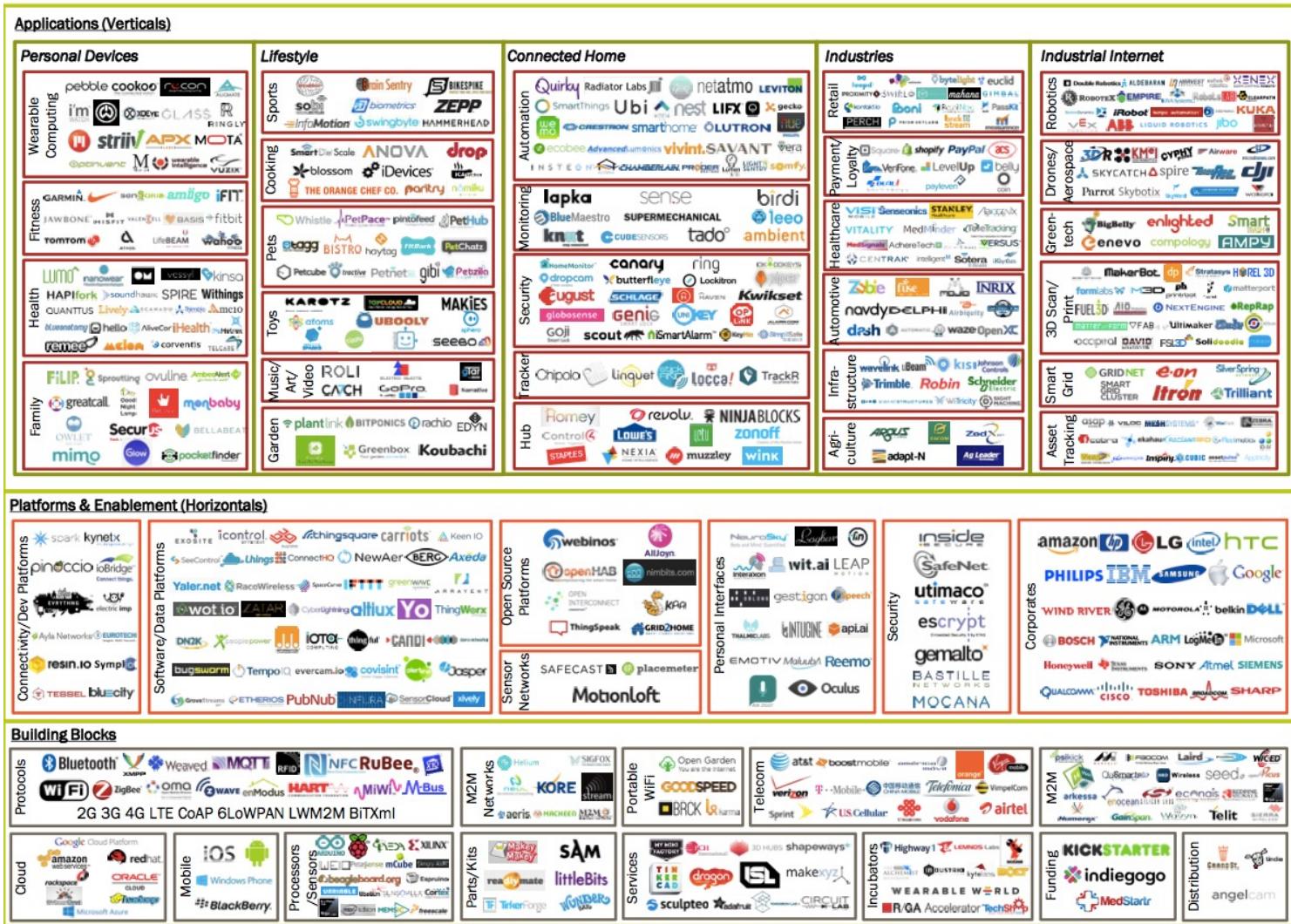
# What is IoT?

## Global IoT market structure

Key solutions	IoT infrastructure			
	Hardware	Software	Integrated solutions	Consulting
— Semiconductors — Connectivity — Measurement sensors — Power batteries	— Data analytics software — Firmware devices/sensors — Platform (connection and control sensors without hardware)	— Monitoring and controlling — Positioning and tracking — Production optimization — Risk management — Security	— Consulting services	

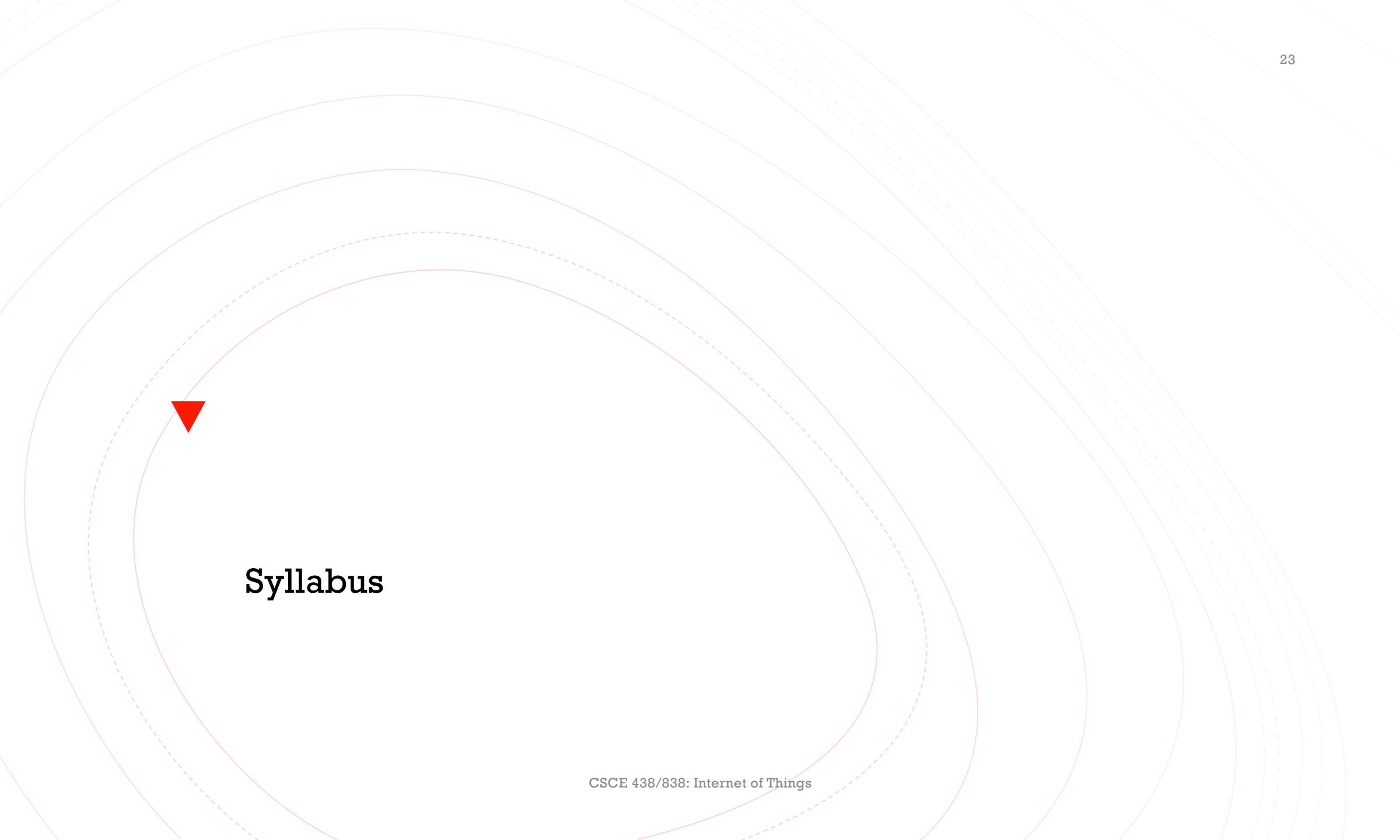
Source: Frost & Sullivan – Worldwide IoT market forecast 2009-2019, 2014

# Who is IoT?



© Matt Turck (@mattturck), David Rogg (@davidjrogg) & FirstMark Capital (@firstmarkcap) FIRSTMARK





# Syllabus

CSCE 438/838: Internet of Things

# Course Structure



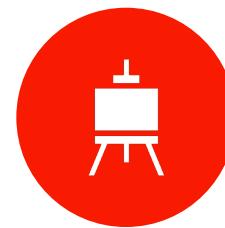
LECTURES:  
M-W 9:30-10:20AM,  
AVH 119



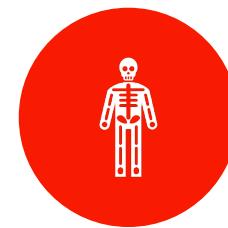
LABS:  
F: 8:30-10:20AM,  
AVH 119



PROJECT:  
F: 8:30-10:20AM, AVH 119;  
SCHORR 114/117



WEBSITE: CANVAS



CODE: GITLAB

# CONTENTS

- Intro to IoT
- Build things – devices and sensors
- Connect things – connectivity
- Get data from things – cloud
- Analyze data from things – analytics and machine learning
- Advanced Things (as time permits)
  - Localization
  - Synchronization
  - Connected vehicles
  - Security
  - Business issues and models
  - Smart city
  - Smart grid
  - Policy issues



# Office Hours

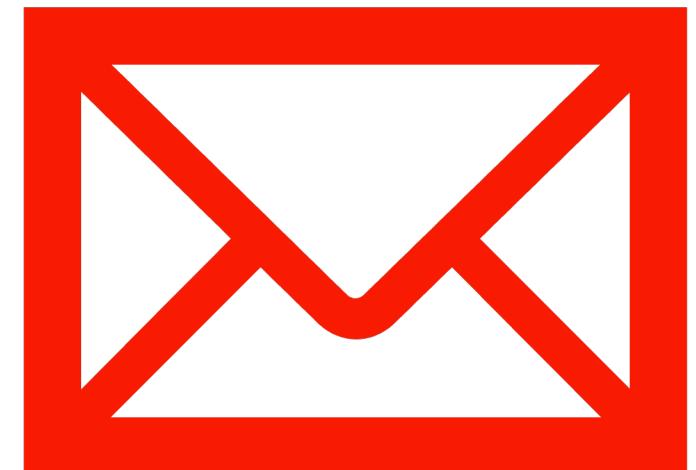
By appointment

You are encouraged to use e-mail

[mcv@unl.edu](mailto:mcv@unl.edu)

PLEASE USE [CSCE838]

in the subject line of your e-mails!



# Office Hours

**PLEASE USE  
[CSCE838]**

**in the subject  
line of your  
e-mails!**

# Office Hours

**PLEASE USE  
[CSCE838]**

**in the subject  
line of your  
e-mails!**

# Course TA

- Mohsen Bagheri
- Will be helping with the lab and project
- Email: [mbagheri2@huskers.unl.edu](mailto:mbagheri2@huskers.unl.edu)
- Office Hours: Th 8:30am – 10:20am AVH 104D

# Course Organization

- TWO exams (tentative: Oct. 11 & Nov. 20)
- LAB Assignments (first half of semester)
- ONE TEAM PROJECT assignment
- Dates announced at least a week in advance



# Grade Distribution

Lab Assignments: 30%

Exam 1: 15%

Exam 2: 15%

Project: 35%

In-class Participation:  
5%

# Lecture Notes

- Lecture notes will be available on Canvas.  
Please make sure that your email address in  
Canvas is active.
- SoC Policy: All students in SoC courses are  
expected to regularly check their email so they  
do not miss important announcements.
  
- **ASSIGNMENTS and EXAMS** will be based on  
lecture notes.

## Recommended Course Text

- Slides are developed based on material in these textbooks, so it might be helpful to get your hands on some of them:
- **The Amazon Way on IoT by John Rossman**  
(ISBN: 978-0692739006)
- **Enchanted Objects by David Rose**  
(ISBN: 978-1476725635)
- **Wireless Sensor Networks  
by Ian F. Akyildiz and Mehmet C. Vuran**  
(ISBN: 978-0470036013)
- **Enterprise Internet of Things Handbook  
by Arvind Ravulavaru**  
(ISBN: 978-1788838399)
- **Better Embedded System Software by Philip Koopman**  
(ISBN: 978-0984449002)





# Course Organization

- Slides uploaded on Canvas before class
- Internet of Things with a holistic approach
  - Problem-based discussions of IoT for a bottom up development
- Will require some flexibility in solving problems
  - Switching hardware platforms easily
  - Different development environments
  - Combining different sources
- You will solve these problems in lab assignments



# Lab Assignments

- Helloworld, basics of things, watchdog
- Clock, timers, interrupts
- Sensing, data acquisition, reset, run-time error logs
- Connectivity, LoRa
- Cloud connectivity, data reporting/request
- IoT data analytics and storage
- IoT data machine learning and decision making
  
- Lecture philosophy: Agile, JITT



# Lab Assignments

- Pre-lab
- Lab



# Course Project



# 2015 - 2022 Projects

- <https://www.youtube.com/watch?v=U406q72qHZk&feature=youtu.be>
- <https://youtu.be/7PbEqz497nU?t=14s>
- <https://www.youtube.com/watch?v=bwszdX2NuHg>



# 2015 - 2022 Projects



# Course Project

- **35% of your final grade**
- You will create a project team consisting of 3-4 students
- You will have access to
  - Schorr 114/117
  - Equipment
  - Previous project codes
- Further information TBA



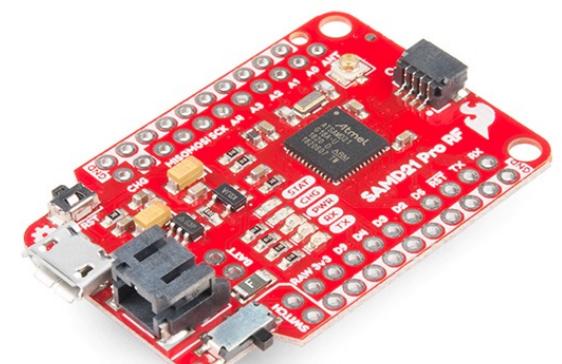
# CPN LAB (Schorr 117)

- Sparkfun Pro-RF → 30
- Sparkfun 1-channel gateway → 7
- 8 – Channel LoRaWAN gateway → 1
- Capacitive Soil Moisture Sensors → 5
- Raspberry PI → 1
- Small water pumps → 5
- Temp & Humidity Sensor → 2



# Sparkfun Pro RF - LoRa

- <https://www.sparkfun.com/products/14916>
- **Microcontroller: SAMD21G18A**
  - Cortex M0+
  - 256KB Flash Memory
  - 32MHz External Oscillator
  - 4 Digital and 5 Analog IO Pins with exclusive GND pins
- **Radio Module: Hope RFM95W LoRa modem**
  - Point to Point Radio capabilities
  - LoRa Enabled
  - Frequency range: 915 MHz
  - Range up to 1 mile line of sight
  - U.FL Antenna
- Arduino-based hardware/software



CSCE 438/838: Internet of Things

# Project Organization

- Each team will continuously develop and deliver a Development Plan documentation (a.k.a. Final report\*)
- Each team will present a DEMO at the end of the semester
- Development Plan + DEMO = FINAL



# Project Milestones

 Project team formation, initial paper, and gate review (5%)

 Checkpoint one (10%)

 Checkpoint two and Midterm report (10%)

 Pre-demo (5%)

 Final Demo (25%)

 Final Report (25%)

 Peer evaluations (20%)

# Project Organization

- Code development
- Open source
- Sharing is caring
- Everything will be on gitlab



# Project

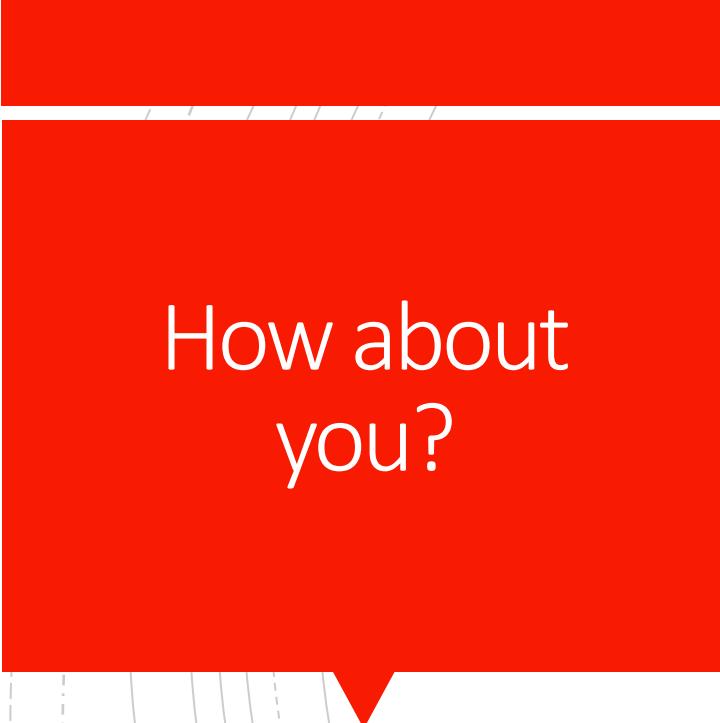


**BE BOLD**



**BE NOVEL**





How about  
you?

- Name
- Major (thesis topic)
- Why IoT?
- What do you want to get out of this class?
- Career Goal

