ECE 590/COMPSI 590
Special Topics: Edge Computing

IoT Meets the Cloud:
The Origins of Edge Computing

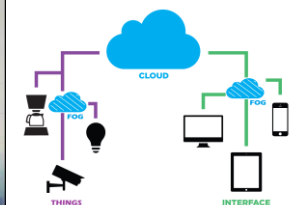### Wednesday August 29th, 2018

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Last Class: Introduction to Edge

- Edge computing
  - Advantages: **latency**, **bandwidth**, **privacy**
  - Different devices
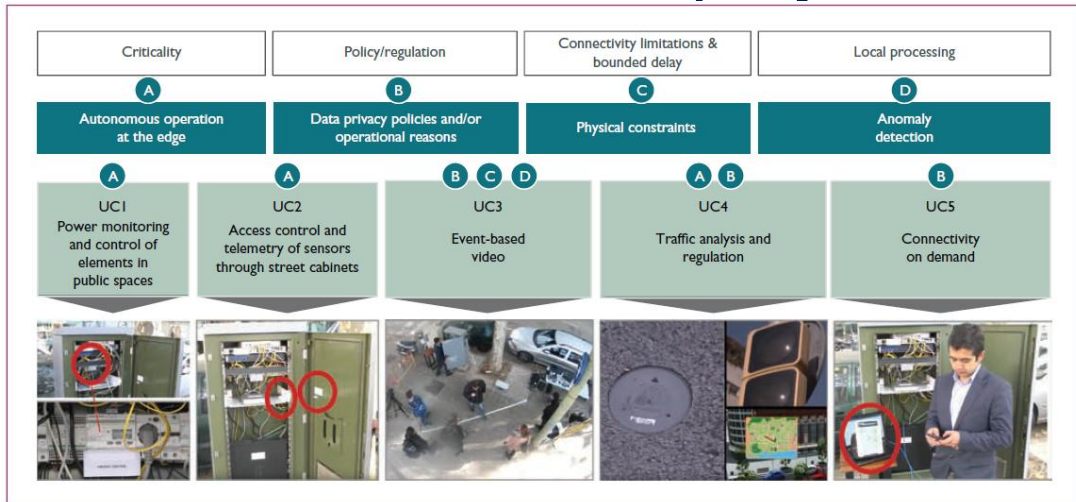 - Different degree of application centralization

  ANDREESSEN HOROWITZ

- Research themes

2

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Barcelona PoC Deployment

Criticality	Policy/regulation	Connectivity limitations & bounded delay	Local processing
(A)	**(B)**	**(C)**	**(D)**
Autonomous operation at the edge	Data privacy policies and/or operational reasons	Physical constraints	Anomaly detection
(A)	**(A)**	**(B) (C) (D)**	**(A) (B)**	**(B)**
UC1 Power monitoring and control of elements in public spaces	UC2 Access control and telemetry of sensors through street cabinets	UC3 Event-based video	UC4 Traffic analysis and regulation	UC5 Connectivity on demand

A New Era for Cities with Fog Computing, Yannuzzii et al

3

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Edge Computing at Chick-fil-A (1/2)

July 2018

4

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Edge Computing at Chick-fil-A (2/2)

Azure

AWS

Google
Cloud

Cloud-fil-A

5

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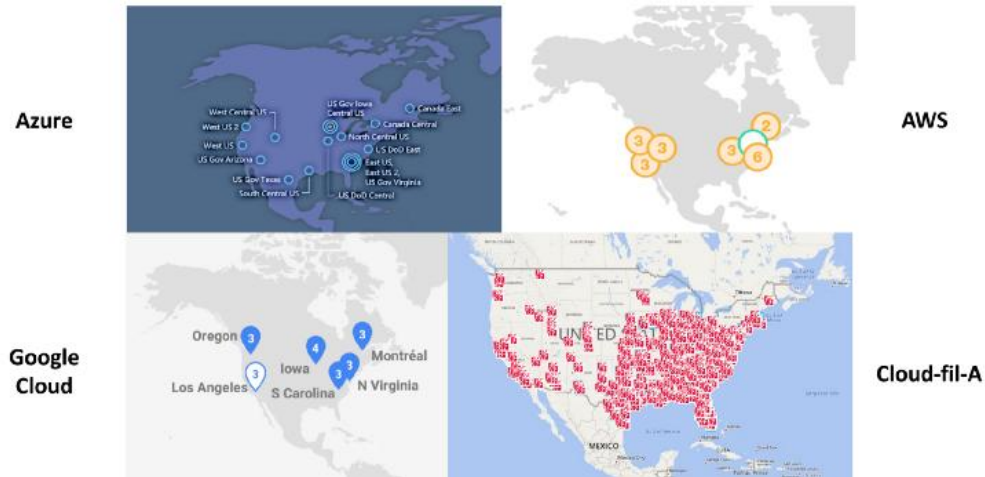
Updates and the Quiz

- Posted several more papers for paper presentations
- **Quiz**

6

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This Class

- Research projects and project proposals
- Path towards the edge: Cloud computing
- Path towards the edge: Internet of Things
- Modern multi-tier architectures

7

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Does Anyone Have a Project Idea They Want to Run by the Group?

8

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Research Project Timelines:
A Reminder

- Teams established: Friday **September 17th**
- Proposal due: Monday **October 1st**
- Progress report due: **Friday October 26th**
- Final presentations: **weeks of November 18th and 25th**
- Final report due: **Friday December 14th**

9

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Bonus Points:
Connect Research Project to Duke

- 2 to 5 extra points

10

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Research Project Proposal:
An Overview (1/2)

- Describe your core idea
- Demonstrate that it is new
- Explain how you will validate it

11

Research Project Proposal:
An Overview (2/2)

- Short
  - ➢ .. But, in many cases, **the most difficult part of the work**

- Integral part of research
  - ➢ Important skill to develop
  - ➢ Required for fellowship applications, …
  - ➢ I wrote 5+ over this summer, and will have written another 5+ by the time this class ends in December

12

Research Project Proposal: The Four Whys

- Why this?
- Why now?
- Why me?
- Why you?

13

Research Project Proposal: Structure

- Written proposal: 2-3 pages
  - ➤ Latex suggested but not required
- Components:
  - ➤ The core idea
  - ➤ Related work ("state of the art")
  - ➤ How you will test your idea
  - ➤ Project plan
  - ➤ (Optional) How it helps Duke community

14

Research Project Proposal Components (1/3)

- The core of your idea
  - ➢ What are you proposing to do?
  - ➢ Please include **1-2 diagrams** to illustrate your idea
- Related work ("state of the art"), with an explanation of how your proposed work is different
  - ➢ 10+ citations
  - ➢ Related work in academia
  - ➢ Related work in industry

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Research Project Proposal: Components (2/3)

- Describe how you will test your idea. Be as specific as possible.
  - ➢ Tools
  - ➢ Scenarios
  - ➢ Other solutions you will compare yours to

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Research Project Proposal: Components (3/3)

- Project plan
  - Timeline: Describe what you will do each week between October 1st and December 15th
  - Risks: Describe the risks: what are the ways your project can fail? What will you do if the risks materialize?
- (Optional) How your project helps Duke community
  - Be specific

17

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Research Project Proposal: Reviews

- Schedule a review meeting with me over the week of September 24th and September 30th
- Present your proposal in class on October 3rd
  - 5-10 minutes, depending on the number of teams we will have
  - An informal presentation; use whatever means are necessary to convey your idea
  - Comment on the proposals of others
- I will give you additional suggestions, if any, by October 8th

18

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Next Step: Progress Report: Due Friday October 26th

- Describe progress against the plan outlined in your proposal

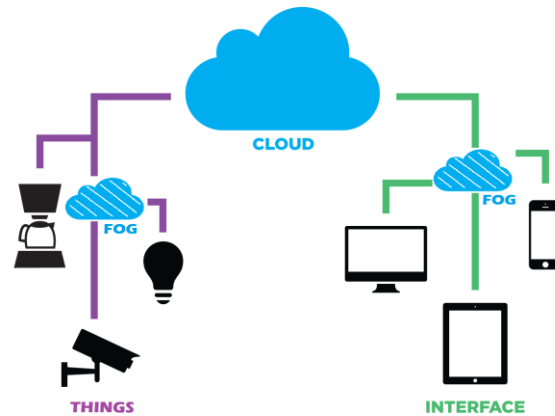- Also an integral part of research

19

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This Class

- Research projects and project proposals
- Path towards the edge: Cloud computing
- Path towards the edge: Internet of Things
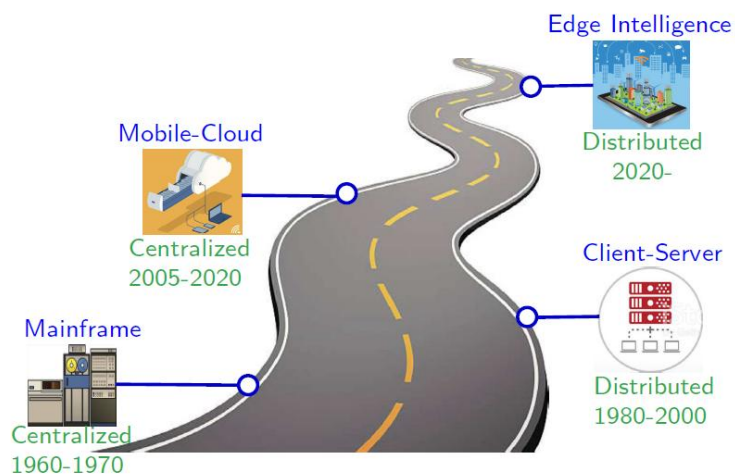- Modern multi-tier architectures

20

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Edge: IoT Meets the Cloud

21

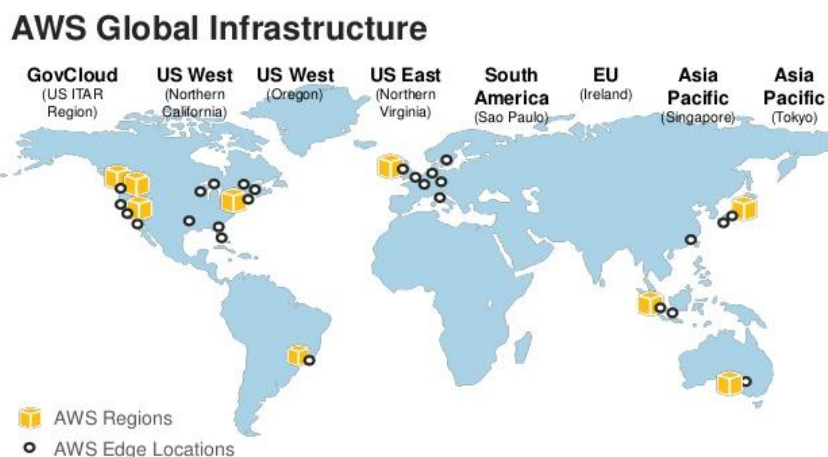Duke UNIVERSITY

The Pendulum

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The Cloud: Applications and Providers

- Amazon Web Services, Microsoft Azure, Google Cloud, IBM Cloud

- Virtual machines, of different grades
- An endless, always updating list of specialized services

23

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Cloud Centralization: AWS Example

AWS Global Infrastructure

| GovCloud (US ITAR Region) | US West (Northern California) | US West (Oregon) | US East (Northern Virginia) | South America (Sao Paulo) | EU (Ireland) | Asia Pacific (Singapore) | Asia Pacific (Tokyo) |

AWS Regions
AWS Edge Locations

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Cloud Centralization: Microsoft Azure Example

25

The Cloud: Massive Operation (1/2)

26

The Cloud: Massive Operation (2/2)

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The Cloud: Shared Substrate

DADDY, WHAT ARE CLOUDS MADE OF?

LINUX SERVERS, MOSTLY
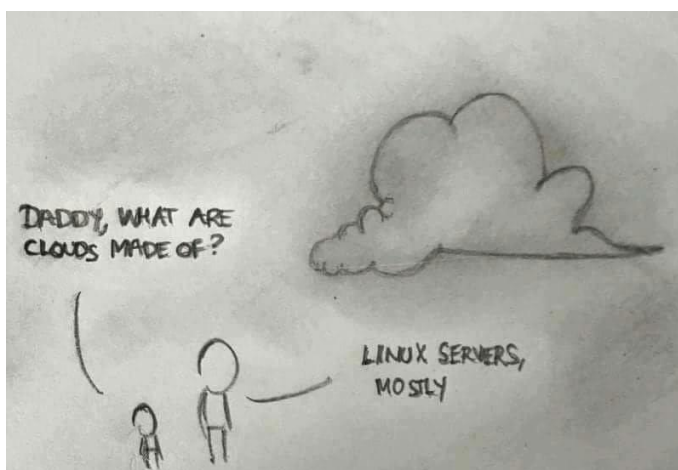
- Shared servers
- Shared cores
- Shared network

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Cloud: Some of the Properties

- Geographically centralized
- Massive, scalable
- Managed, physically secure
- Shared
- Cloud outages are uncommon
- … but task latency variations are the norm
- …

29

Side Note: Cloud as an Enabler of Vibrant Web Ecosystem

- Spurred innovation

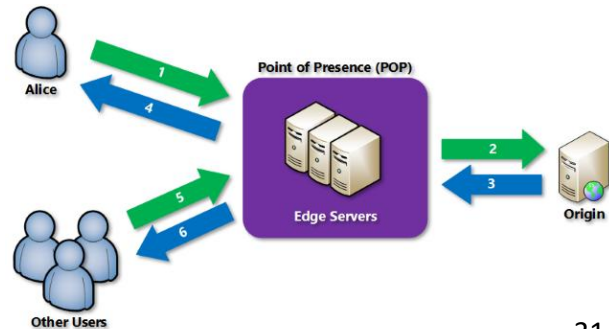- Perhaps, edge doing the same for the IoT?

30

Edge Precursors: CDNs (1/3)

- Content Delivery Networks
  - ➤ Akamai, AWS CloudFront, Fastly
- Original "edge nodes"

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Edge Precursors: CDNs (2/3)

- **Content** Delivery Networks - static content replication

- Fewer points than in edge computing settings
  - ➤ E.g., Akamai: ~200,000, AWS CloudFront: 100 POPs

32

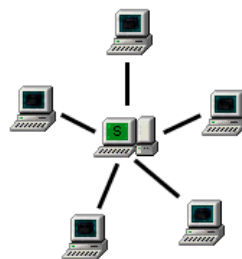Duke UNIVERSITY

Edge Precursors: CDNs (3/3)

- Interesting new development (2017): using CDNs to customize web server responses via Lambda@Edge

- Possible research project: extending CDN mechanisms to edge computing
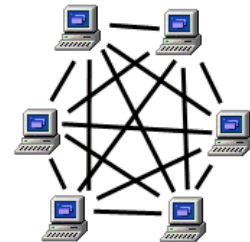
33

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Edge Precursors: Peer-to-Peer

- P2P: Napster, Kazaa, Bitcoin

- File sharing
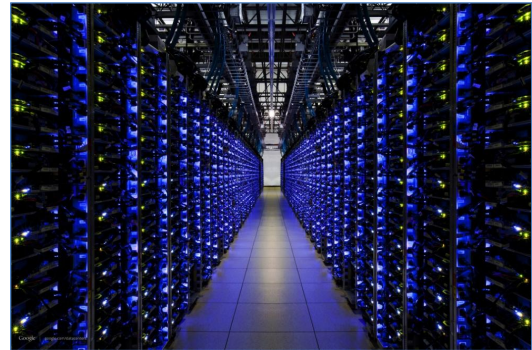- Focused on decentralization mechanisms above all

Server Based Network   Peer to Peer Network

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Related Area, for Some Edge Research: Distributed Workloads on the Cloud

- … and in multi-core systems

- Homogenous substrates
- Non-responsive operations

- Research projects on edge analytics need to be specific about the differences in their settings and traditional ones
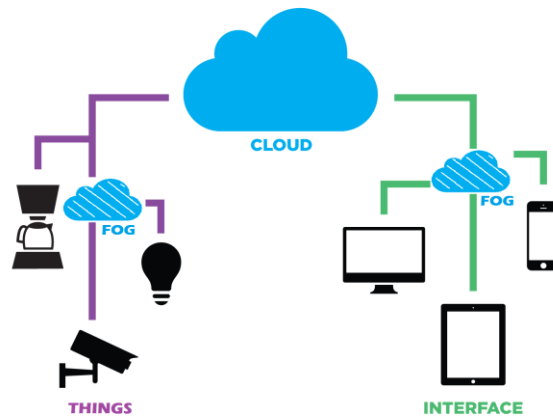
35

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Intellectual Heritage: Distributed Clouds

AWS Global Infrastructure

| GovCloud (US ITAR Region) | US West (Northern California) | US West (Oregon) | US East (Northern Virginia) | South America (Sao Paulo) | EU (Ireland) | Asia Pacific (Singapore) | Asia Pacific (Tokyo) |

AWS Regions
AWS Edge Locations

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Edge: IoT Meets the Cloud
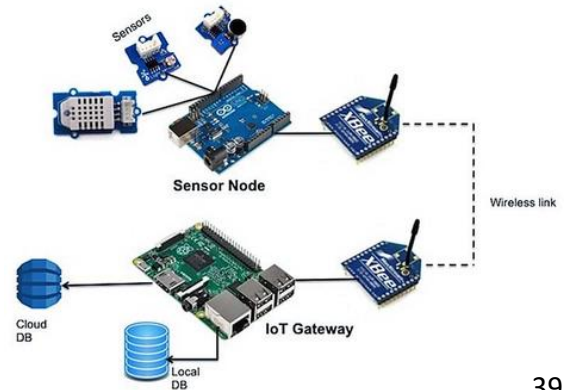

37

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This Class

- Research projects and project proposals
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- **Path towards the edge: Internet of Things**
- **Modern multi-tier architectures**

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History: IoT

- Devices → smart devices → connected devices
  - ➢ Thanks, Moore's Law!

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For Example, Towards IoT: Evolution of a Smart Watch

- CES 2016

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Side Note: By Now, Modern Cars Are All Electronics

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Side Note: Progress in the IoT is Limited by Energy Storage

• No Moore's Law for batteries

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IoT Properties (1/3)

- Tightly constrained design space
  - ➢ Often specialized for the application
  - ➢ Proliferation of protocols and vendor-specific solutions
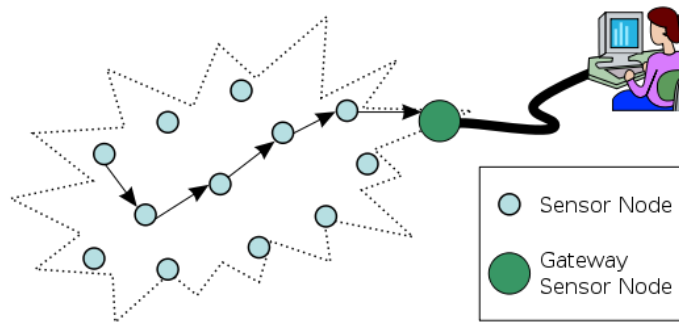
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IoT Properties (2/3)

- Low computing capacity
  - ➢ E.g., laptop: 2.4 GHz, Raspberry Pi: 1.2 GHz, Arduino Due: 0.084 GHz, Amazon Dash Button: 0.016 GHz
- Minimized/reduced energy consumption
- Difficult to secure
- …

44

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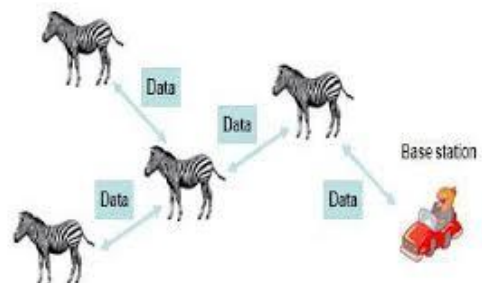
Edge Precursors:
Mobile Ad Hoc and Sensor Networks

- Sensor Node
- Gateway Sensor Node

- Focused on sensing

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Sensor Network Example: ZebraNet

- Early 2000s

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Sensor Network Example: RoombaNet

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Sensor Networks:
Focused on Multi-hop Connectivity

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Industry Approach:
3-Tier Architectures Instead of Multihopping

- Sensors → gateway → cloud

49

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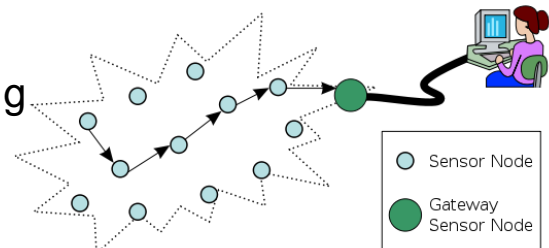

Edge and Sensor Networks:
Differences

- No consideration of the cloud
- No multi-point decision-making

- Research projects on resource discovery and peer assistance in edge need to be explicit about the differences in their settings and traditional ones

50

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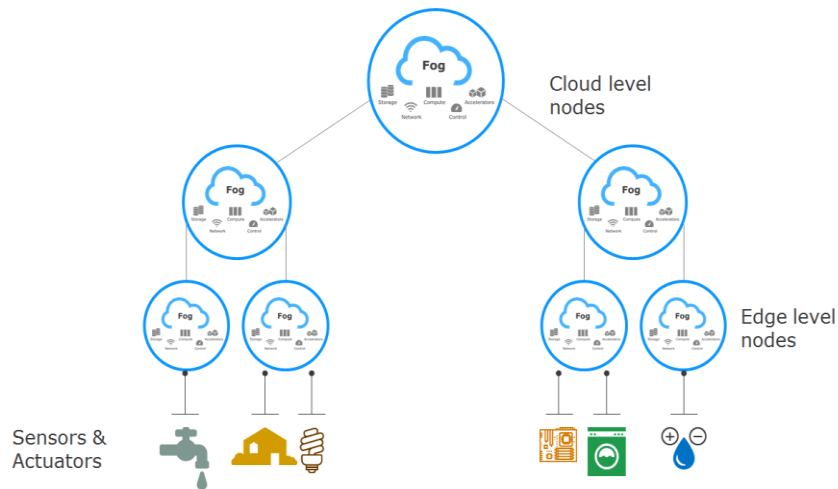- Modern and envisioned multi-tier architectures

51

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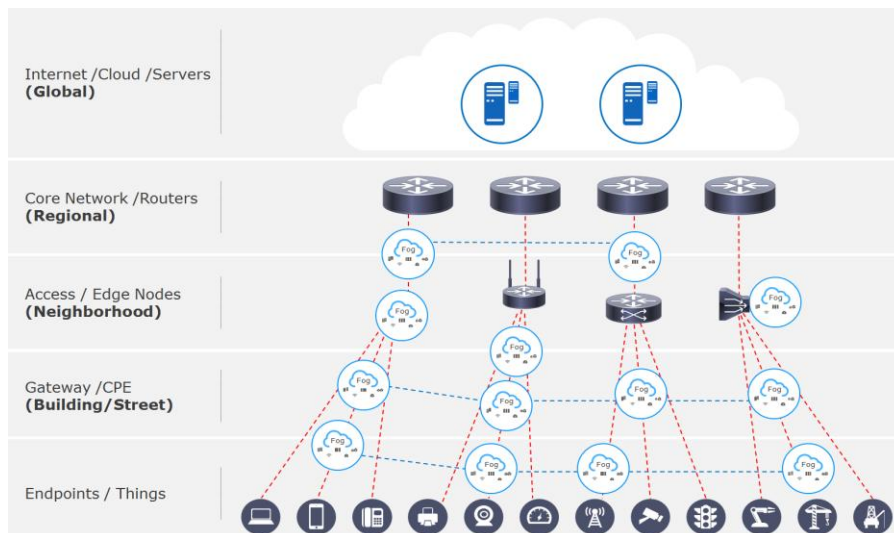# Barcelona PoC Deployment

A New Era for Cities with Fog Computing, Yannuzzii et al

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8/29/2018

Multi-tier Architectures

Cloud level nodes

Edge level nodes

Sensors & Actuators

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Internet /Cloud /Servers **(Global)**

Core Network /Routers **(Regional)**

Access / Edge Nodes **(Neighborhood)**

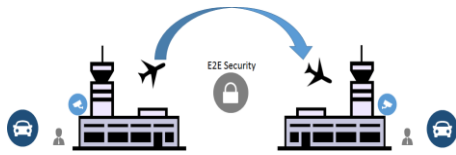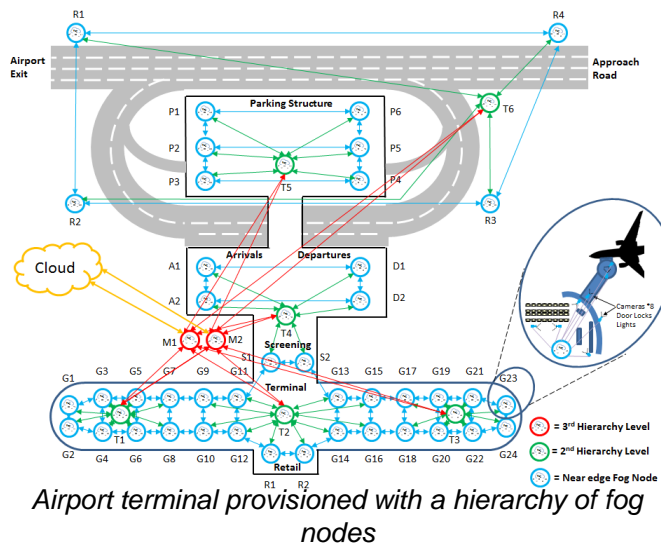Gateway /CPE **(Building/Street)**

Endpoints / Things

Smart city fog deployment: buildings, neighborhoods, regions connected with each other

54

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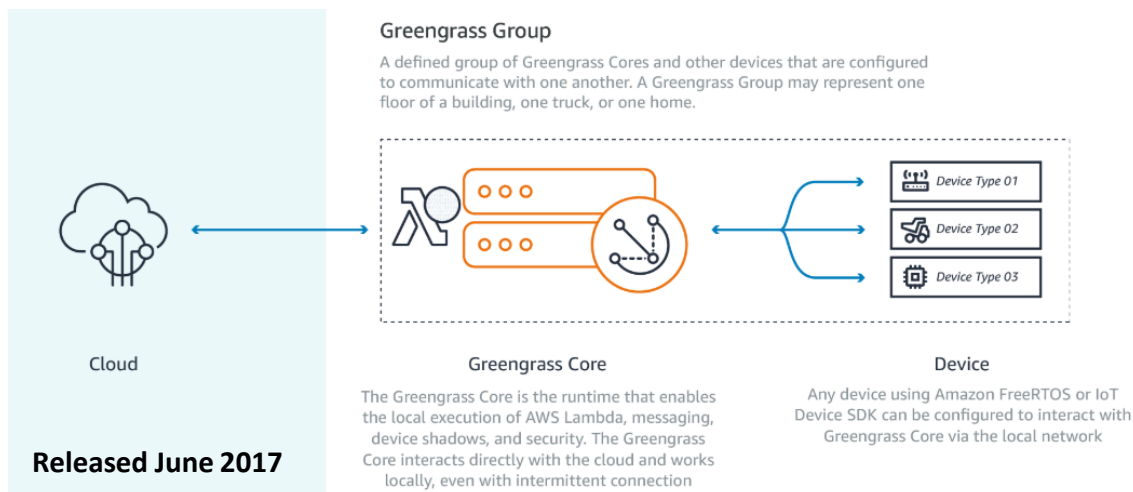
27

Example Use Case: Securing Air Travel

- Multiple locations need to work together
- Cameras important part of the system
  - ➤ 1 Tb/day/camera
- Immediate action needed
- Applications deployed: risk scoring, vehicle capture, baggage capture

Airport terminal provisioned with a hierarchy of fog nodes

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Current Platforms: AWS Greengrass

Greengrass Group
A defined group of Greengrass Cores and other devices that are configured to communicate with one another. A Greengrass Group may represent one floor of a building, one truck, or one home.

Cloud

Released June 2017

Greengrass Core
The Greengrass Core is the runtime that enables the local execution of AWS Lambda, messaging, device shadows, and security. The Greengrass Core interacts directly with the cloud and works locally, even with intermittent connection

Device
Any device using Amazon FreeRTOS or IoT Device SDK can be configured to interact with Greengrass Core via the local network

56

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Edge Properties

- Decision-making, actuation
- Data manipulations and transformations
- Heterogeneity
- Hierarchy
  - ➢Cloud is involved in the system
- …

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Class Recap

- Project proposals
- Origins of the edge, on the cloud side:
  - ➢CDNs, P2P systems
- Origins of the edge, on the IoT side
  - ➢Sensor networks
- Properties of edge systems

58

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Next Class and Homework (1/2)

- Topic: *Edge Helping the IoT*
- Readings for the class:
  - ➢ Introduction to AWS Greengrass
  - ➢ Description of a cloud outage that affected IoT devices
  - ➢ "Internet of Things has a Gateway Problem"
  - ➢ You and Your Research

59

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Next Class and Homework (2/2)

- Pick a presentation date if you have not already

- Start going over references and thinking about ideas for your research project
  - ➢ My office hours: 9-11 AM Mondays

60

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