

### Fog Computing: Challenges and Solutions

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### My Background (1/2)

#### Participating in GHC since 2012



Baltimore'12

Phoenix'14

Houston'15, 16

#### Helping organize GHC since 2015

• Co-chair, Internet of Things and Wearable Tech Track — 2 panels, 2 hands-on workshops, 12 presentations





### My Background (2/2)

Associate Research Scholar

PhD: Columbia University



**Industry experience** 









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### **Fog: Descended Cloud**



2000 - 2015

2016 – 2030?

An architecture that uses one or a collaborative multitude of end-user clients or near-user edge devices to carry out a substantial amount of computation, storage, communication, and control





## **Cloud Computing: Computing in Datacenters**



### Cloud

- AWS: 44 locations, Azure: 30 locations
- For emerging applications: latency, bandwidth limitations





# **Fog: Computing Closer to the Users**

#### Fog

 Distribute computation, storage, communication and control services immersively closer to end-users along the Cloud-to-Things (C2T) continuum



Smart city fog deployment: computing in buildings, neighborhoods, regions



multiple points in

the hierarchy

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### **Enabling Futuristic Applications**

#### Helps computing-heavy emerging applications

- Local computing
- Local content processing
- Local storage



Autonomous cars



Drones

Augmented and virtual reality



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### **Actively Developing Field**

#### **Descending intelligence from the cloud**





Microsoft'17

#### Adding intelligence to local nodes



Dell'17



AT&T'17

#### **Ensuring interoperability**









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### **OpenFog Consortium: Accelerating Fog**





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- Reference architecture, whitepaper on autonomous driving
- 2016-2017 Co-chair, Communications Working Group



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# OpenFog Reference Architecture: Core Pillars



- Requirements to every part of the supply chain
- Available at: www.openfogconsortium.org/ra/



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### **Differentiating Principle: Hierarchy**









- Senior collaborators: Hazer Inaltekin, Liang Zheng, Mung Chiang (lab lead)
- Student collaborators: Surin Ahn, Litian Liu, Edward Chang, Chege Gitau















### Allocating functionality in fog: who does what, and how to put it all back together?



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### Characterizing Fog (1/2)

#### Local execution



#### Server-, consumer- grade





AWS EC2, λ



Tokyo, JP

#### On, off campus

### **Stressing different elements**

- Compute, networking, storage
- Measure: communications, computing
- 100+ hours of measurements



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# Characterizing Fog (2/2)

#### Understand properties of execution points and options

- Informs task placement algorithms and approaches
- Statistical characterizations



• Other observations: e.g., different behavior on and off campus

#### Code, data will be publicly available GitHub





#GHC17

### **Restructuring Computing for Fog**



#### **Different levels of hierarchy working together**

- Responsive applications: multi-level operation
- Data processing: decomposed analytics
- Non-traditional control, optimization, machine learning techniques





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# **Testing Fog-Specific Decompositions**





- Linear regression decomposition: 70% reduction in data transmission
- Demos: NYC Media Lab
  Summit'17, IEEE FWC'17, ACM
  SenSys'17

Video: princetonedge **>** YouTube channel



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### **Summary and Future Work**

### Fog computing: enabler of futuristic applications

### **Emerging architecture with unique characteristics**

- Hierarchical
- Heterogeneous
- Agile







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# Thank you

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