Making the Internet-of Things (IoT) Efficient with Edge Clouds

Chandra Krintz
Professor
Dept. of Computer Science
UC Santa Barbara
ckrintz@cs.ucsb.edu

Joint Work with Prof. Rich Wolski

IEE Research Review
May 31st 2017
<table>
<thead>
<tr>
<th>Google+Facebook+Amazon+Netflix+Kayak+Uber+...</th>
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</thead>
<tbody>
<tr>
<td><strong>Likes Jimmy Fallon</strong></td>
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<tr>
<td><strong>Reads crime dramas</strong></td>
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<tr>
<td><strong>Household Income: 150000</strong></td>
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<tr>
<td><strong>Age 38-40</strong></td>
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<tr>
<td><strong>Likes Movie Usual Suspects</strong></td>
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<tr>
<td><strong>Drives a Ram truck</strong></td>
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<tr>
<td><strong>Has 2 cats and a dog</strong></td>
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<td><strong>Sister is a lawyer</strong></td>
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<tr>
<td><strong>Children play hockey</strong></td>
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<tr>
<td><strong>Favorite color: Blue</strong></td>
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<td><strong>Dislikes snakes</strong></td>
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<tr>
<td><strong>Dislikes war movies</strong></td>
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<tr>
<td><strong>Likes basketball</strong></td>
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<td><strong>Dislikes Actor Robert Redford</strong></td>
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<td><strong>2013 Salesman of Year</strong></td>
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<tr>
<td><strong>Spent $50 on wine</strong></td>
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<tr>
<td><strong>Played Hockey in college</strong></td>
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<td><strong>Traveled to Italy in 2014</strong></td>
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<tr>
<td><strong>Dislikes Chinese food</strong></td>
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<tr>
<td><strong>Male</strong></td>
</tr>
<tr>
<td><strong>Has 3 kids</strong></td>
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<tr>
<td><strong>Father passed away</strong></td>
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<tr>
<td><strong>Mother lives in Florida</strong></td>
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<tr>
<td><strong>Likes hiking</strong></td>
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<tr>
<td><strong>Went to ND State</strong></td>
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<tr>
<td><strong>Is politically active</strong></td>
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<tr>
<td><strong>Works out at a gym</strong></td>
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<tr>
<td><strong>Is tall</strong></td>
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<tr>
<td><strong>Plays bridge</strong></td>
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<tr>
<td><strong>On the PTA</strong></td>
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<tr>
<td><strong>Dislikes Actress Jennifer Anniston</strong></td>
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<tr>
<td><strong>Owns a SmartTV</strong></td>
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<tr>
<td><strong>Purchased house in 2011</strong></td>
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<tr>
<td><strong>Owns an RV</strong></td>
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<td><strong>Has a Roku box</strong></td>
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<td><strong>Spent $100 on raffle</strong></td>
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<td><strong>Likes online news sites</strong></td>
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<tr>
<td><strong>Owns a laptop</strong></td>
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<tr>
<td><strong>Rides a motorcycle</strong></td>
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<tr>
<td><strong>Has a Major life insurance holder</strong></td>
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<td><strong>Salesman</strong></td>
</tr>
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<td><strong>Has Amazon Prime</strong></td>
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<td><strong>Likes spicy food recipes</strong></td>
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- **Spent $50 on wine**
- **Has a Major life insurance holder**
- **Salesman**
- **Has Amazon Prime**
- **Likes spicy food recipes**
- **Likes Actress Angelina Jolie**
- **Hates doing dishes**
- **House value: $500,000**
The Cloud: Revolutionizing Commerce

- What will you buy?
- When will you buy it?
- What will you pay?

Internet Activity

Inference and Prediction
What Else Can We Revolutionize with Cloud + Analytics?

- Bring to areas that are underserved by technology
  - Not commercially viable (yet)
  - Remote, rural; labor-intensive
  - Lack inexpensive connectivity

- Problem-driven foci
  - Vast data sources (sensors, images, records, weather, ...)
  - Multidisciplinary: solve harder problems
  - Potential for automation, computational power, and data-driven decision support
Example: SmartFarm

- What should I grow?
- When should I water?
- What will my yields be?

Inference and Prediction
Clustering as a Service: Field Management

- Identify contiguous management zones
  - Irrigation, soil health management, yield est.
  - Using electro-conductivity and other metrics about the soil
    - Moisture holding capacity, composition, elevation, Lat/Lon

- K-means based clustering is a popular/useful approach
  - Multi-dimensional
  - Many variants, which one is "best"?
  - Requires technical expertise
SmartFarm Clustering Service

- Upload your data
- Compute clusters
- Identify best via a scoring function (info criterion)
- Visualize results
Example: Where’s The Bear? (WTB)

- What animals are here?
- How many are there?
- Are they hungry?

Inference and Prediction
Internet of Things (IoT)

Private Wireless/Radio Networks:
- Low Latency / High BW

Internet:
- High Latency,
- Low and Variable Bandwidth,
- Intermittent Connectivity

Public & Private Clouds
(Ex: Amazon, Aristotle)

Existing Internet-Cloud architecture is **not well suited** for IoT: energy-efficiency, data-driven actuation, & realtime response...

Sensing Tier
A New Infrastructure For Things (I4T)

Sensing Tier

Private Wireless/Radio Networks:
Low Latency / High BW

Edge Tier

Internet: High Latency,
Low and Variable Bandwidth,
Intermittent Connectivity

Public & Private
Clouds
(Ex: Amazon, Aristotle)

Cloud Tier

- API-Compatible with Amazon/Google Clouds
- Highly available and fault tolerant (self managing)
- Multi-analytics (Hadoop, Spark; DNNs, ML, image proc.)
I4T Programming Platform

- Serverless Platform of Things (SPOT)
  - Self-service, easy to use by all
- Programming support
  - Portable across IoT tiers → Simple event-triggered functions
- Distributed runtime system
  - Open source, fault-resilient
  - Efficient function placement

![Diagram showing I4T Programming Platform components]
Where's The Bear (WTB)

- Multi-tier IoT system
  - Move the *code to the data (images)* not vice versa
  - Via *Edge Clouds*: robust, self-managing appliances, on-site
    - Low latency, high-bandwidth direct connectivity to cameras
    - Local image classification
Where's The Bear (WTB)

- Multi-tier IoT system
  - Move the *code to the data* (*images*) not vice versa
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Where’s the Bear?
Results: 4890 randomly selected images

Classification Accuracy, 4890 Images, >= 90% Confidence
- 87% Correct
- 12% Deer Err
- 1% Bear Err
- 0.2% Coyote Err

Transmit only those of interest
1473 vs 4890
= 1.6hrs vs 5.3hrs

Which also saves researcher time
(1250 images/hr)
A New Kind of Computer Science

- Problem driven and empirical
  - Food-Energy-Water nexus
- Societal and regional impact
- Multidisciplinary collaboration
- Leverages entrepreneurial activity
- Engages the community

UCSB
Thanks!

UCSB RACELab
The Lab for Research on Adaptive Computing Environments
Computer Science Department, Harold Frank Hall (E-5), Santa Barbara, CA

- Collaborators: UCSB, CalPoly, UC Davis, Fresno State, Powwow Energy, Sedgwick Reserve, UC Extension, Private Growers

- Support: Google, Huawei, IBM Research, Microsoft Research, NSF, NIH, California Energy Commission

ckrintz@cs.ucsb.edu
http://www.cs.ucsb.edu/~ckrintz/racelab.html