

# Carnegie Mellon University Silicon Valley

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## Mobile Computing: Challenges and Opportunities for Autonomy and Feedback



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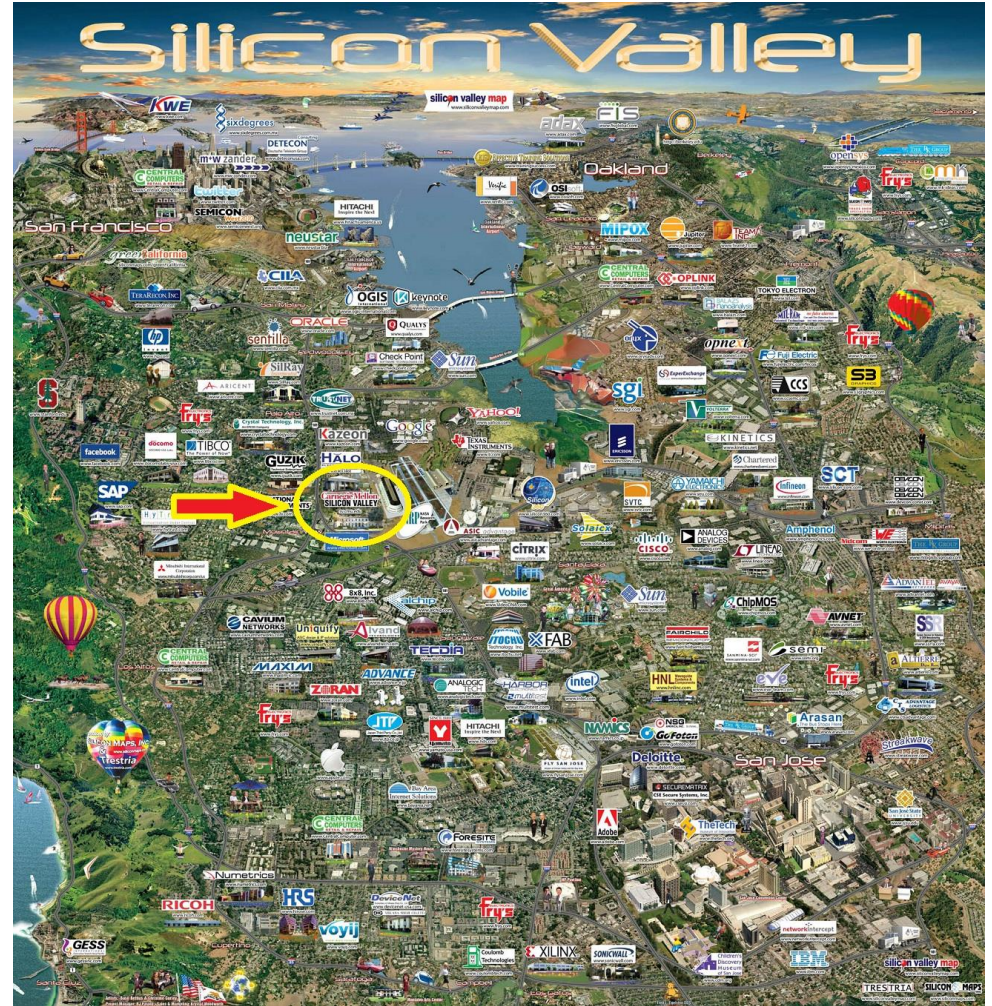
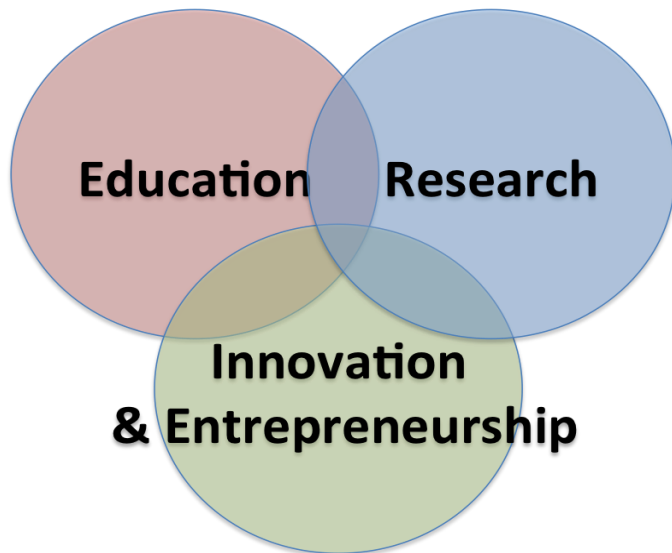
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# CMU in Silicon Valley

- Established 2002
- Significant growth in the past 10 years



# Background

- Mobile computing as a disruptive force
- First wave of mobile computing:
  - Voice was king
- Second wave of mobile computing:
  - Computer is king
  - *Platform thinking* – similar to desktop and laptop
  - Challenges the inherited mobile systems infrastructure
- Challenge: Develop the next-generation mobile computing infrastructure

# Challenges

Challenge	Description
Robustness	Wireless characteristics are inherently variable
Responsiveness	Growing demand implies growing load
Power	Physics imposes hard limits
App Development	Distributed computing introduces complexity

## Disclaimers:

- These four challenges are not independent
- Other challenges exist
- Some challenges are well-known, and now re-emerging

# Impact of Platform Thinking: Robustness Challenge

- *Robustness challenge*: In wireless networks, the physical medium is generally
  - dynamic,
  - variable in reliability, and
  - devices can and do move.

# Impact of Platform Thinking: Responsiveness Challenge

- *Responsiveness challenge*: With the growth in mobile consumption of streaming media
  - desire to balance competing needs of different traffic flows against fixed resources
  - revived interest in mechanisms to externally control an otherwise static network (e.g., SDN) and policies that enforce rational resource allocation
  - *real-time resource allocation* is a necessity, but current operator practice treats it as a static problem

# Impact of Platform Thinking: Power Challenge

- *Power challenge*: The competitive nature of mobile app marketplaces taxes the power usage of mobile phones
  - rapid evolution of on-phone computing performance and app capabilities
  - mobile phone must operate at or below the so-called “three watt limit,” else it gets too hot to handle
  - minimize the time a mobile device is tethered for charging

# Impact of Platform Thinking: App Development Challenge

- *App development challenge*: mobile apps often consist of developer's code + some cloud service
  - IP packets traveling mobile-to-cloud or mobile-to-mobile transit extensive wireless edge and core networks to reach their destinations: Latency is often a problem
  - few developers know how to statically divide an app for power optimization
  - depending on partitioning, power-cost of computing and communication will change, possibly drastically
  - inherently unknown nature of app's input-dependent behavior makes static partitioning unrealistic



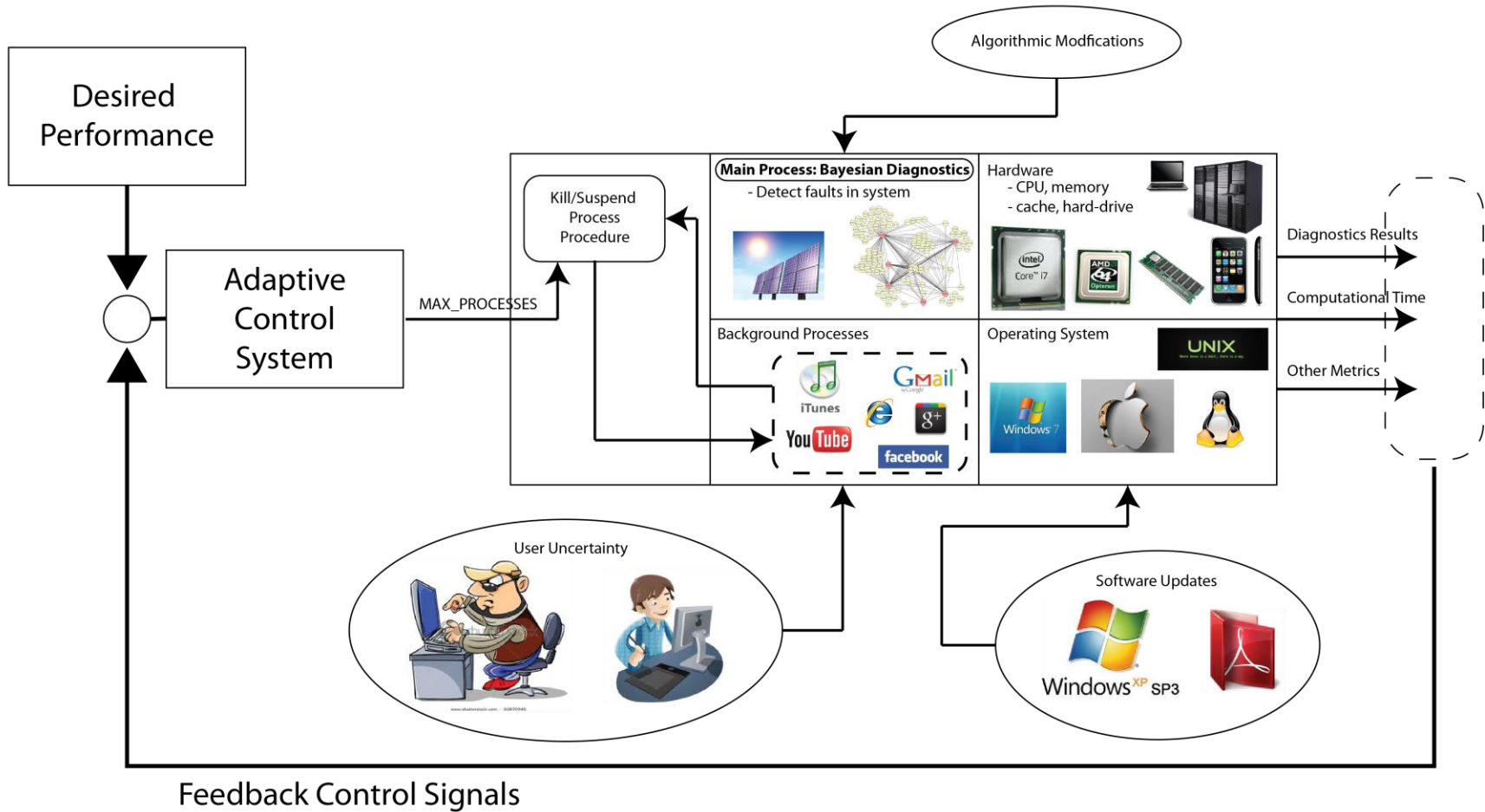
# What's Next?

- Apps expose desired network resource allocation (bandwidth, maximum latency):
  - Network conducts auctions to set prices and priorities
  - Feedback loop is closed when the apps receive results of the auction and modify their requests accordingly
  - Network operator maximizes revenue
- Apps and networks jointly do power management:
  - App instances are running on millions of devices, they provide meta-data for state of wireless connections
  - Learn network-dependent power behavior: Correlate power usage with signal strength across many apps
  - Video streaming app: weak signal triggers use of a codec that minimizes retransmissions, minimizing wasted power

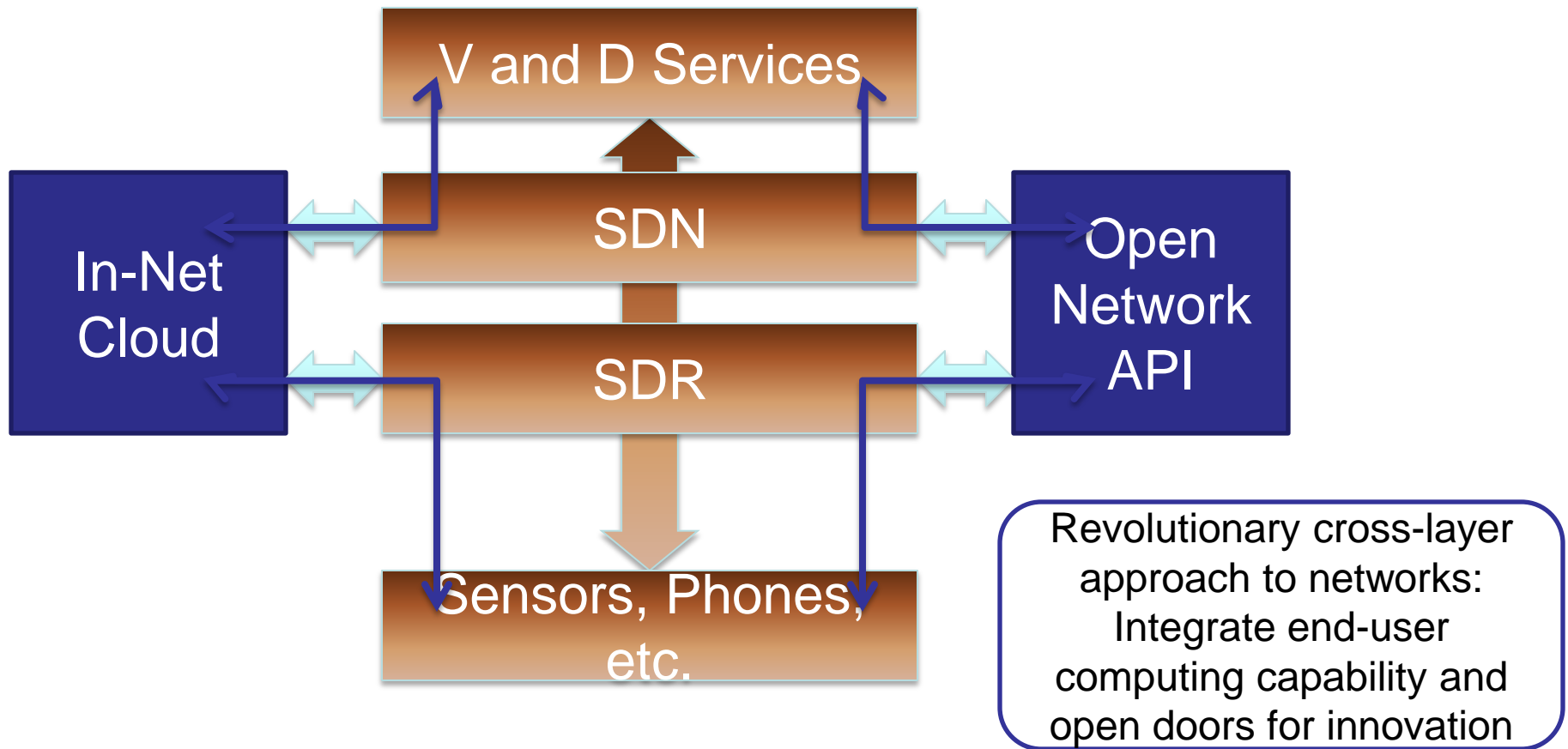
# Power Challenge

- Power management: the most pressing issue in mobile app creation and mobility computing?
- Power usage can be:
  - measured across different, concurrent app instances
  - these measurements can then be correlated with network measurements and models
- Machine learning and system identification can be then be done used for feedback control:
  - setpoint would be power consumption
  - the control actions would be to dynamically migrate parts of an app between the device and the cloud
- Compared to previous research [Chen 2012, Thiagarajan 2012], we propose to automatically partition a broader class of apps

# Responsiveness Challenge



# Software-Defined, Open Mobile Networks Test Bed



# Conclusions & Next Steps

- Second wave of mobile computing:
  - *Platform thinking* – similar to desktop and laptop
- Challenge: Develop the next-generation mobile computing infrastructure
  - Robustness
  - Responsiveness
  - Power
  - App Development
- Mobile Computing Testbed at CMU Silicon Valley
  - We're looking for collaborators