Mobile Computing: Challenges and Opportunities for Autonomy and Feedback

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- 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

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<td>Power</td>
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<td>Distributed computing introduces complexity</td>
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Disclaimers:
- These four challenges are not independent
- Other challenges exist
- Some challenges are well-known, and now re-emerging

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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

 Desired Performance

 Adaptive Control System

 MAX PROCESSES

 Kill/Suspend Process Procedure

 Main Process: Bayesian Diagnostics
 - Detect faults in system

 Algorithmic Modifications

 Diagnostics Results

 Computational Time

 Other Metrics

 Background Processes

 Operating System

 Hardware
 - CPU, memory
 - cache, hard-drive

 User Uncertainty

 Feedback Control Signals

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Software-Defined, Open Mobile Networks Test Bed

Revolutionary cross-layer approach to networks: Integrate end-user computing capability and open doors for innovation.
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