FORGE: Power-Aware Cross-Layer Adaptation for Mobile Applications

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Motivation & Goal

Motivations

- Mobile devices operate under heavy constraints on power & computation capabilities.
- Mobile devices are increasingly used in video streaming applications.

Goals

- Study and evaluate cross-layer (application, middleware, OS, hardware) adaptation techniques for performance vs. quality vs. power tradeoffs for mobile handheld devices.
- Need to develop techniques and interfaces that facilitate effective communication between the layers.

Applications

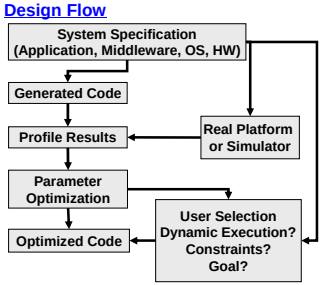
- Entertainment (games, video-streaming, video-conferencing, cell-phones, etc.)
- Wearable computers, scientific explorations
- Monitoring and defense applications

Application Profiling for Power-Aware Transcoding

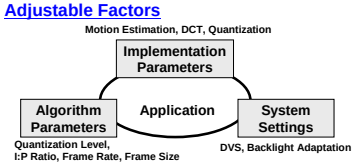
Intuition

- Profiling helps us understanding the power/quality/performance impacts of various application parameters and optimizing the system.

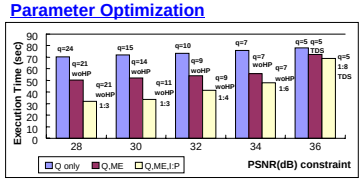
Design Flow



Adjustable Factors



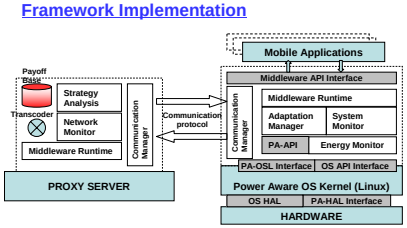
Parameter Optimization



•S. Mohapatra, R. Cornea, H. Oh, K. Lee, M. Kim, N. Dutt, R. Gupta, A. Nicolau, S. Shukla and N. Venkatasubramanian: *A Cross-Layer Approach for Power-Performance Optimization in Distributed Mobile Systems* . NSF Next Generation Software Program in conjunction with IPDPS, Apr. 2005.

DYNAMO: A Middleware Framework for Cross-Layer Optimization

Framework Implementation

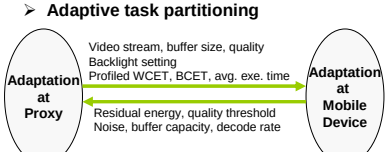


Approaches

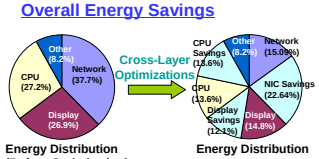
- Applications & middleware interact with power-aware OS/hardware through power-aware APIs (PA-APIs).
- Middleware-level communication manager transfers state and control information between device and proxy.
- Integrated optimizations (energy savings)

Adaptations Using DYNOMO

- Energy-aware application adaptation
- Power management of NIC, LCD, CPU
- Adaptive task partitioning



Overall Energy Savings



- Total energy savings ~ 48%
  (for a medium action video clip called Foreman)

http://dynamo.ics.uci.edu

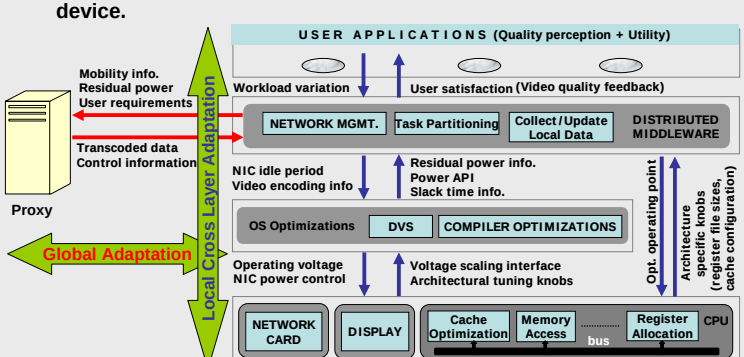
Approach: Cross-Layer Optimization

Limitations of Current Approaches

- Limited coordination between the different system layers
  - Address concerns at one or two system layers
  - Make assumptions about adaptations at other system layers
- Device Centric
  - Cannot exploit global system knowledge
  - Reactive adaptations
- Lack of generalized framework

Our Approaches

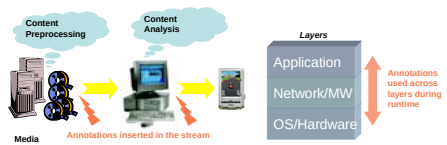
- Cross-layer coordination directed by a distributed middleware framework can effectively address the above limitations.
- Build power-aware distributed embedded system framework that can
  - Exploit global changes (e.g., network congestion, system loads, mobility patterns, location information).
  - Distribute local information (e.g., device mobility, residual power) for improved global adaptations.
  - Coordinate power management strategies at different layers.
  - Maximize the utility (application QoS, power saving) of a mobile device.



A Globally Coordinated Approach in FORGE:
Tradeoffs between power, performance, QoS across various computational layers

•S. Mohapatra, R. Cornea, H. Oh, K. Lee, M. Kim, N. Dutt, R. Gupta, A. Nicolau, S. Shukla and N. Venkatasubramanian: *A Cross-Layer Approach for Power-Performance Optimization in Distributed Mobile Systems* . NSF Next Generation Software Program in conjunction with IPDPS, Apr. 2005.
•S. Mohapatra, R. Cornea, N. Dutt, A. Nicolau, and N. Venkatasubramanian: *Integrated Power Management for Video Streaming to Mobile Handheld Devices* ACM Multimedia 2003.

Content Annotation for Power Optimization



Intuitions

Content is Important!

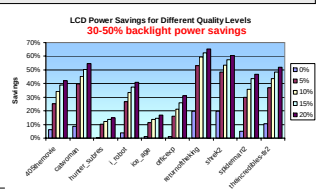
- Content greatly influences program execution.
- Preprocessing allows annotation insertion.
- Content-aware runtime for power savings

A content-aware framework benefits all abstraction layers, which now perform their optimizations cognizant of the nature and patterns in the workload.

Case Study

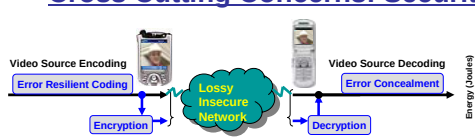
Backlight Power Minimization

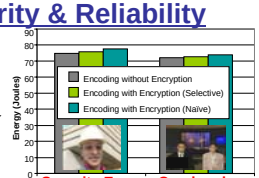
- Annotations capture brightness variation in video and drive backlight adjustment at runtime while compensating the displayed image to maintain quality.



http://forge.ics.uci.edu/content-aware

Cross Cutting Concerns: Security & Reliability





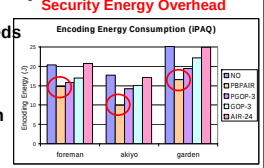
Security Energy Overhead

Intuitions

- High quality mobile multimedia communication needs
  - Secure transmission → Encryption
  - Lossless transmission → Error-resilient coding
- Mobile handheld devices have
  - Battery life constraint → Energy efficient design

Approach

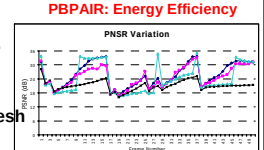
Our major concern is exploiting trade-offs between security level, error resiliency, encoding efficiency and energy consumption in mobile handheld devices.



PBPAIR: Energy Efficiency

How?

- Evaluate video encryption schemes w.r.t. energy.
- PBPAIR: Probability Based Power Aware Intra Refresh



PBPAIR: Fast Recovery

•K. Lee, N. Dutt and N. Venkatasubramanian: *An Experimental Study on Energy Consumption of Video Encryption for Mobile Handheld Devices* . ICME, Jul. 2005.
•M. Kim, H. Oh, N. Dutt, A. Nicolau and N. Venkatasubramanian: *Probability Based Power Aware Error Resilient Coding*. SIUMI'05 in conjunction with ICDCS, Jun. 2005.