Energy-aware adaptation for mobile applications

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Motivation

- Conserving power in mobile systems
- Existing Approaches
  - Improving Batteries
  - Low-power design
  - Hardware power management
- Need for higher level solutions

Approach

- Limit power consumption when necessary by reducing quality
  - Application-level adaptation of Data Fidelity level: trade fidelity with power consumption
- Issues:
  - What's the 'exchange rate' ?
  - How can the OS support energy-aware applications? Goal Directed Adaptation

Background:Odyssey

- Platform for adaptation: supports dynamic adaptation of data *fidelity* by application
- *Viceroy* monitors resources
- *Wardens* contain type-specific functionality
- Originally used to deal with network bandwidth limitations here extended to enable power conservation

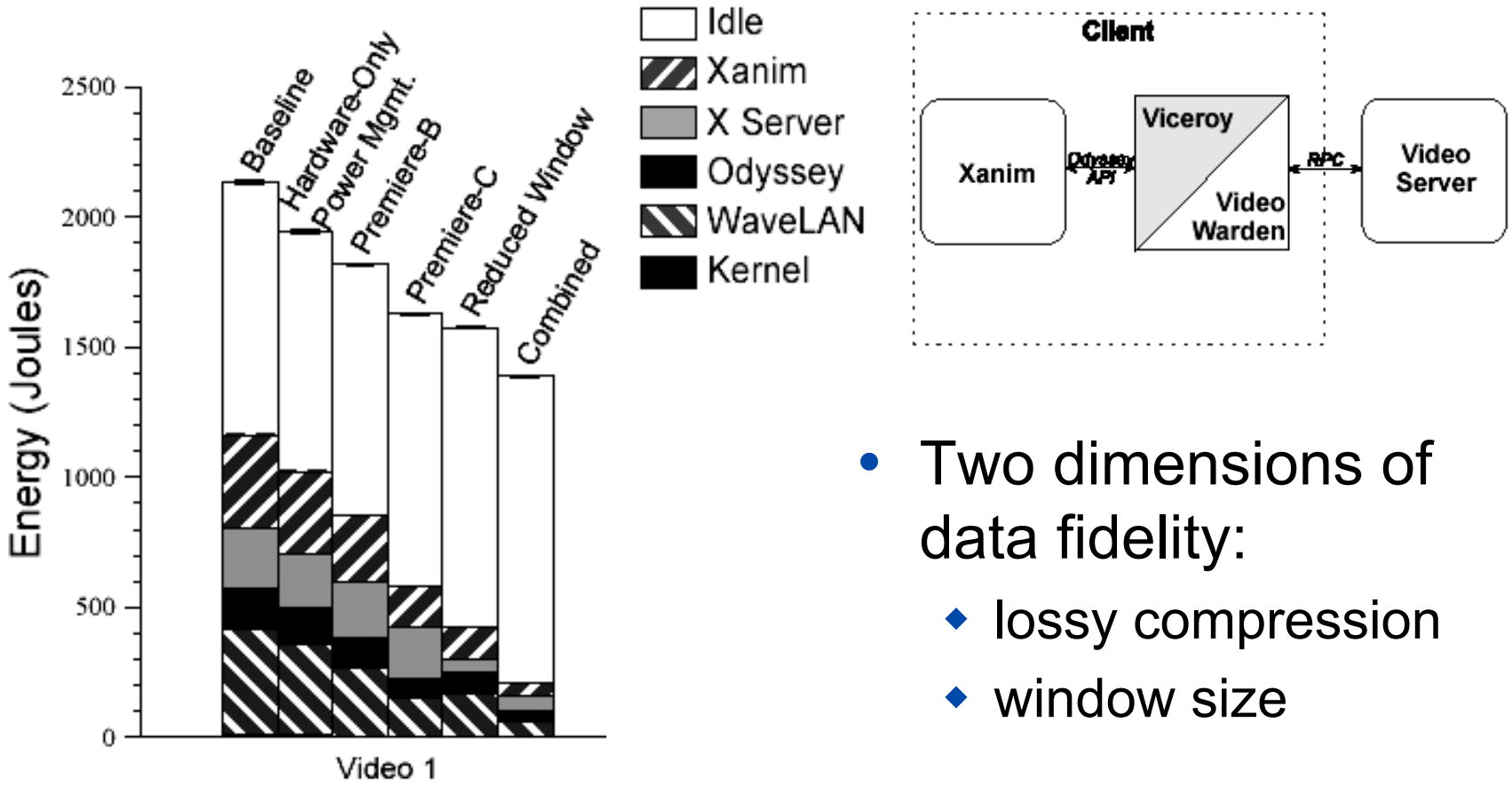
Energy vs Fidelity: Questions

- Find potential savings of lowering fidelity
- Sensitivity to applications and data content
- Effect of using with and without hardware power management
- Explore the effect of concurrency on the energy impact of lowering fidelity

Experimental Setup

- Odyssey client: IBM Thinkpad P233
  - Adaptation disabled
- PowerScope: Energy usage profiling of processes/functions
  - use controlled voltage supply
  - sample PC, pid and current @600Hz
  - generate profile from samples and symbol tables
- Problems?

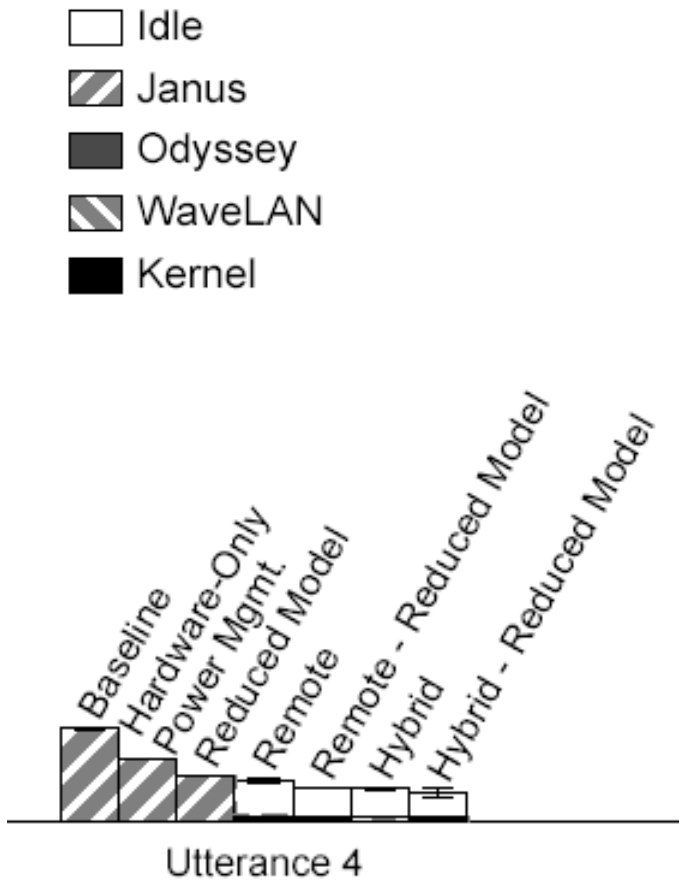
Energy vs Fidelity: Video Player



- Two dimensions of data fidelity:
  - lossy compression
  - window size

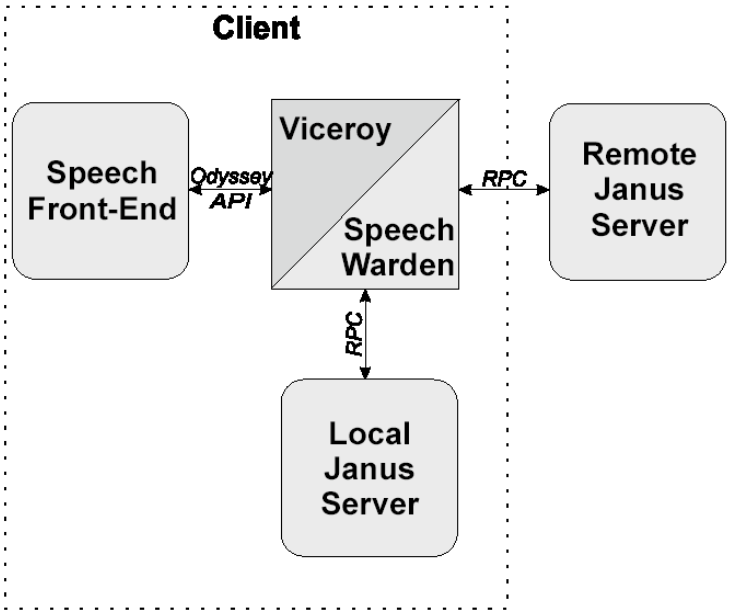
Energy vs Fidelity: Speech

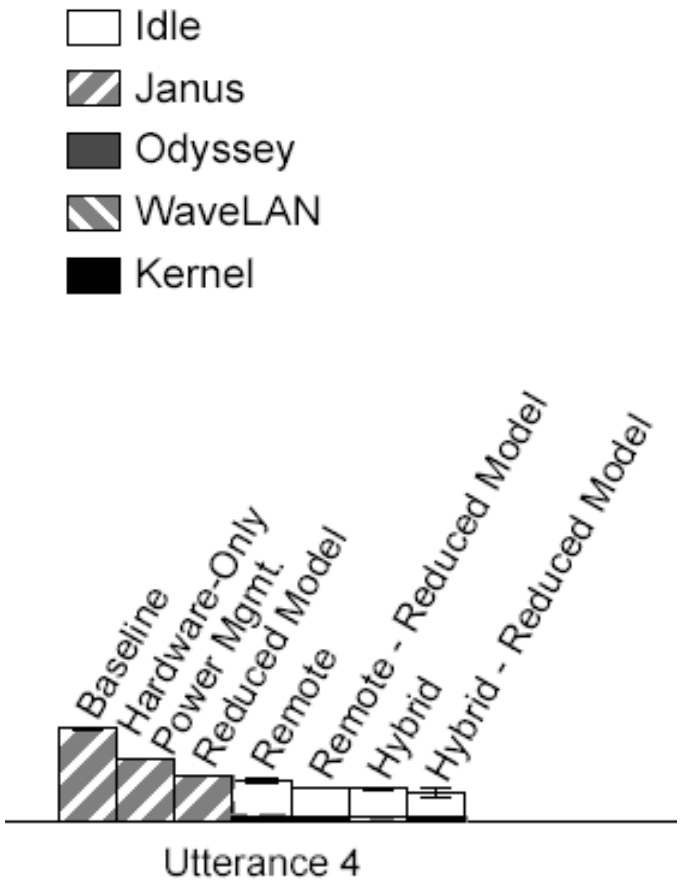
- Two dimensions of fidelity:
  - Size of vocabulary
  - Complexity of Acoustic model
- Lower fidelity by remote processing



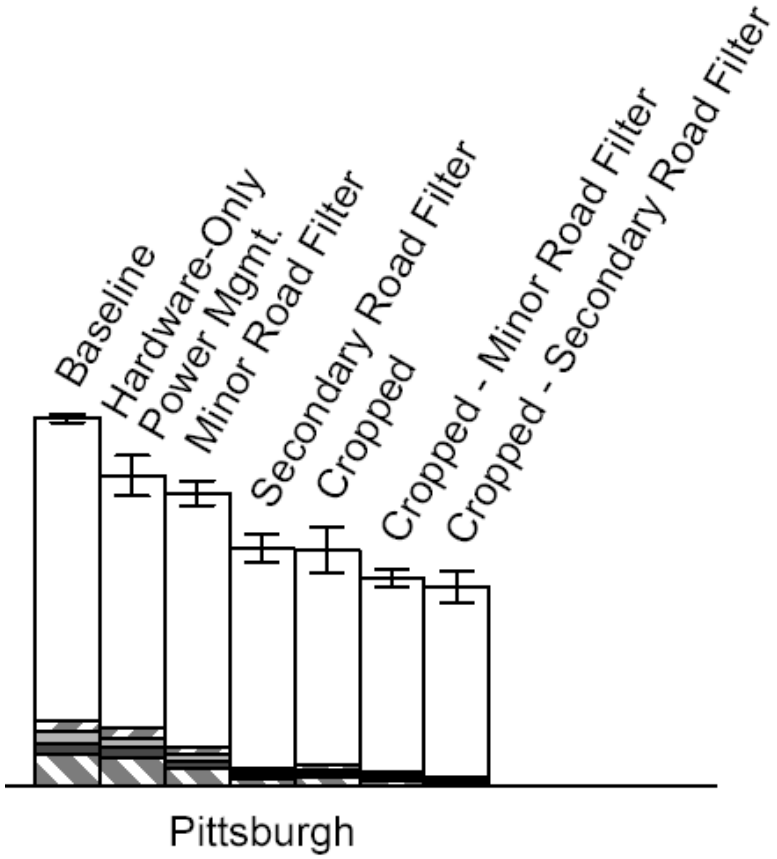
Energy vs Fidelity: Speech

- Two dimensions of fidelity:



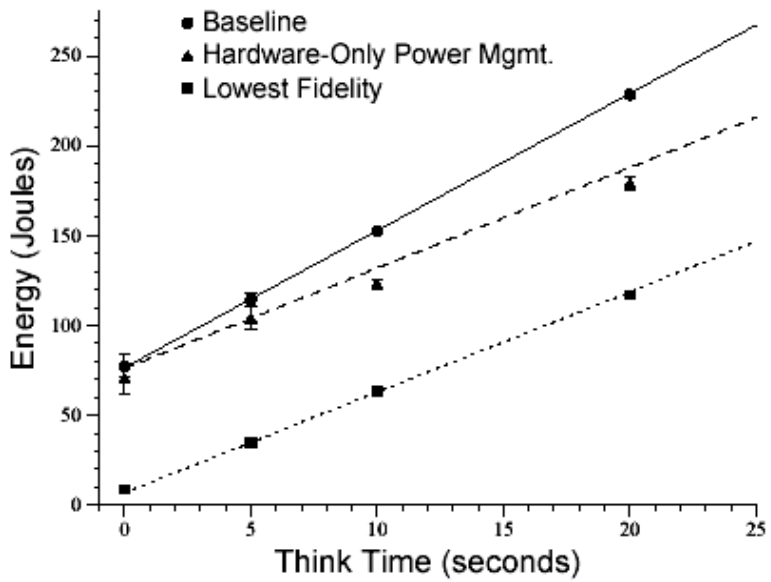


Energy vs Fidelity: Map Viewer



- Two ways to lower fidelity:
  - Filtering fine details
  - Cropping
- 'Think Time' consumes energy

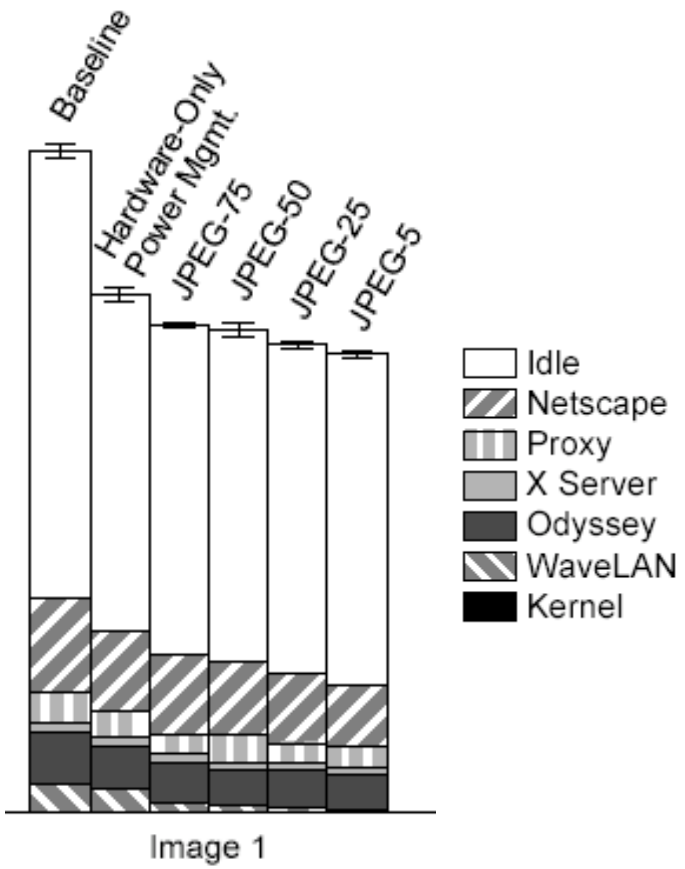
Energy vs Fidelity: Map Viewer



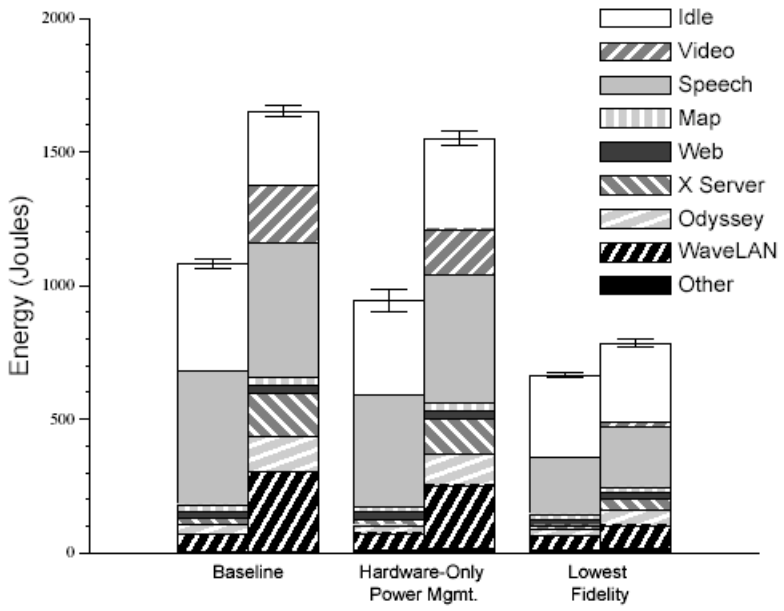
- Effect of Think-time
  - Reduction from hardware management scales with think time
  - Fidelity reduction provides a fixed benefit.

Energy vs Fidelity: Web Browser

- Transcoding of images using lossy JPEG compression
- Only reduces network access energy



Energy vs Fidelity: Concurrency



- Concurrency can affect energy usage both ways (amortized costs vs thrashing)
- Usually helps fidelity reduction by lowering ‘idle’ costs

Energy vs Fidelity: Summary

- Lower Fidelity does save energy (obvious)
- Significant variations
  - across data objects(upto 29% for map)
  - across applications
- Combined with hardware power management, can have a better effect than sum of their individual effects

Zoned Backlighting

- Build displays with multiple backlights
- Assume that energy cost of lighting $1/N^{th}$ of the screen is $1/N^{th}$ of energy cost fr lighting the whole display
- Selectively illuminate display areas depending on application requirements
- Hardware doesn't exist

Goal-Directed Adaptation

- User sets goal for battery lifetime
- Applications support multiple fidelity levels
- System can direct adaptation to
  - meet this goal whenever feasible
  - provide best user experience possible
- Steps involved:
  - Estimate remaining energy
  - Predict future consumption based on past
  - Trigger Adaptation

Predicting Future Demand

- Base estimate on smoothed observations from past and present

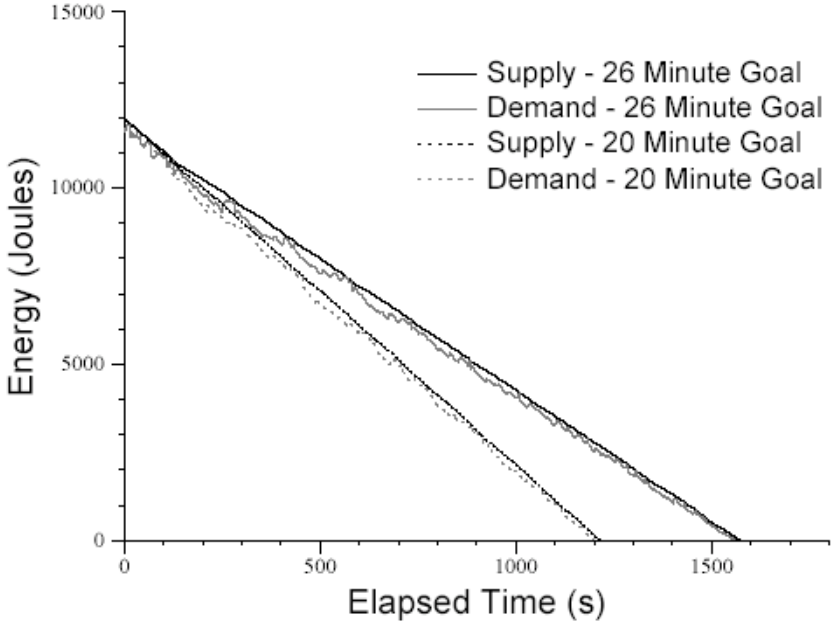
$$New = (1 - \alpha) \bullet (this\_sample) + \alpha \bullet Old$$

- Vary α as energy drains
- Balance stability vs. agility depening on distance of goal
- Adjust half-life to 10% of time remaining

Triggering Applications

- When predicted demand > supply, adapt applications to lower fidelity
- When surplus > 5% of residual energy + 1% of initial energy, increase fidelity
- Hysteresis and limit on frequency of adaptations to ensure stability
- For multiple concurrent applications :
  - use static user-specified priorities to choose

Results



Half-Life	Goal Met	Residue (J)		Adaptations	
0.01	100%	204.6	(17.7)	93.6	(3.7)
0.05	100%	124.1	(38.0)	33.2	(4.0)
0.10	100%	129.2	(21.6)	14.6	(5.4)
0.15	80%	97.6	(22.2)	6.8	(2.9)