Energy-aware adaptation for mobile applications

Jason Flinn and M. Satyanarayanan
School of Computer Science
Carnegie Mellon University

Speaker:Chang chin-her

Outline

- **Introduction**
- **Background**
- **Energy impact of fidelity**
- **Zoned backlighting**
- **Goal-directed energy adaptation**
- **Conclusion**

Introduction(1/2)

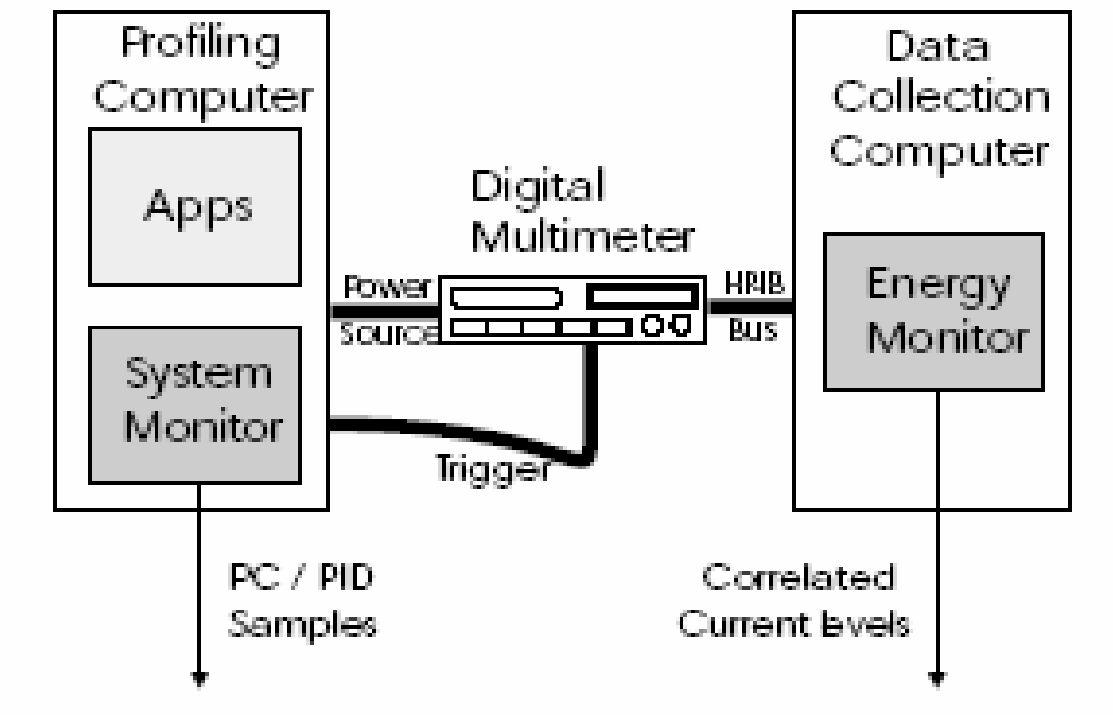
- Explore how applications can dynamicall modify their behavior to conserve energy.
- To validate the energy benefits of adaptation.

Introduction(2/2)

- Suggest a novel approach to reducing the energy drain of the display.
- To show how the operating system can control adaptation by concurrent applications to give a battery life of user-specified duration.

Background(1/3)

- **The PowerScope energy profiler**

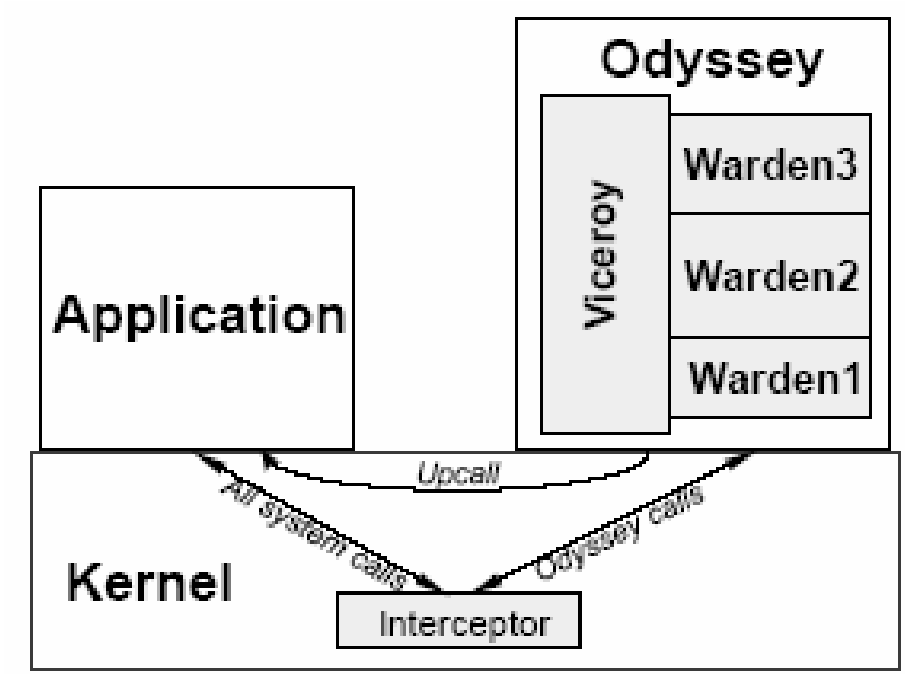


Background(2/3)

- **The Odyssey platform for adaptatio**
  - Fidelity
  - Concurrency
  - Agility
  - Minimalism

Background(3 / 3)

- **Odyssey architecture**
  - *Viceroy*
  - *Wardens*
  - *Interceptor*
  - Upcall



Energy impact of fidelity

- *Does lowering data fidelity yield significant energy savings?*
- Could lowering fidelity enhance those achievable through well-known hardware power management techniques?

Energy impact of fidelity

Methodology

- First, measured the baseline energy usage for each object at highest fidelity with hardware power management disabled.
- Second, measured energy usage with hardware-only power management.
- Third, for each lower fidelity level we measured energy usage with hardware power management enabled.

Energy impact of fidelity

Experimental setup

Clients:
IBM ThinkPad 560X laptop
233MHz Pentium
64MB of memory
Linux 2.2 operating system
2 Mb/s wirelessWaveLAN network

Servers:
desktop computers
200MHz Pentium Pro
64 MB of memory.

Component	State	Power (W)
Display	Bright	4.54
	Dim	1.95
WaveLAN	Idle	1.46
	Standby	0.18
Disk	Idle	0.88
	Standby	0.24
Other	Idle	3.20

Energy impact of fidelity
Video player (1/2)

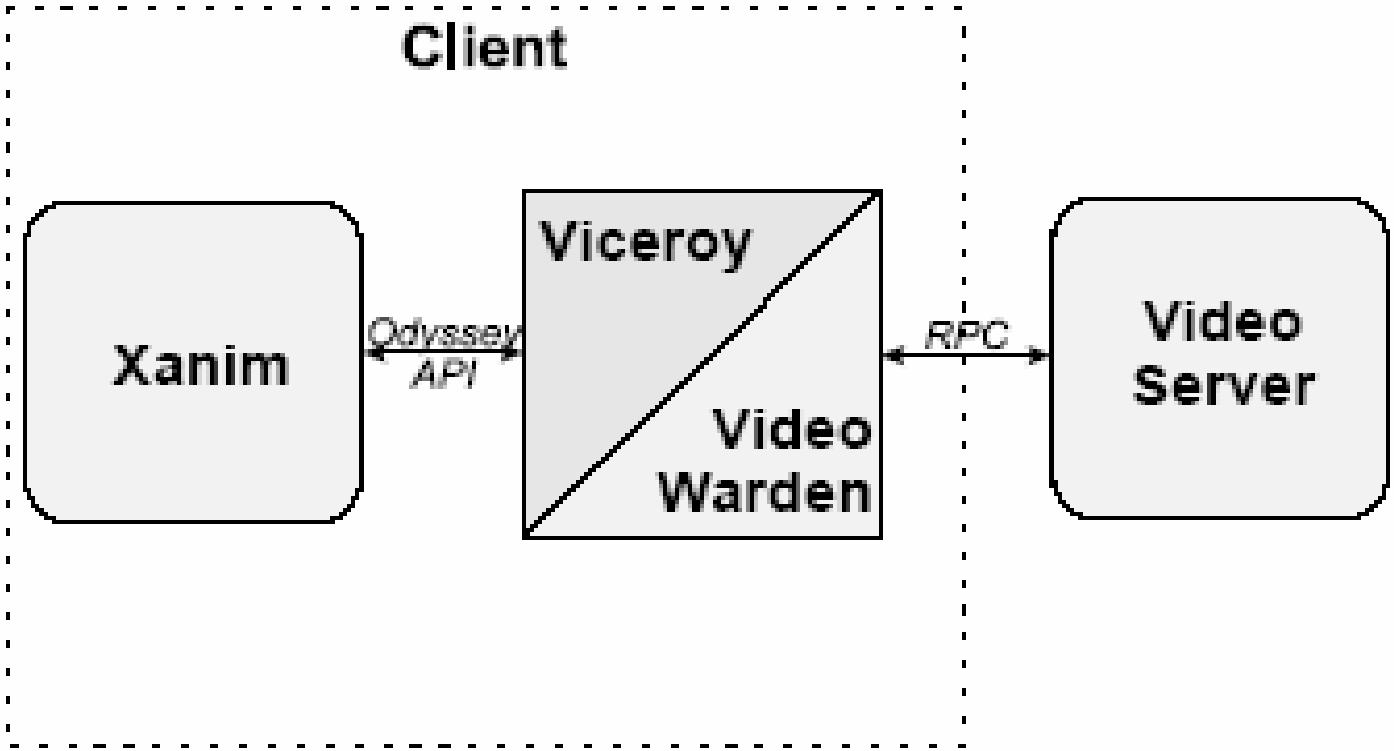
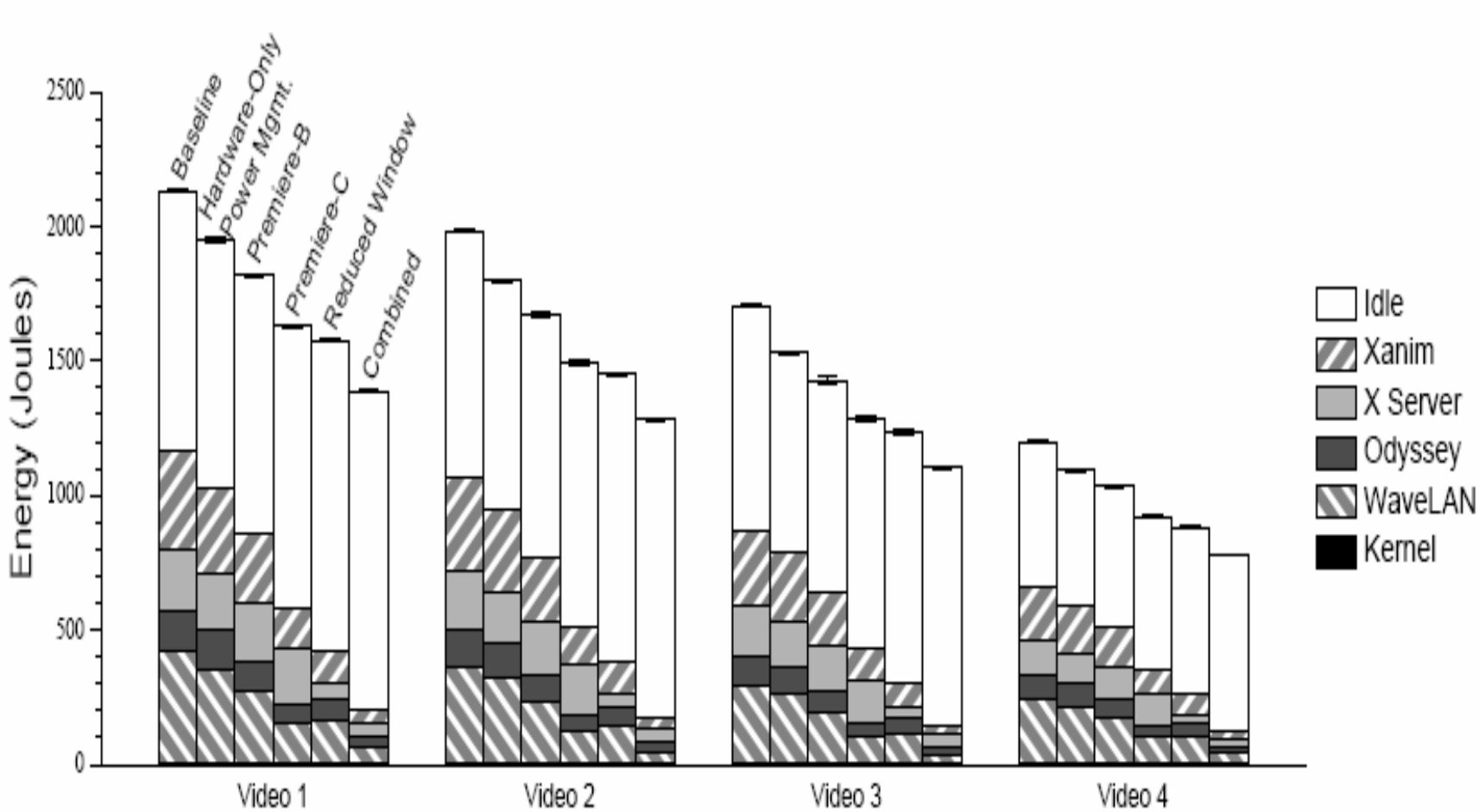


Figure 5. Odyssey video player

Energy impact of fidelity
Video player (2/2)



Energy impact of fidelity
Speech recognizer (1/2)

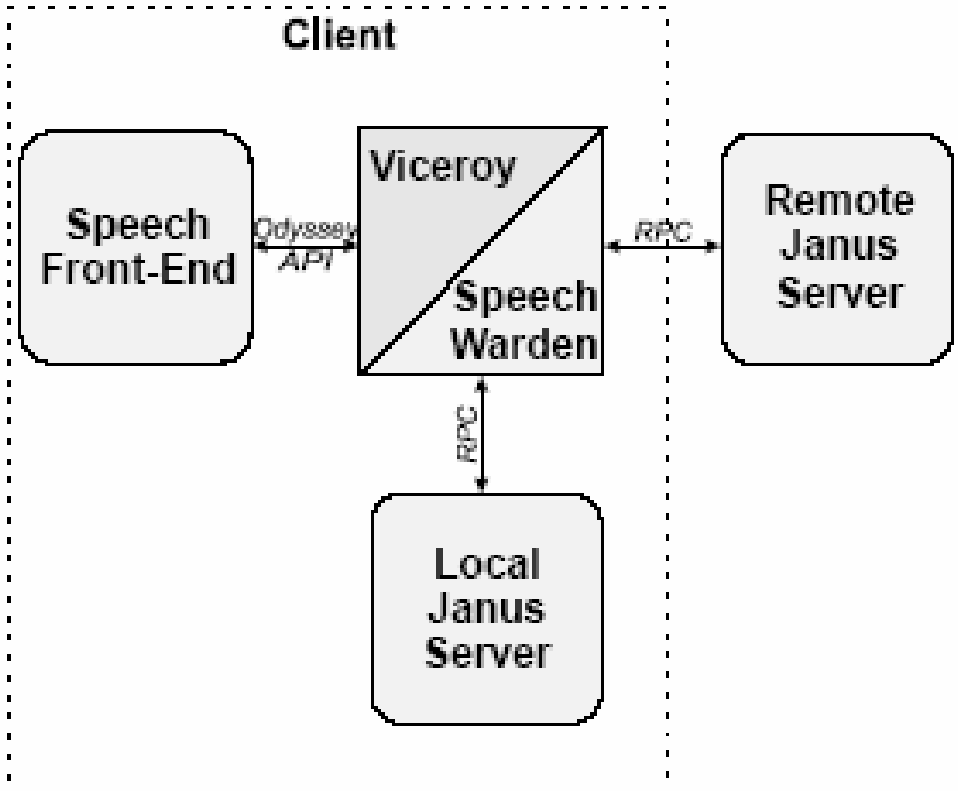
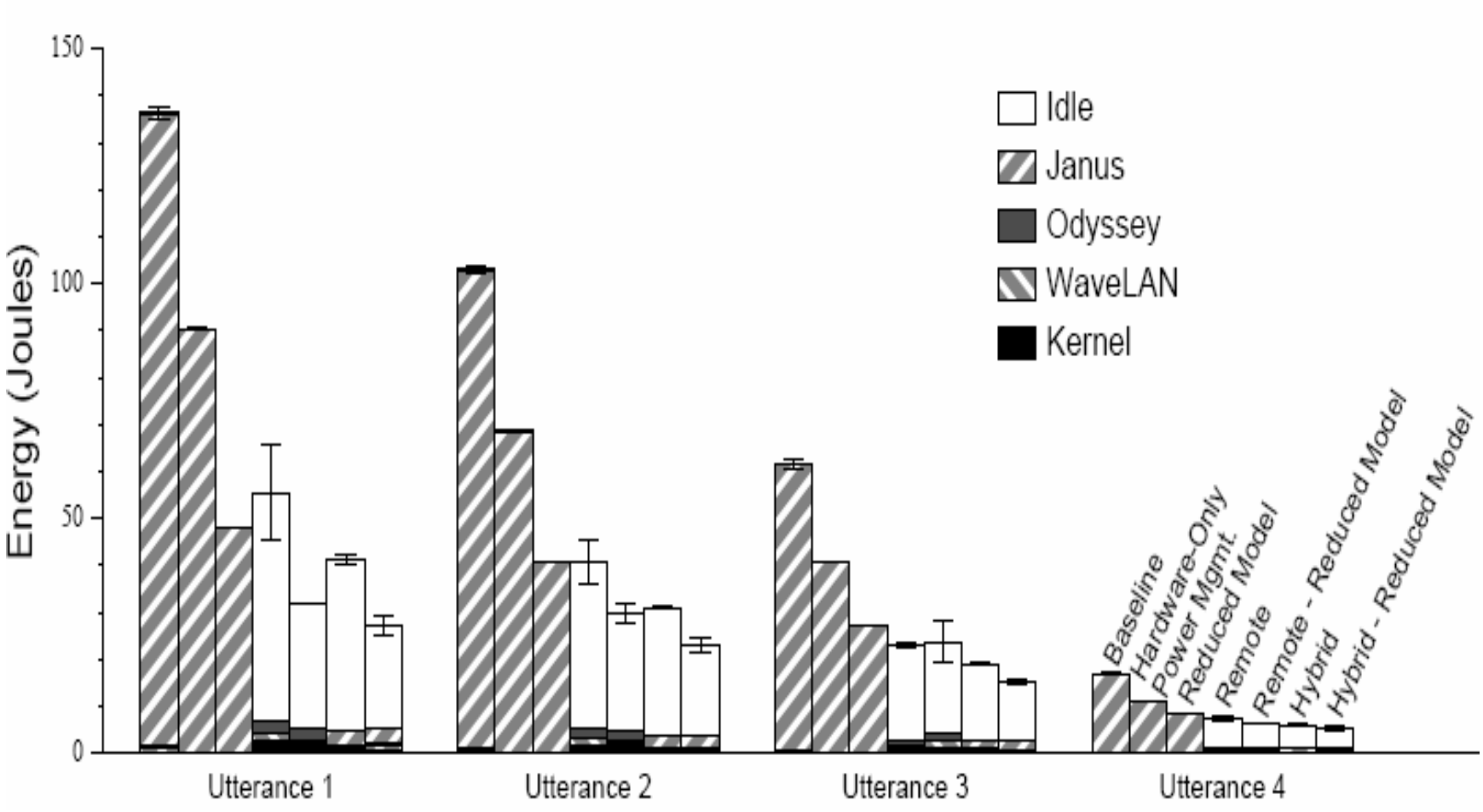


Figure 7. Odyssey speech recognizer

Energy impact of fidelity
Speech recognizer (2/2)



Energy impact of fidelity
Map viewer (1/3)

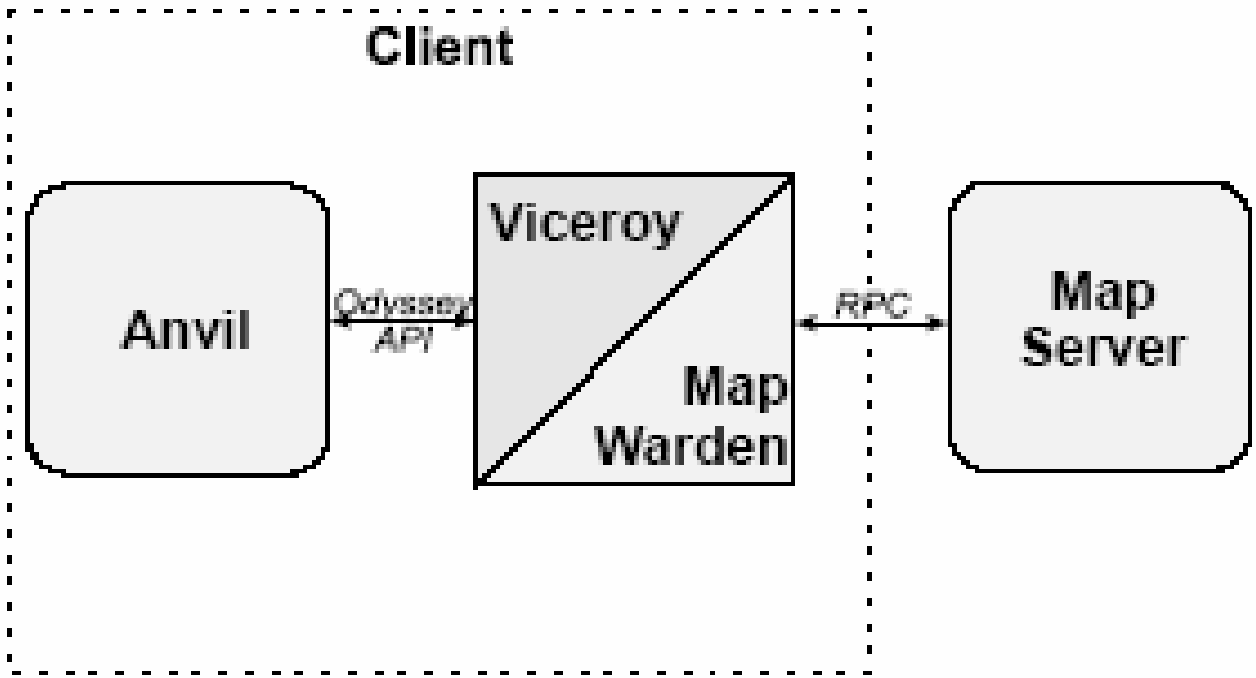
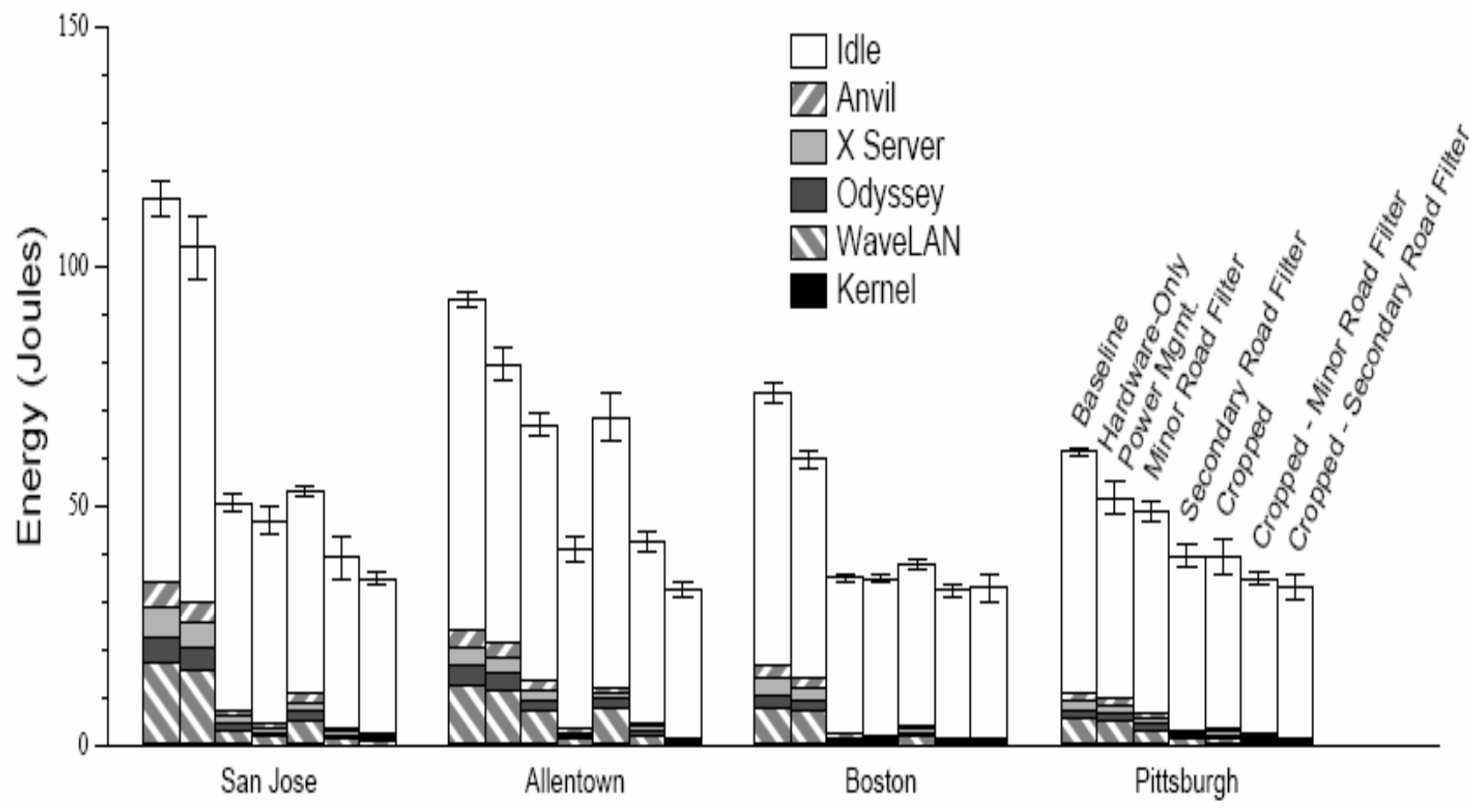


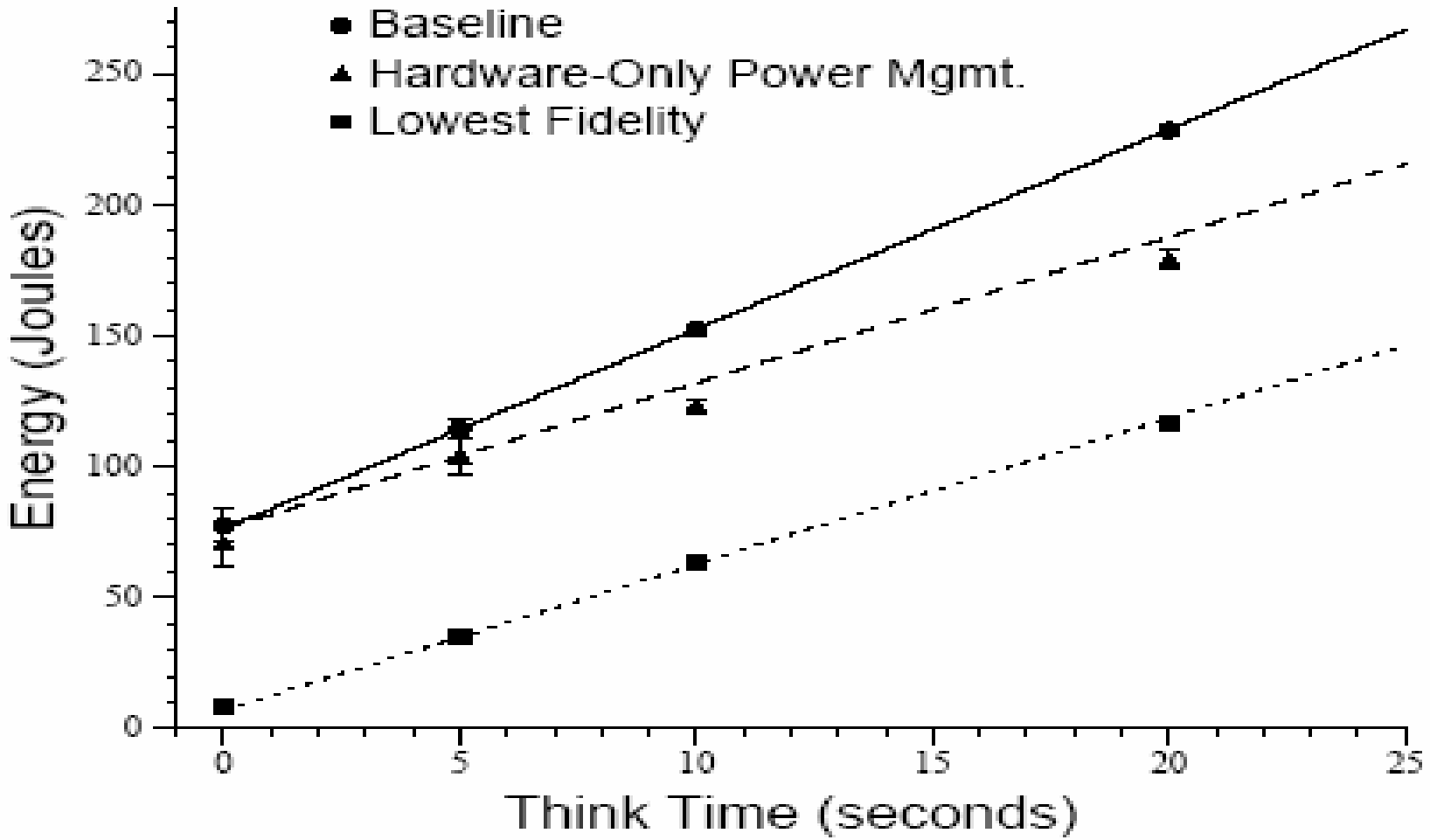
Figure 9. Odyssey map viewer

Energy impact of fidelity
Map viewer (2/3)



Energy impact of fidelity

Map viewer (3/3)



Energy impact of fidelity
Web browser (1/3)

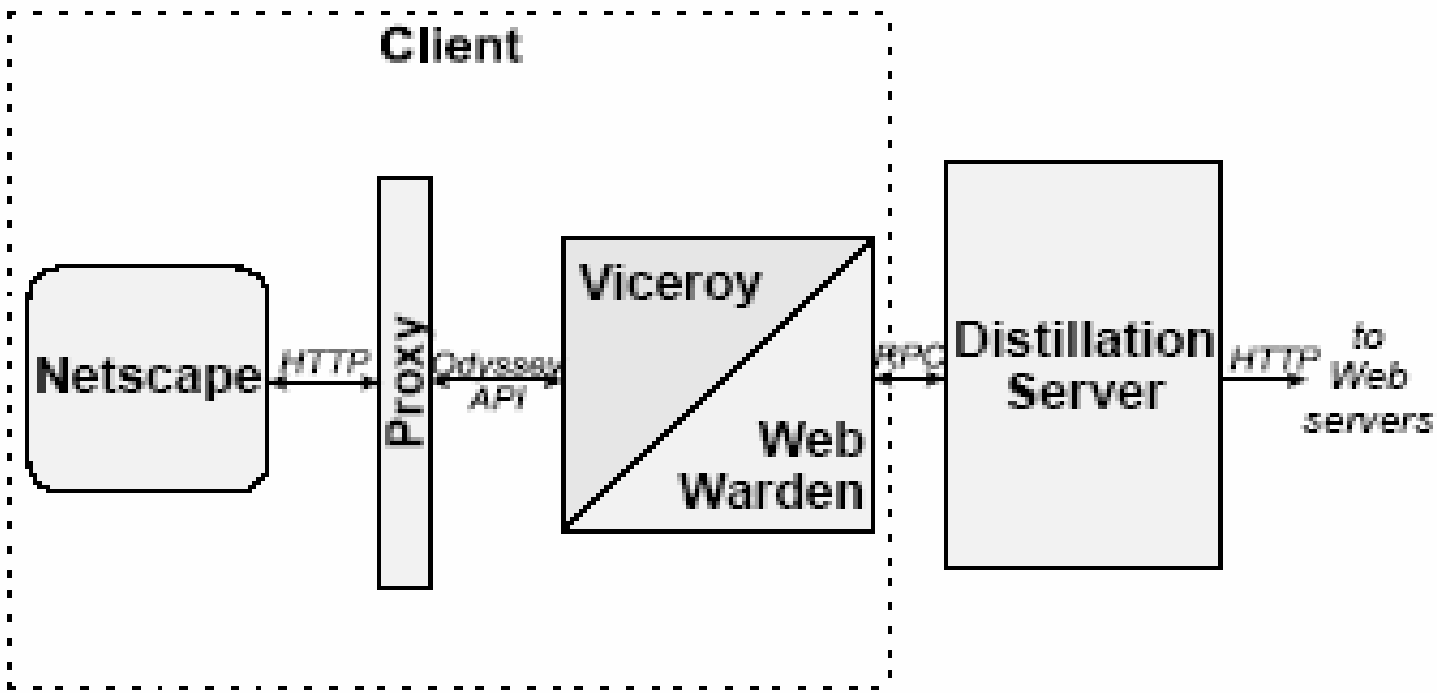
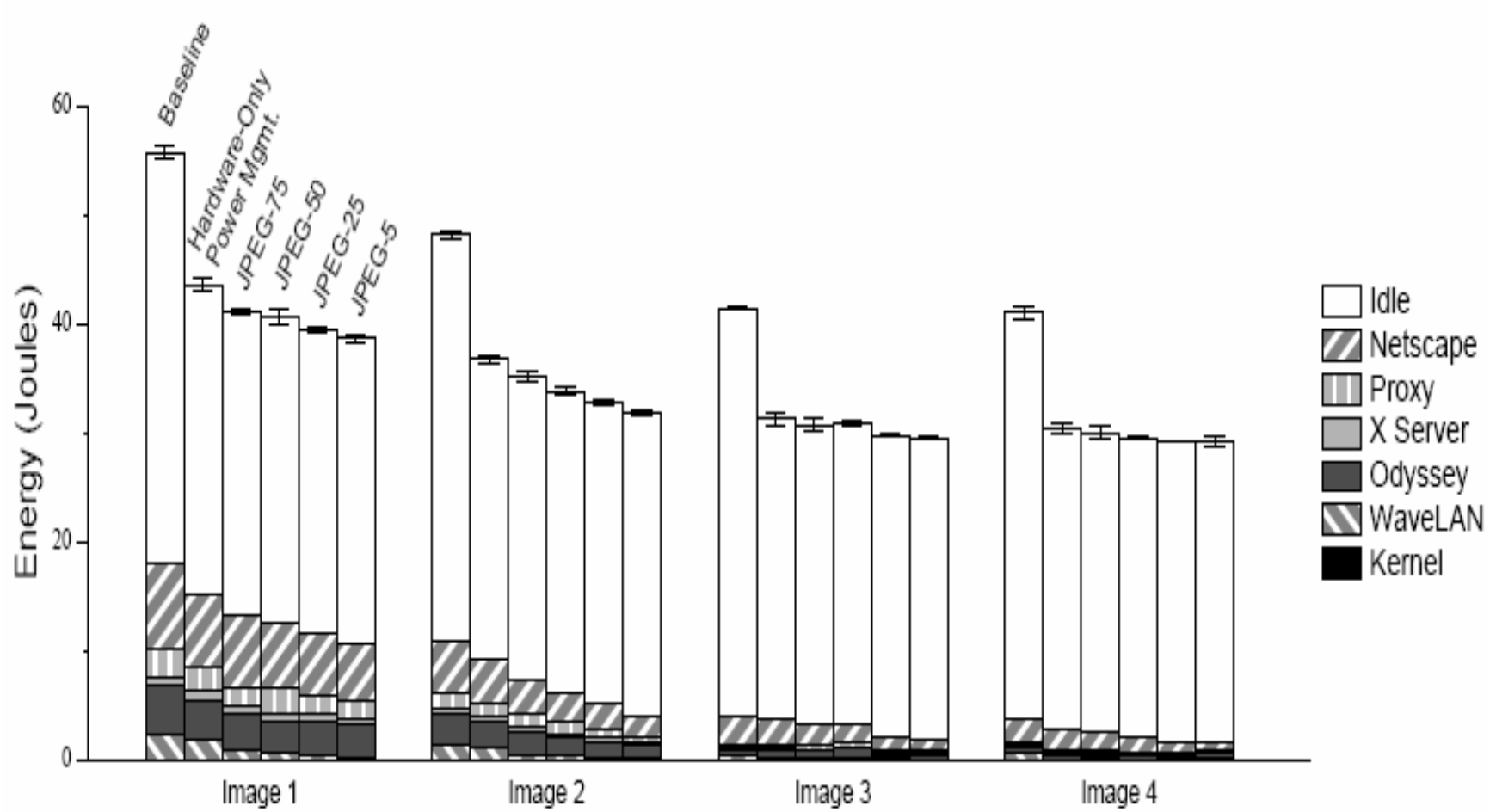
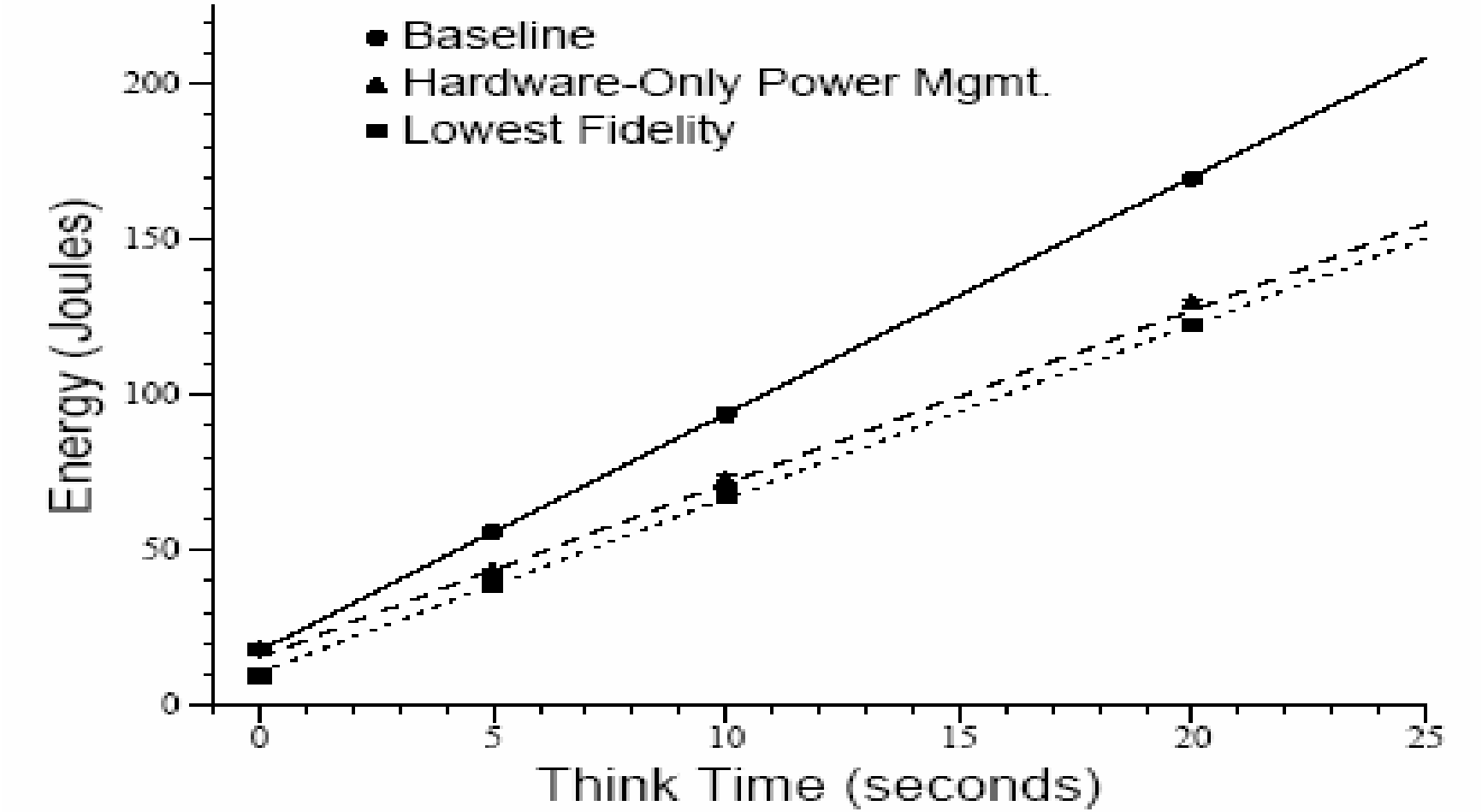


Figure 12. Odyssey Web browser

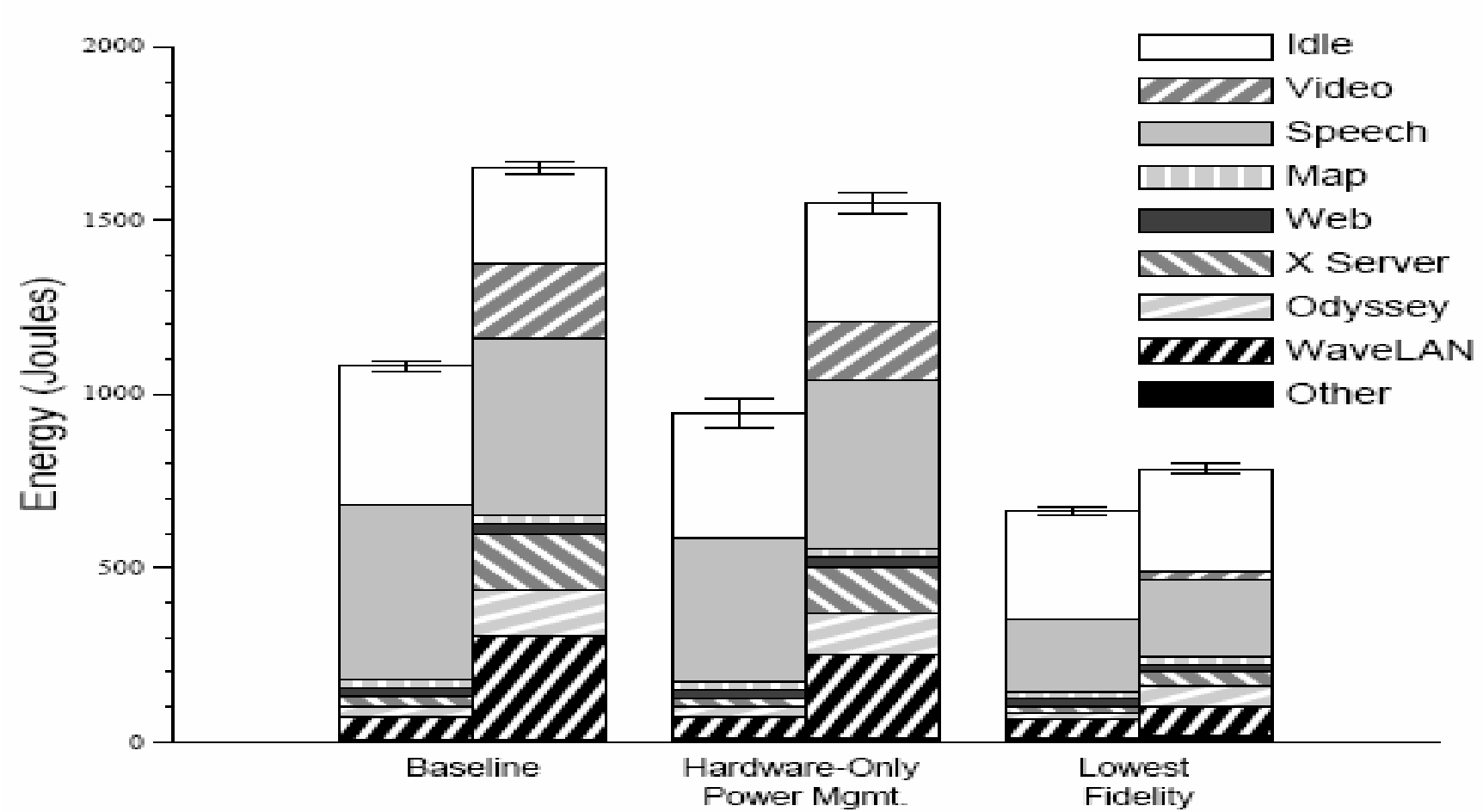
Energy impact of fidelity
Web browser (2/3)



Energy impact of fidelity
Web browser (3/3)



Energy impact of fidelity
Effect of concurrency

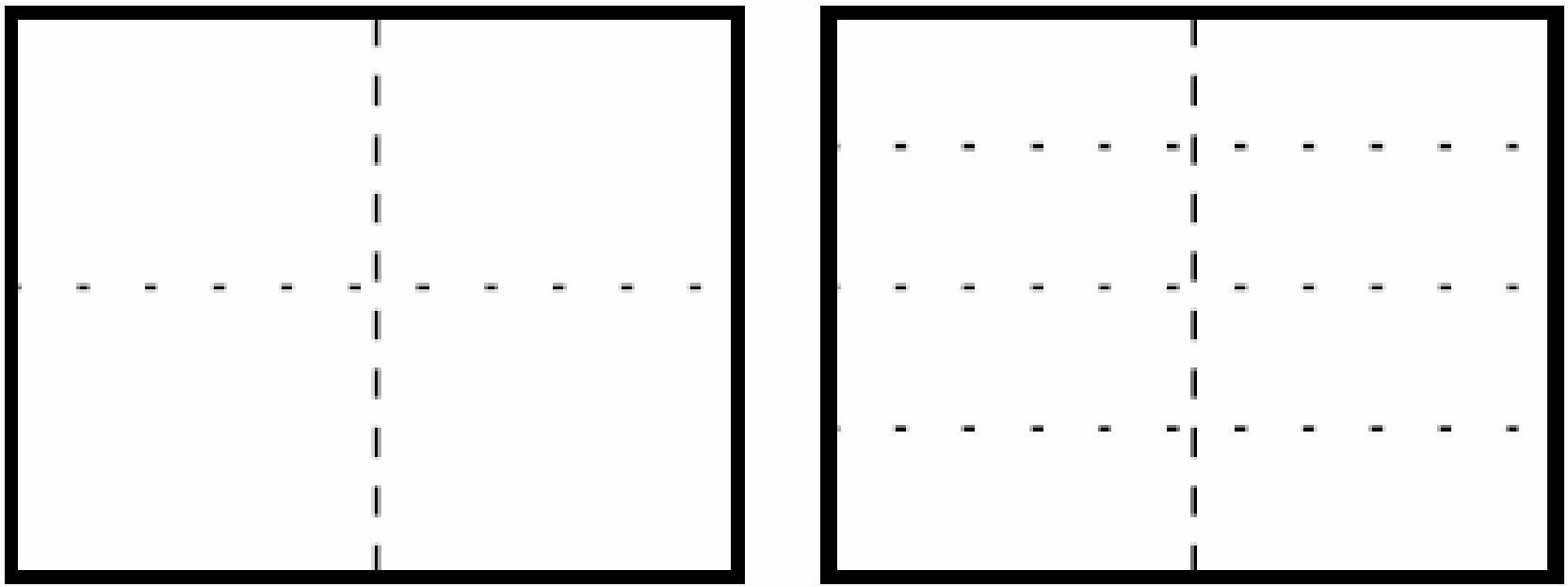


Energy impact of fidelity

Summary

Application	Think Time (s.)	Baseline	Hardware Power Mgmt.	Fidelity Reduction	Combined
Video	N/A	1.00	0.90–0.91	0.84–0.84	0.65–0.65
Speech	N/A	1.00	0.66–0.67	0.22–0.36	0.20–0.31
Map	0	1.00	0.80–1.01	0.06–0.13	0.07–0.18
	5	1.00	0.81–0.91	0.38–0.67	0.31–0.54
	10	1.00	0.74–0.84	0.53–0.77	0.42–0.58
	20	1.00	0.76–0.78	0.69–0.89	0.51–0.67
Web	0	1.00	0.85–1.06	0.40–0.75	0.32–0.54
	5	1.00	0.74–0.78	0.88–0.97	0.66–0.71
	10	1.00	0.75–0.78	0.93–0.98	0.70–0.74
	20	1.00	0.74–0.77	0.96–0.99	0.72–0.73

Zoned backlighting (1/2)



(a) 4-Zone Display (b) 8-Zone Display

Figure 17. Zoned backlighting

Zoned backlighting (2 / 2)

			Hardware-Only Power Management			Combined		
App.	Think Time (s.)	Baseline	No Zones	4 Zones	8 Zones	No Zones	4 Zones	8 Zones
Video	N/A	1.00	0.90–0.91	0.74–0.76	0.74–0.76	0.65–0.65	0.49–0.50	0.46–0.47
Map	0	1.00	0.80–1.01	0.80–1.01	0.75–0.95	0.07–0.18	0.07–0.16	0.06–0.15
	5	1.00	0.81–0.91	0.81–0.91	0.75–0.85	0.31–0.54	0.26–0.45	0.24–0.43
	10	1.00	0.74–0.84	0.74–0.84	0.68–0.78	0.42–0.58	0.39–0.48	0.33–0.46
	20	1.00	0.76–0.78	0.76–0.78	0.70–0.72	0.51–0.67	0.42–0.55	0.40–0.52

Goal-directed energy adaptation (1/2)
Prototype design and implementation

- Primary design goal was to ensure that Odyssey meets the specified time duration whenever feasible.

- Secondary goal is to provide the best user experience possible.
  - Offer as high a fidelity as possible at all times
  - The user should not be jarred by frequent adaptations.

Goal-directed energy adaptation(2/2)

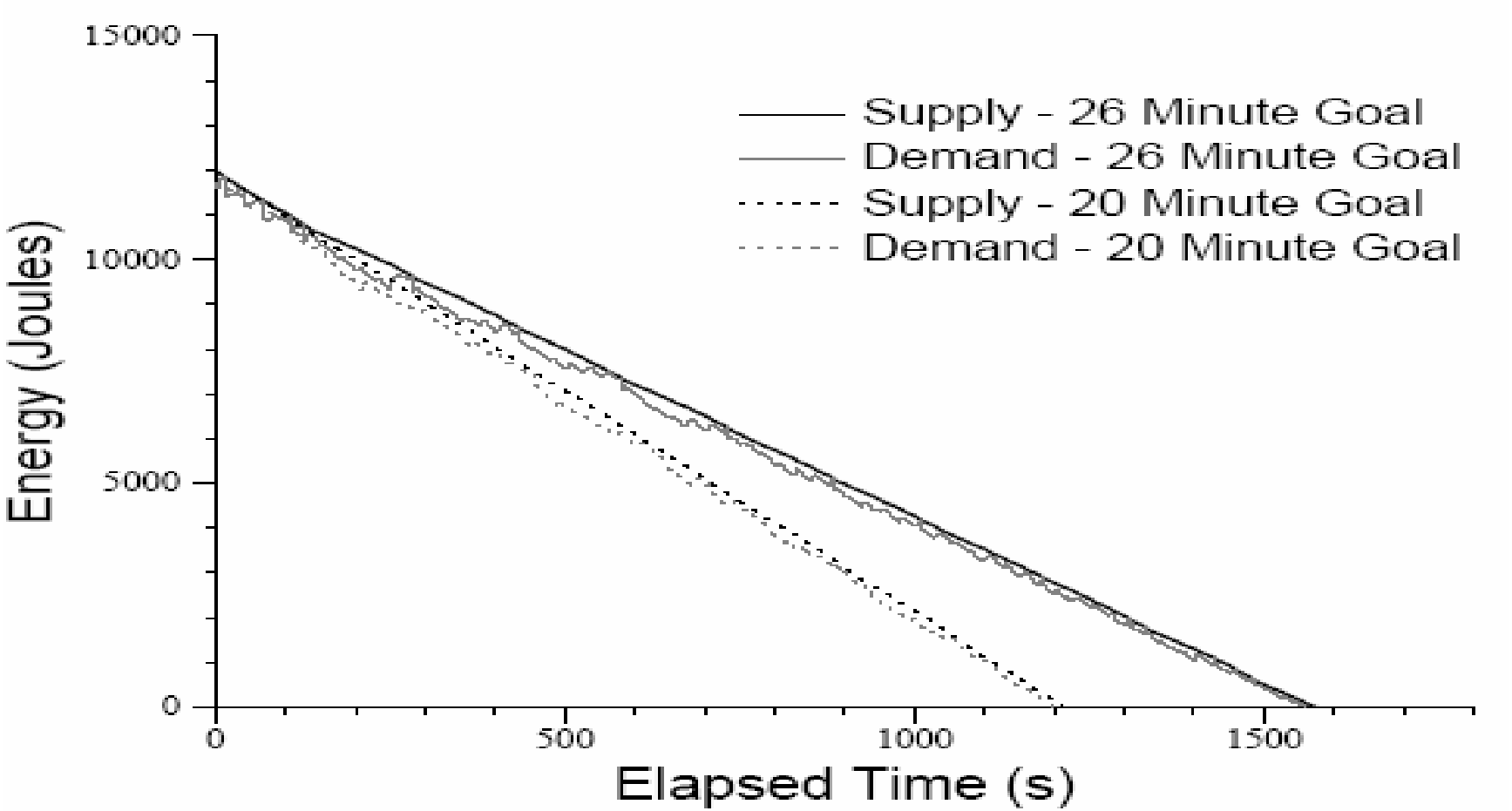
Prototype design and implementation

Achieve those above goals:

- 1. *Determining residual energy*
- *2. Predicting future energy demand*
- *3.Triggering adaptation*

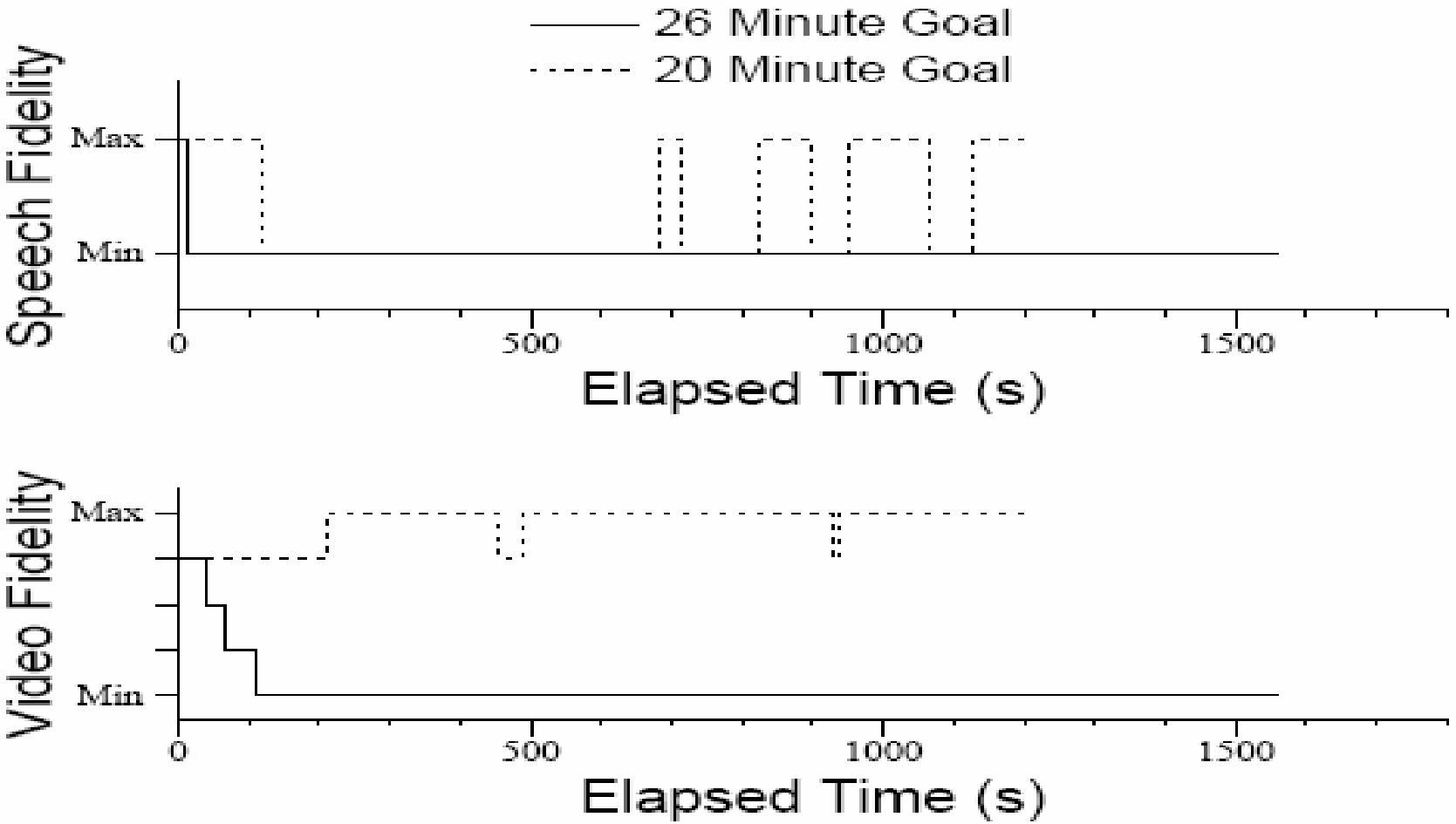
Goal-directed energy adaptation

Validation (1/4)



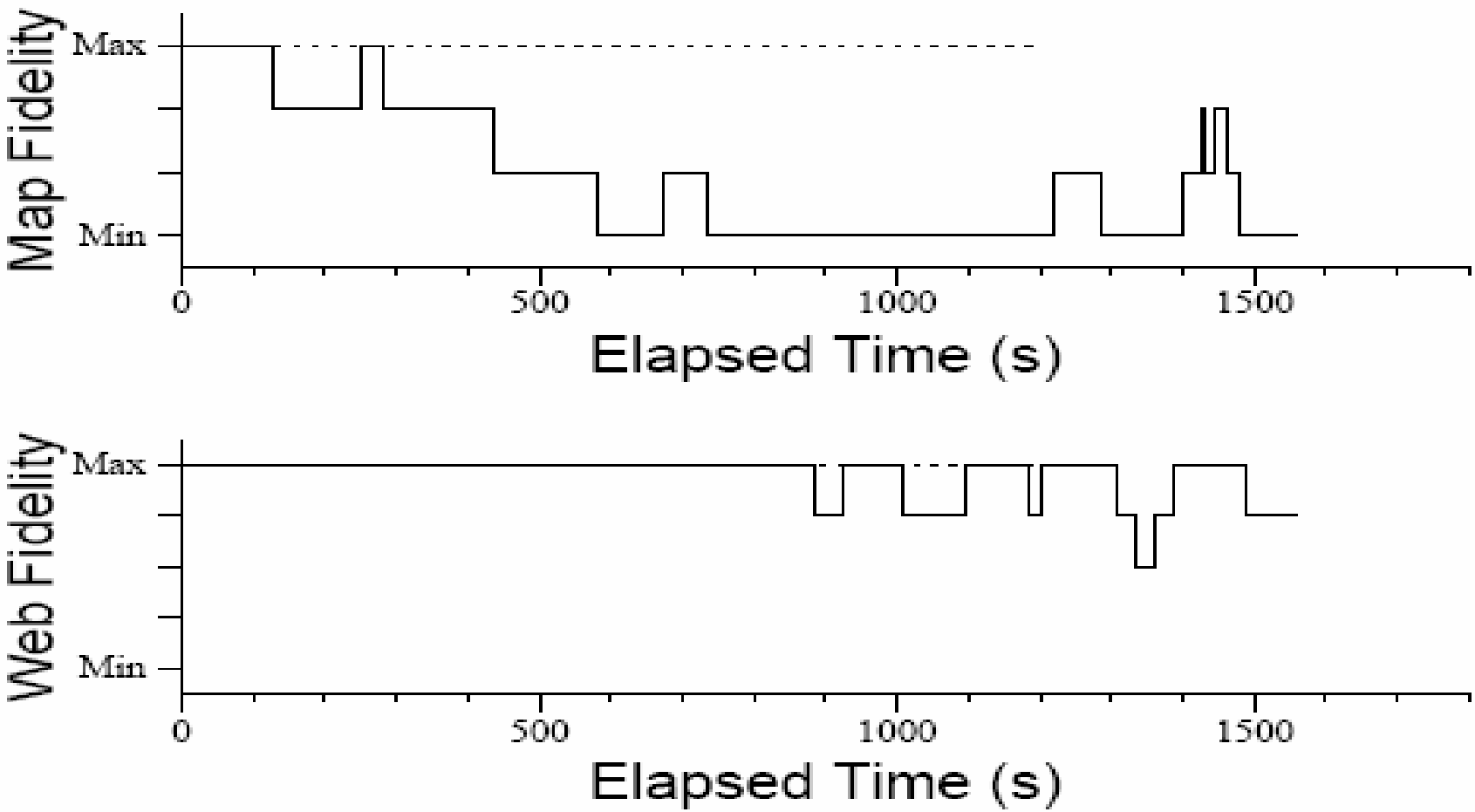
Goal-directed energy adaptation

Validation (2/4)



Goal-directed energy adaptation

Validation (3/4)



Goal-directed energy adaptation
Validation (4/4)

Specified Duration (s)	Goal Met	Residue		Number of Adaptations			
		Energy (J)	Time (s)	Speech	Video	Map	Web
1200	100%	145.2 (25.3)	15.3 (1.9)	10.8 (1.6)	11.0 (4.0)	0.4 (0.9)	0.0 (0.0)
1320	100%	107.5 (61.5)	12.9 (7.2)	2.8 (0.4)	28.2 (5.2)	1.6 (2.6)	0.0 (0.0)
1440	100%	101.2 (22.3)	13.0 (4.5)	5.0 (7.9)	22.6 (9.8)	9.6 (3.8)	1.2 (1.8)
1560	100%	60.2 (28.7)	8.7 (5.9)	1.0 (0.0)	6.0 (2.8)	15.4 (4.6)	7.6 (5.9)

Goal-directed energy adaptation

Sensitivity to half-life

- *new* = (1- α)(this sample)+(α) χ(old)

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)

Goal-directed energy adaptation
Longer-duration experiments

Trial	Goal Met	Residual Energy (J)	Number of Adaptations			
			Speech	Video	Map	Web
1	Yes	345	1	5	5	1
2	Yes	381	1	10	7	11
3	Yes	2486	8	13	5	0
4	Yes	554	2	10	6	8
5	Yes	464	5	6	14	0

Conclusion (1/2)

- Energy-aware adaptation introduces flexibility into this overconstrained solution space.
- Odyssey can be effectively combined with hardware-centric approaches proposed by other researchers.

Conclusion (2/2)

- Many ways in which this work can be extended :
  - explore the robustness of results across diverse platforms.
  - to broaden the range of mobile applications studied.
  - to verify that these results apply in real life.