Vertigo: Automatic Performance-Setting for Linux

Krisztián Flautner
ARM Limited, Cambridge, UK
Trevor Mudge
The University of Michigan

Presented by Choi Hojung

Background(1)

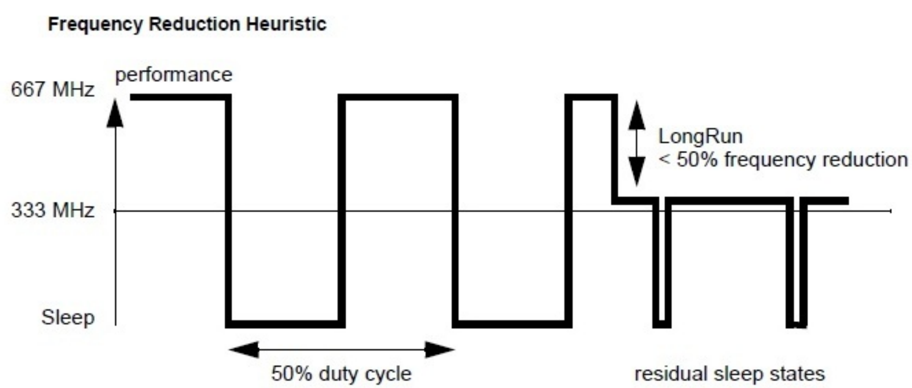
- In 2002
  - need for low power and high performance processors
  - from embedded computers to servers
  - high performance
  - battery operated

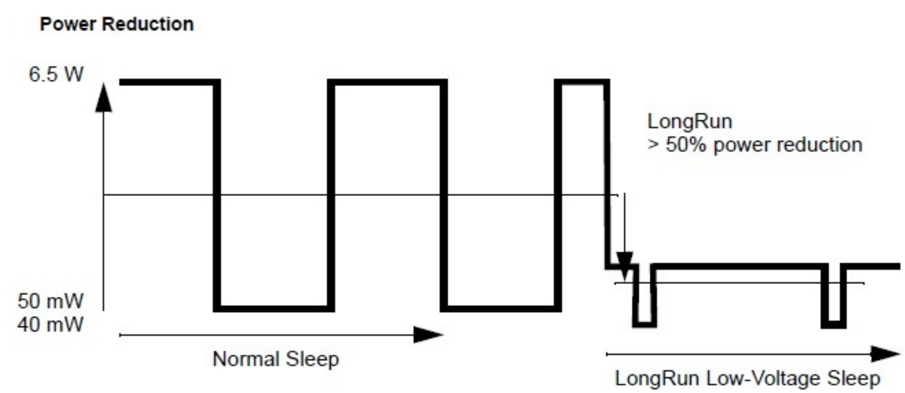
Background(2) – Intel SpeedStep

- SpeedStep by Intel
  - No built-in performance-setting policy
  - A simple approach by the usage model
  - When on AC power, processor runs at higher speed.
  - When on battery power , processor runs at a slower speed, thus saving battery power

Background(3) - LongRun

- LongRun for Crusoe™, by Transmeta
  - power management that dynamically manages the frequency and voltage levels at runtime
  - use historical utilization to guide clock rate selection
  - in processor’s firmware
  - interval-based algorithm





Background(4) - LongRun

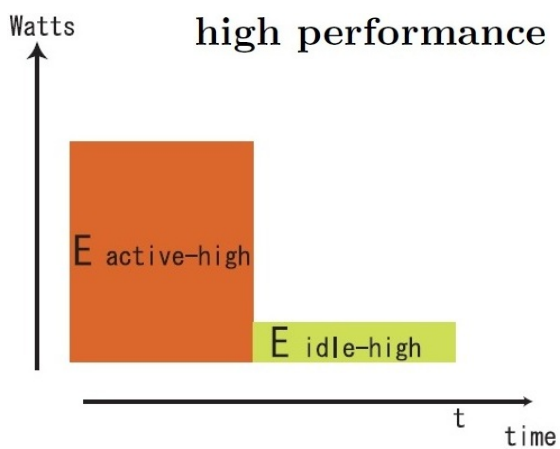
- Flaws & Questions
  - in Processor's firmware
  - utilization periods can be obscured when all tasks are observed in the aggregate
  - not have any information about interactive performance in operating system level
  - a single algorithm perform well under all conditions

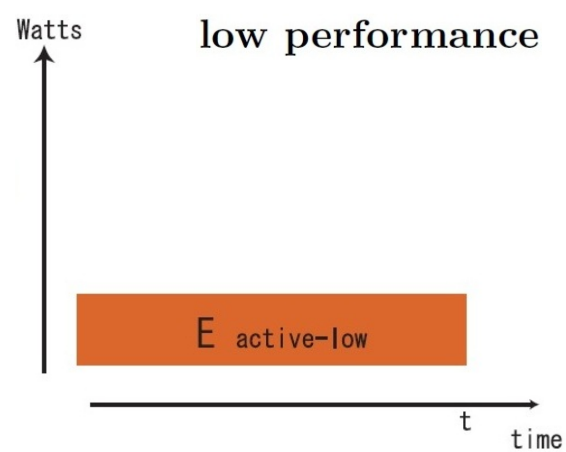
Background(5) - DVS

- Dynamic voltage scaling(DVS)
  - also called Dynamic Voltage and Frequency Scaling(DVFS)
  - reduces the power consumed by a processor by lowering its operating voltage

$$P = C \cdot f \cdot V_{DD}^2$$

  - P : power consumption - V : the supply voltage
  - C : the capacitance - f : operating frequency





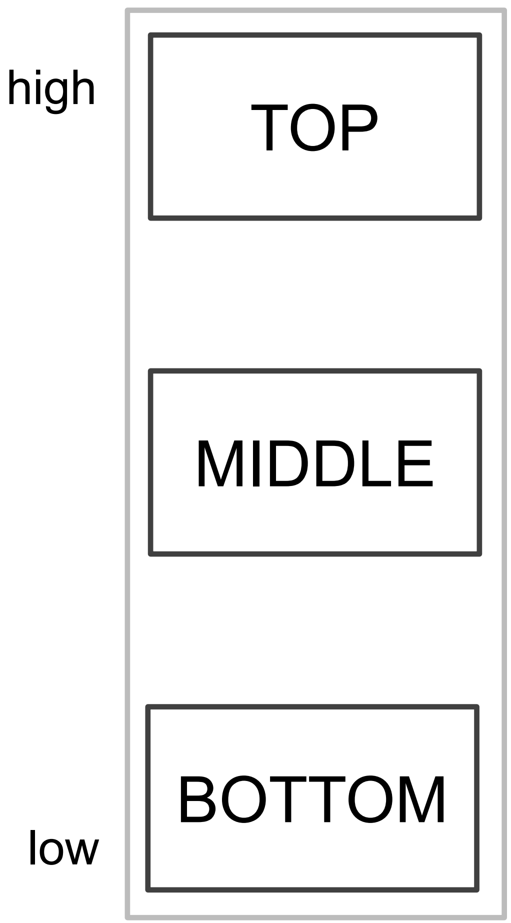
Proposed

- What Vertigo proposed
  - Implemented in OS kernel level to use a richer set of data for prediction
  - to reduce the processor's performance level only when it is not critical to meeting the deadline
  - ensure good interactive performance without undue delay

Design(1) - Vertigo

- Vertigo: multiple performance-setting algorithms

a decision hierarchy



the interactive algorithm

an algorithm for automatically quantifying the performance requirements of interactive apps

the application specific layer

where DVS-aware applications can submit requirements

the perspective algorithm

attempts to estimate the future utilization of the processor based on past information

Design(2) - Keeping track of work

- full-speed equivalent work done
  - to estimate how long a given workload would take running at the peak performance of a processor.

$$Work_{fse} = \sum_{i=1}^{n} t_i p_i$$

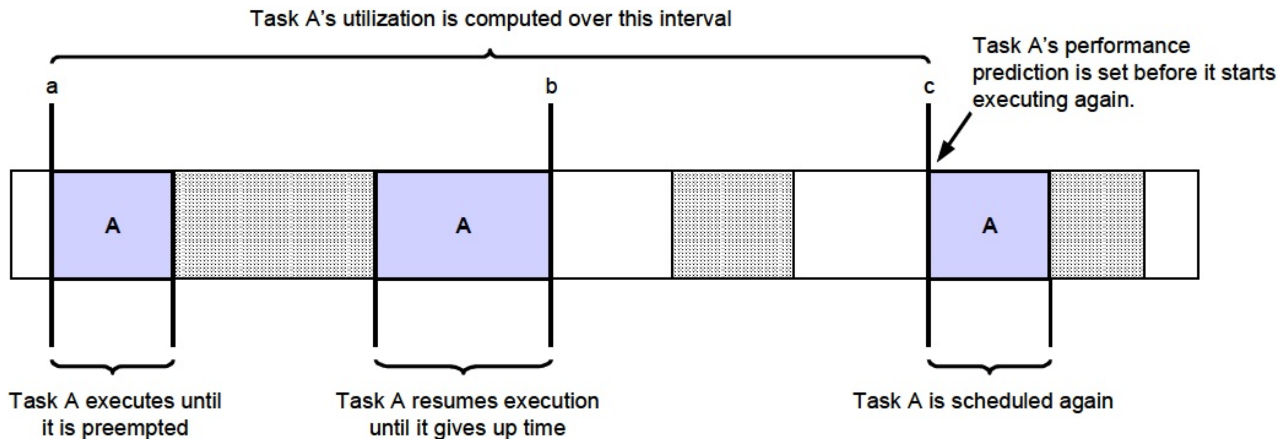
  - *i* : one of the *n* different performance levels during a given interval
  - t_i : non-idle time spent at that performance level in seconds
  - p_i : frequencies specified as a fraction of peak performance.

Design(3) – Perspectives-based algo

- a perspectives-based algorithm
  - at the lowest level in the policy stack
  - aims to derive a rough approximation for the necessary performance level of the processor
  - computes performance predictions from the perspectives of each task
  - uses the combined result to control the performance-setting of the processor

Design(4) - Perspectives-based algo

- Measuring the utilization for task A



– the per-task data structures initialized

a. current state of work counter
b. current state of idle time counter
c. current time
d. a run bit that task has started running

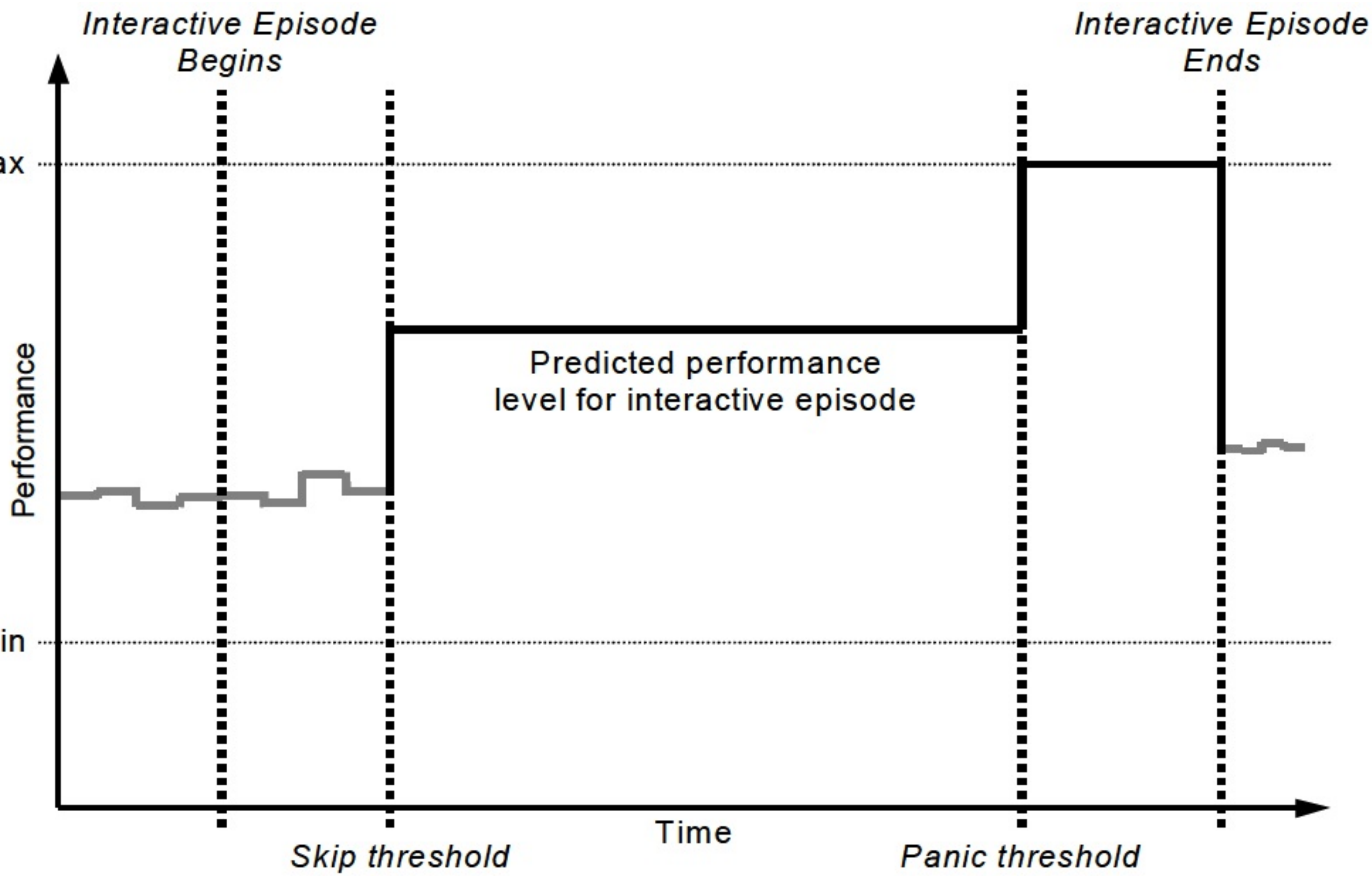
$$Perf = \frac{WorkEst}{Deadline}$$

Design(5) - Interactive applications

- Strategy for ensuring good interactive performance
  - to find the periods of execution that directly impact the user experience
  - to ensure that these episodes complete without undue delay
- How Vertigo detects interactive applications
  - interactive episodes signified by a GUI event
  - by monitoring the appropriate system calls

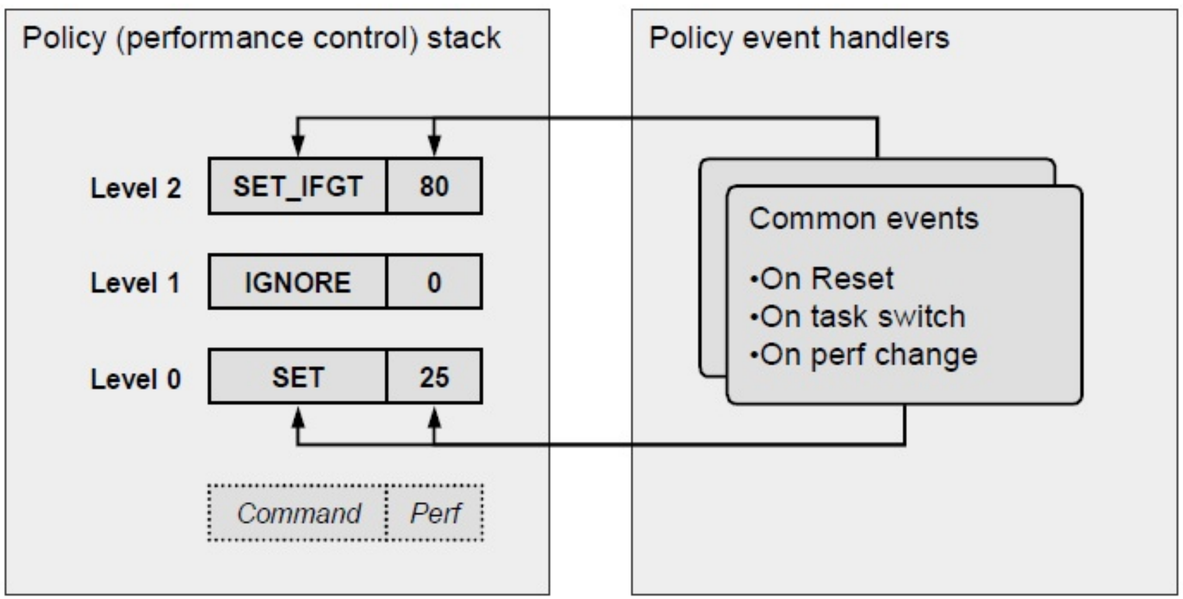
Design(6) - Interactive applications

- the strategy for setting the performance level during an interactive episode

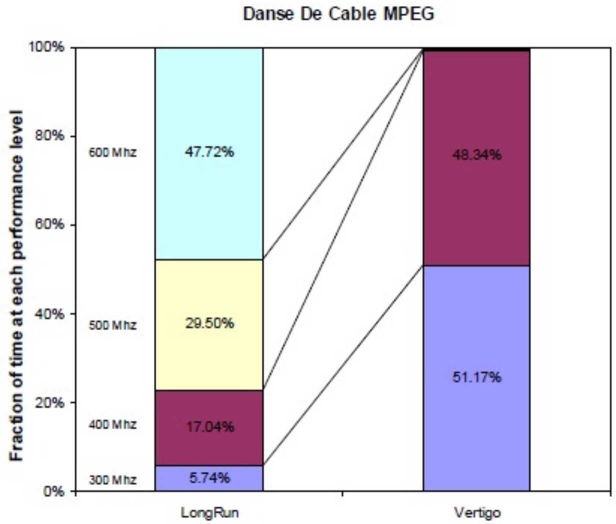


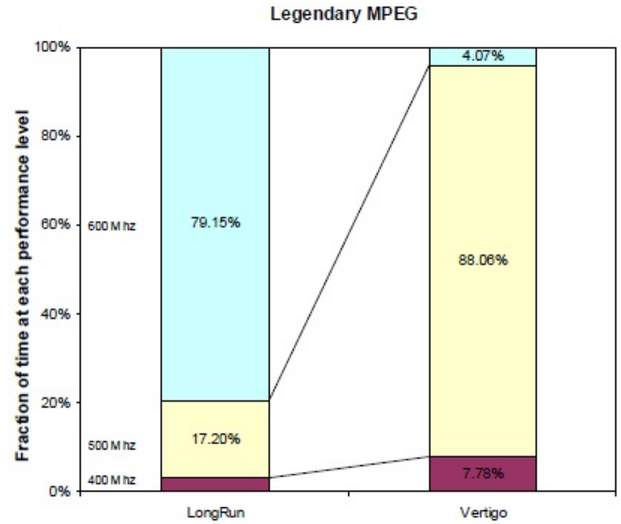
Design(7) – Policy stack

- How policy stack works
  - a mechanism for supporting multiple independent performance-setting policies in a unified manner
  - a policy requests performance level with command
  - When a new level request arrives, commands on the stack evaluated bottom to up to compute



Evaluation(1) - MPEG

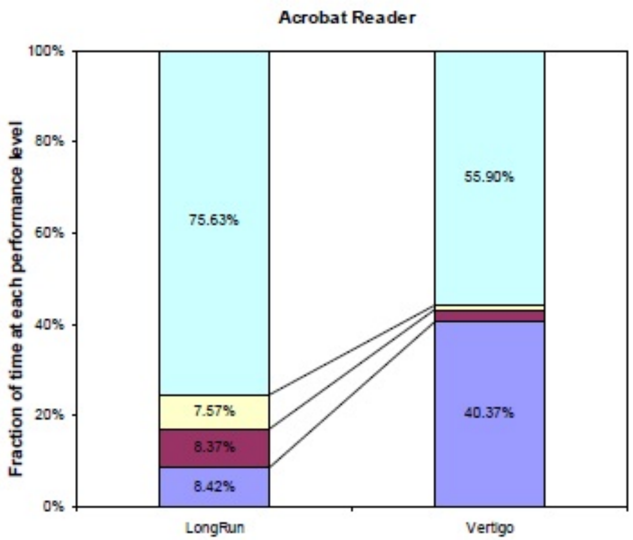


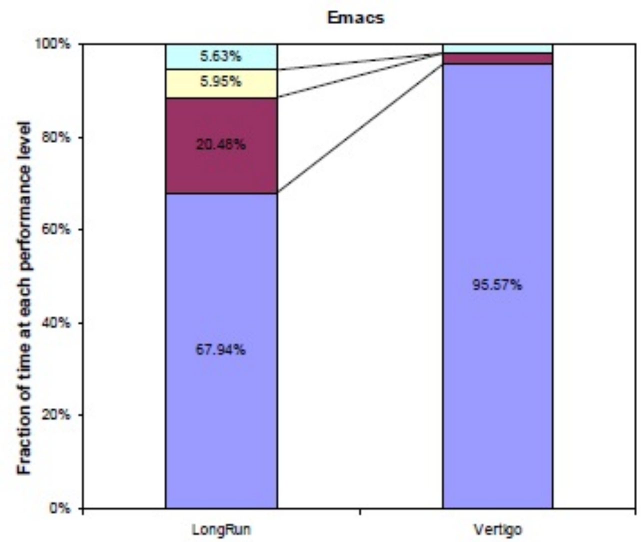


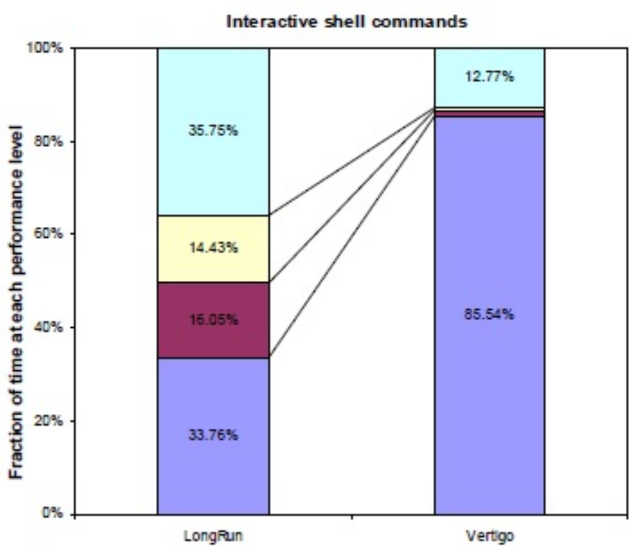
		Execution statistics			MPEG decode	
		Length (s)	Idle	Sleep	Ahead (s)	Exactly on time
Danse De Cable 320x160 +audio	LongRun	247.1	54%	23%	148.10	6
	Vertigo		27%	4%	68.74	1012
Legendary 352x240 +audio	LongRun	19.4	33%	13%	7.20	19
	Vertigo		24%	7%	4.79	65

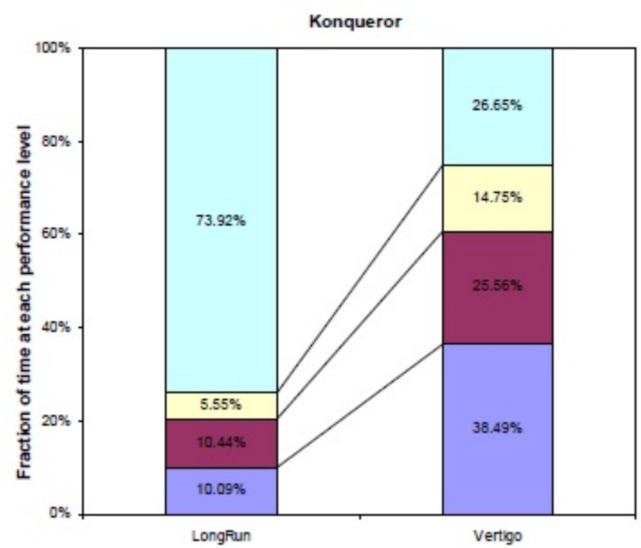
	LongRun					Vertigo					Mean performance reduction over LongRun
	Fraction of time at each performance level (Mhz)				Mean perf level	Fraction of time at each performance level (Mhz)				Mean perf level	
	300	400	500	600		300	400	500	600		
Danse De Cable	6%	19%	33%	**54%**	89%	**51%**	48%	0%	0%	59%	**34%**
Legendary	0%	3%	17%	**79%**	96%	0%	8%	**88%**	4%	82%	**15%**

Evaluation(2) – interactive workload









Conclusions

- LongRun
  - in processor's firmware
  - interval-based algorithm
- Vertigo
  - first approach to implement DVFS in SW level
  - multiple performance-setting algorithms
- LongRun vs Vertigo
  - Both implement DVFS technology
  - a 11%~35% average performance level reduction by Vertigo over LongRun
  - Vertigo can makes decisions based on a richer set of run-time information
  - LongRun has crucial advantage of being OS agnostic

Questions?