Power Versus Quality Trade-offs for Adaptive Real-Time Applications

ES Week - ESTIMedia

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Overview

- Introduction
- Problem statement
- Quality scaling to meet constraints
- Applied to an H.263 decoder
- Evaluation
- Conclusions

Introduction

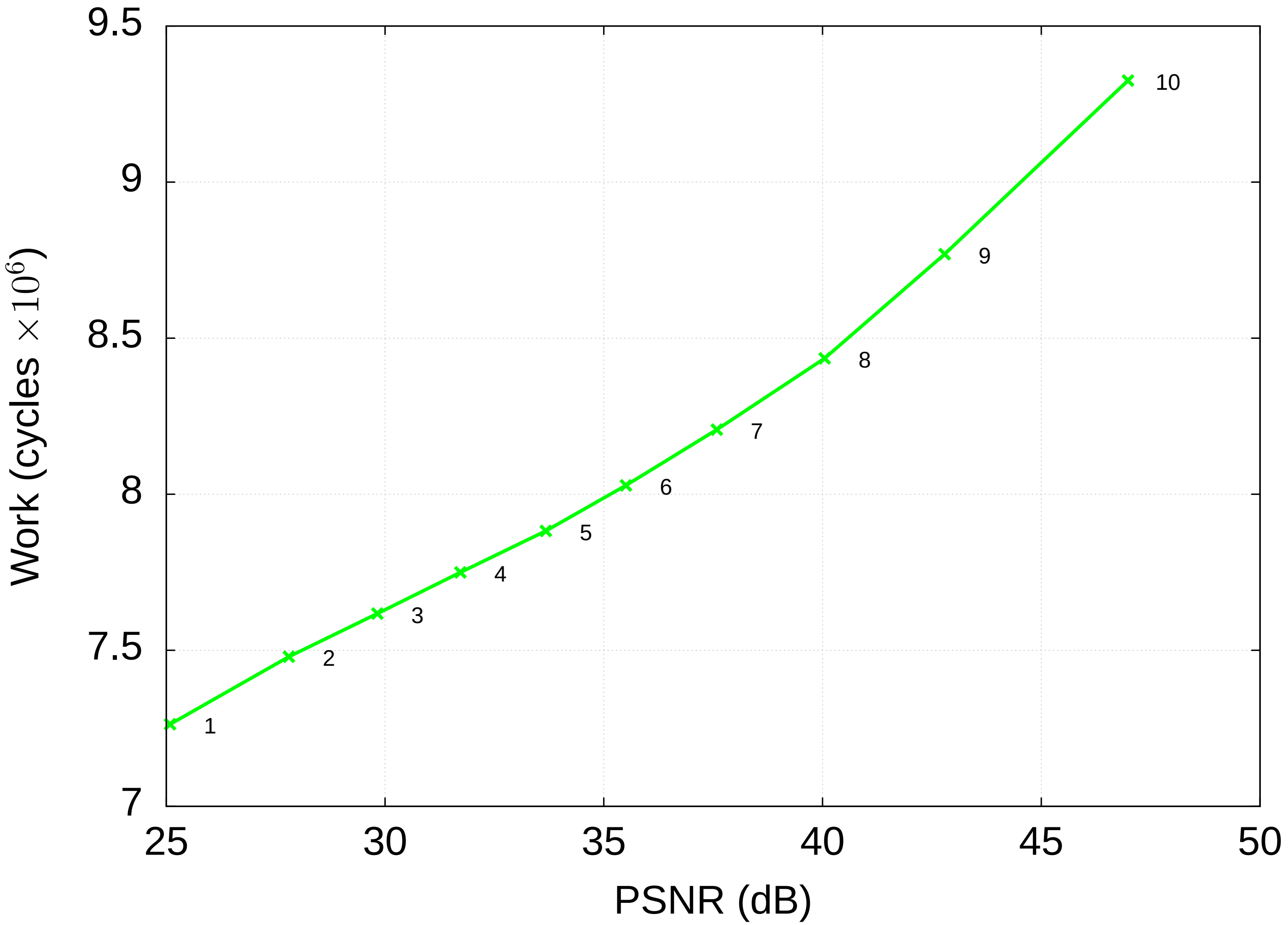
- In embedded systems energy and power is a concern
- Many systems are energy and power constrained
  - e.g. Battery powered devices
- Dynamic Voltage and Frequency Scaling (DVFS) is a common method to lower power consumption
  - Increases execution times
  - Therefore more complicated for real-time systems
- Many DVFS techniques exist for real-time systems
  - e.g scale VF assuming worst-case work

The Problem

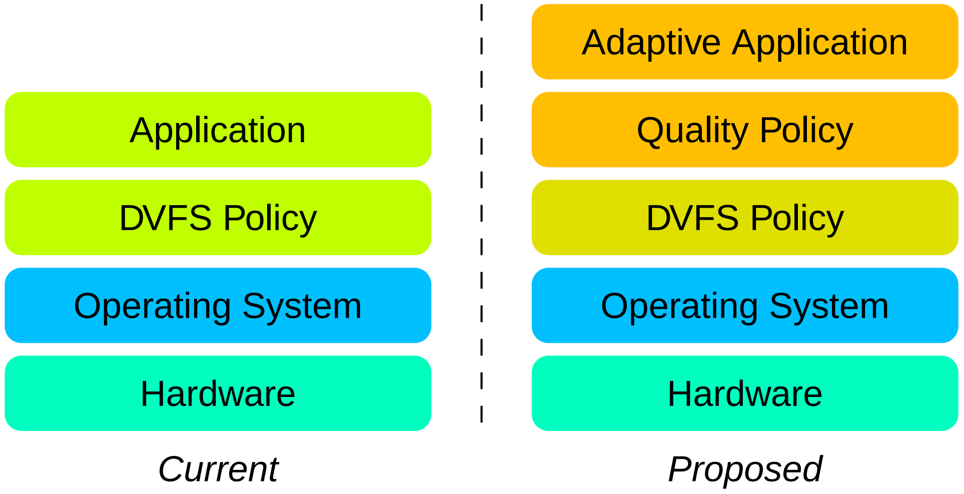
- Adaptive applications with scalable algorithms enable trading output quality for a reduction in work
- Parametrised adaptive algorithms enable controlled quality scaling

- **How to use adaptive-application quality-scaling to meet temporal/energy/power constraints?**

Parametrised Quality-Levels

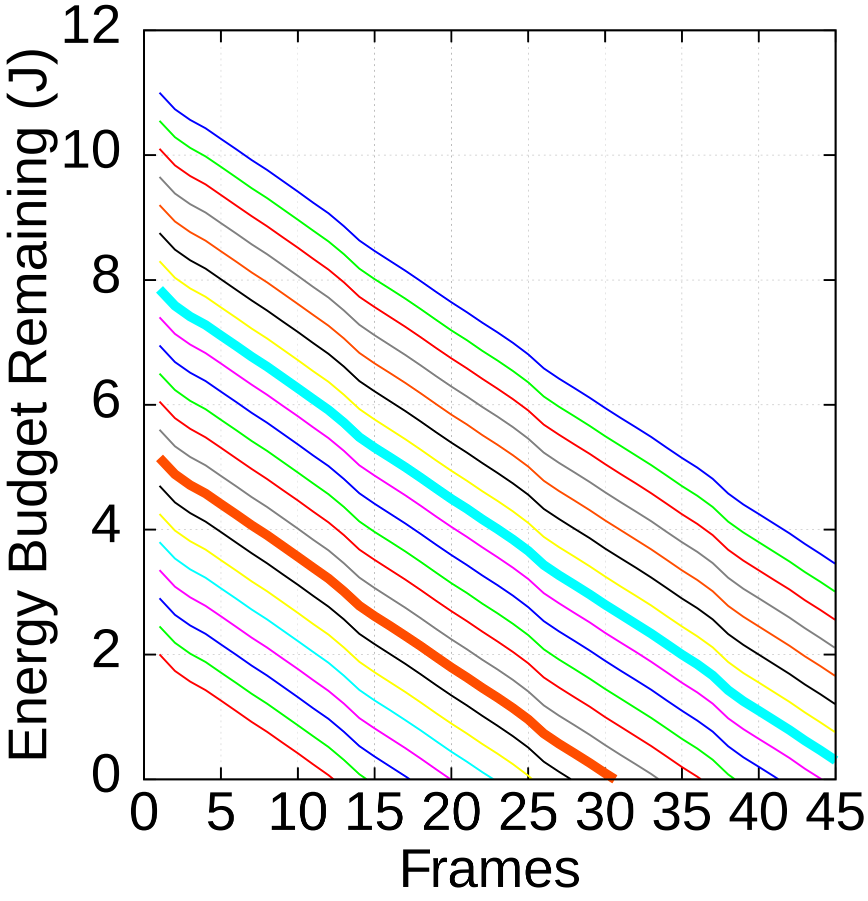


What We Propose

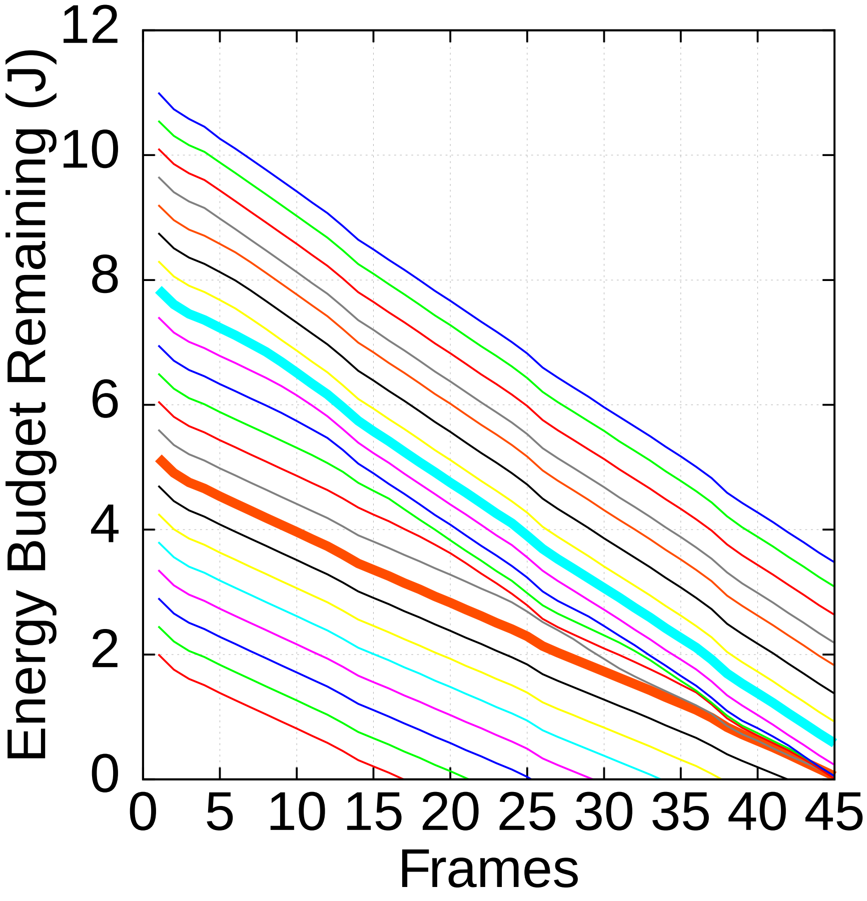


- We propose a run-time control method
  - using existing real-time DVFS techniques
  - for quality scalable adaptive applications
  - to trade quality for energy/power consumption

H.263 Decoder Example



No Quality Scaling



Quality Scaling

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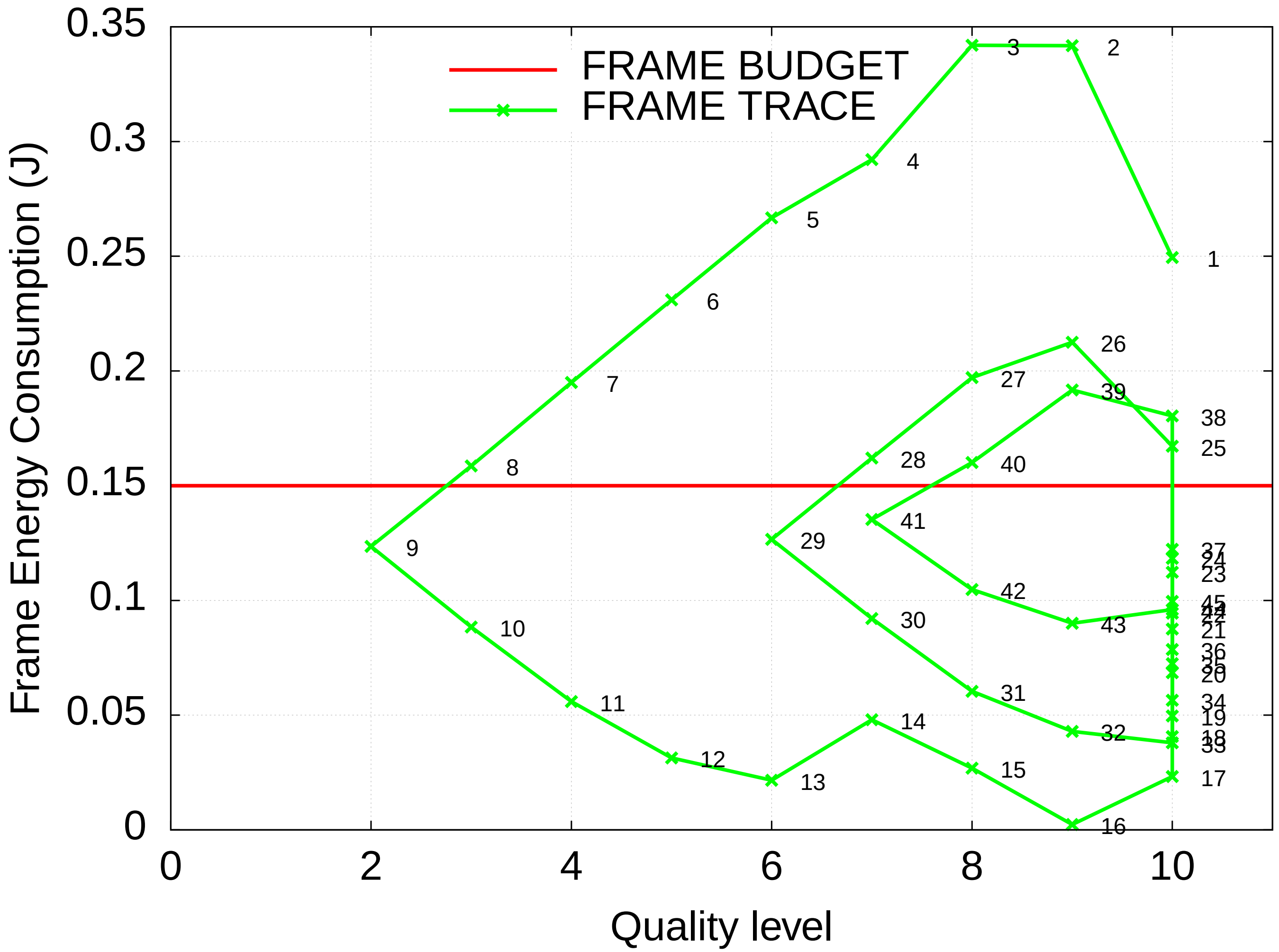
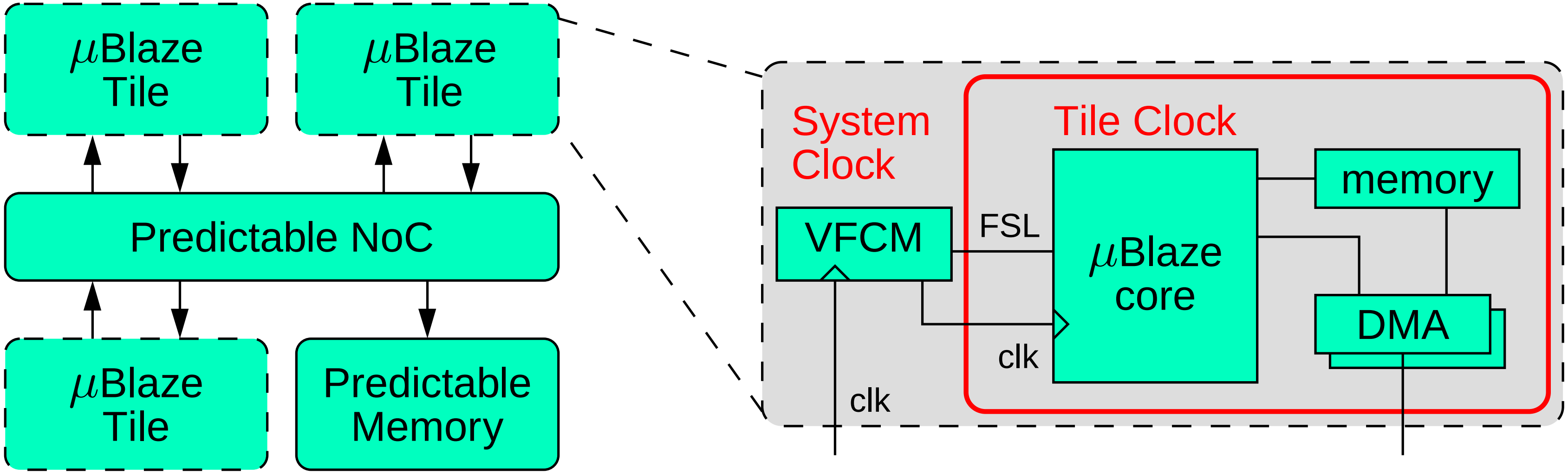
Quality Scaling to Meet Constraints

- Constraints represented as budgets
  - Work budget in $\text{Cycles}_{\text{fmax}}$
  - Energy budget in Joules
- Budgets deplete at run-time
- Choose quality-level from budget levels
  - $\downarrow$Quality $\Rightarrow$ $\downarrow$Work
  - $\downarrow$Work budget consumption $\Rightarrow$ $\uparrow$slack
  - $\uparrow$slack $\Rightarrow$ $\downarrow$Voltage/Frequency $\Rightarrow$ $\downarrow$Power

H.263 Decoder Quality-Scaling

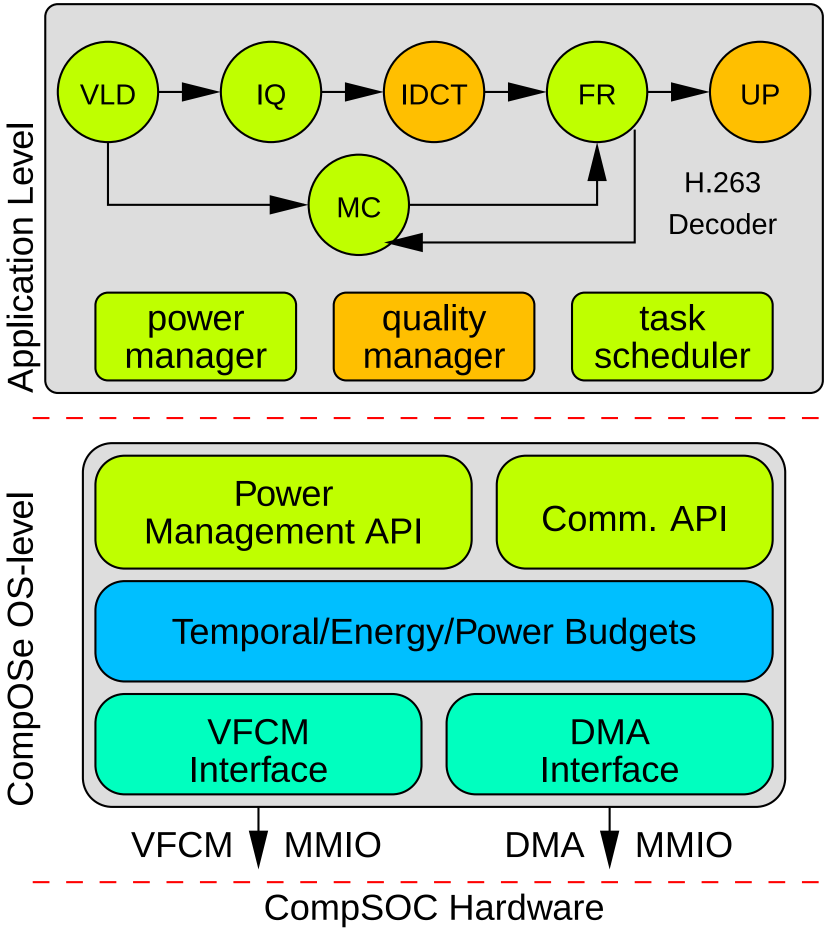


CompSOC Hardware Platform

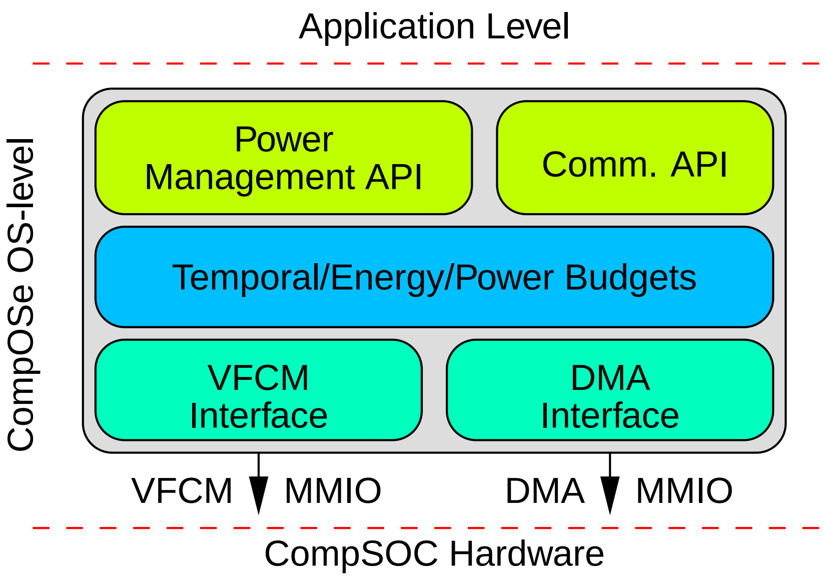


- Tile based architecture
- Voltage and Frequency Control Module (VFCM)
  - Provides per-tile DVFS
  - 16 available VF levels

CompSOC Software Level

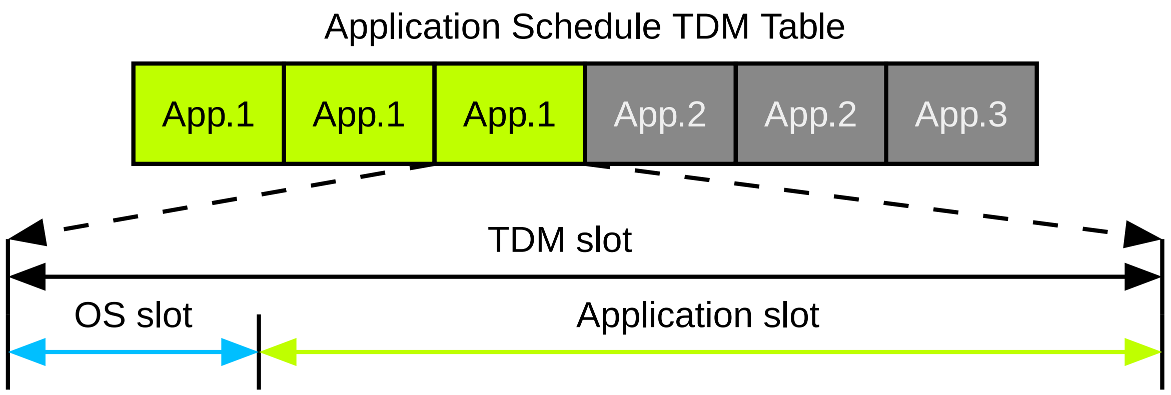


CompOSe Operating System



- Maintains application budgets
- Provides APIs to budgets and hardware
- Composable TDM scheduling of multiple applications

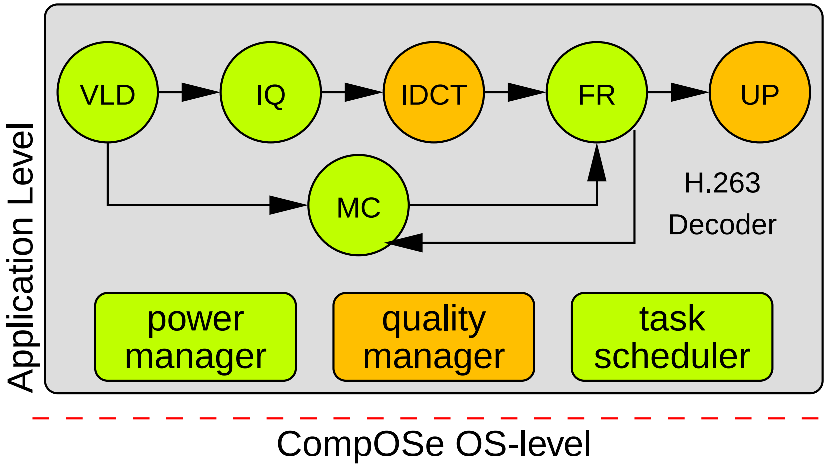
Calculating a Suitable Work Budget



$$\text{Work Budget} = \left\lfloor \frac{\text{Constraint}}{\text{Table Length}} \right\rfloor \times (\text{App. Slots} \times \text{App. Slot Length})$$

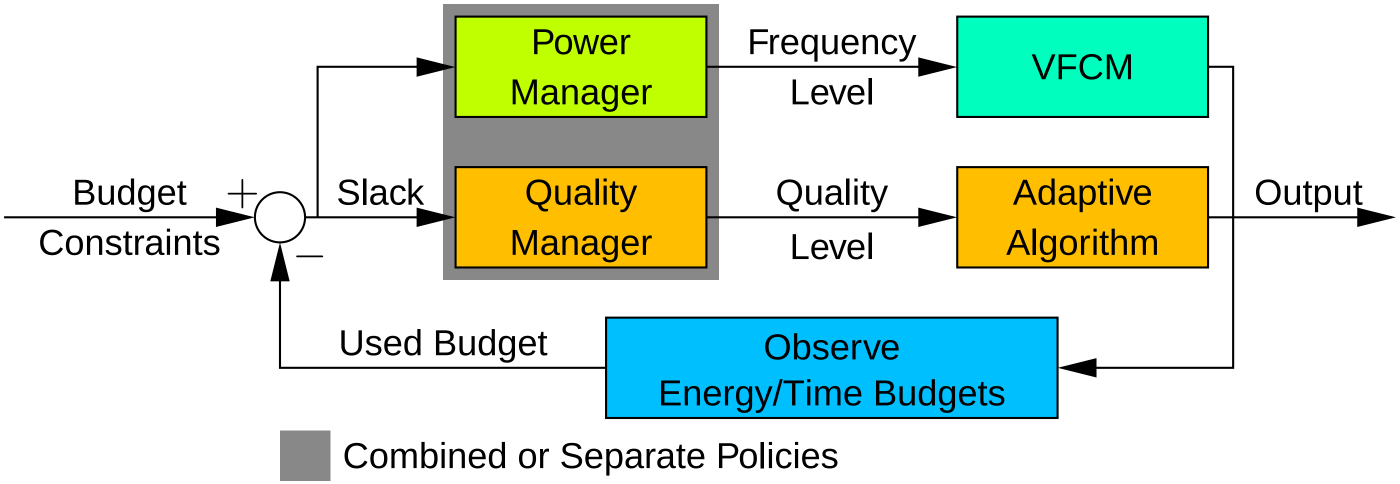
- Calculate No. complete TDM tables that can execute within the constraint
- Multiply this by the amount of service the App. gets in a table iteration

H.263 Decoder Application



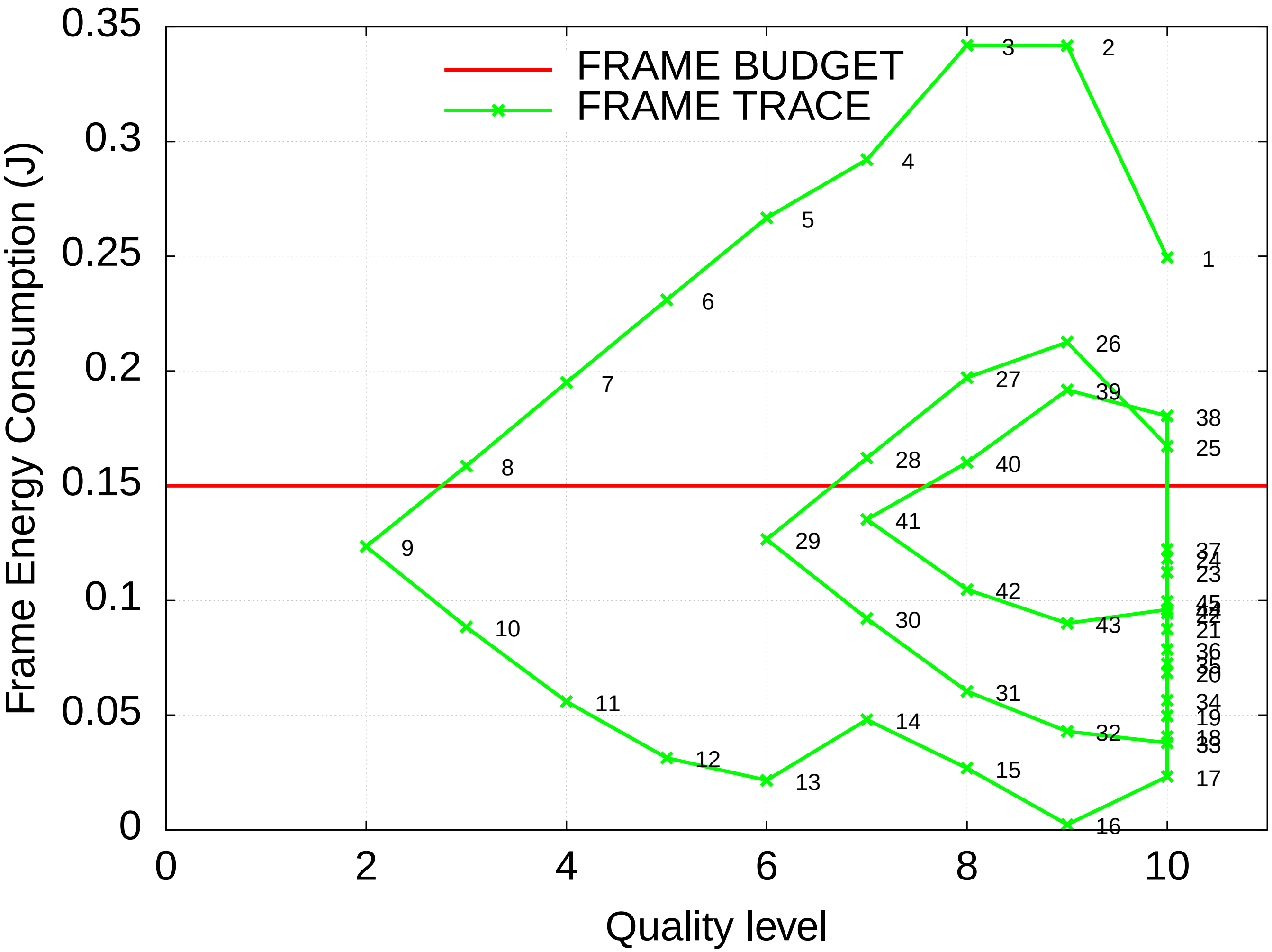
- Modelled as a Synchronous DataFlow (SDF) graph
- Tasks annotated with worst-case work
- Static-order scheduling of tasks
- Application-level *power* and *quality* managers

Quality/Power Control Flow

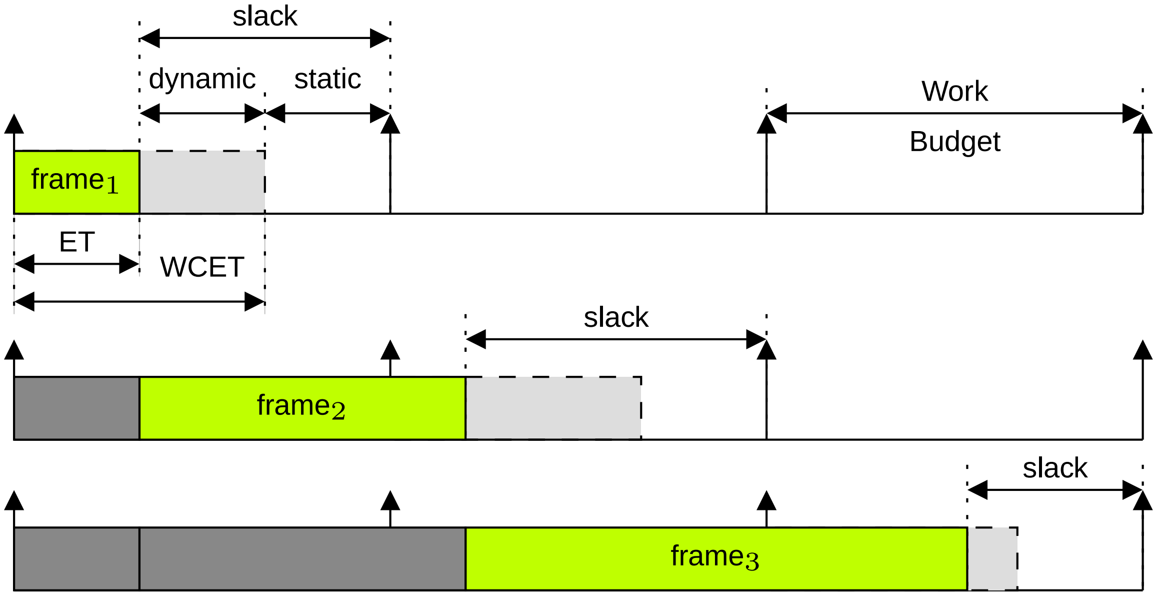


- Executed at run-time
- Calculates slack using observed budgets
- Quality and Power management granularity may differ
- Supports intra-application mixed criticality constraints

H.263 Decoder Quality-Management



Power Management



$$\text{slack} = \text{Work Budget} - \text{ET}$$

$$\text{frequency} = \left\lceil \frac{\text{WCET} \times \text{No. freq. levels}}{(\text{slack} + \text{WCET})} \right\rceil \times \frac{\text{Max. freq.}}{\text{No. freq. levels}}$$

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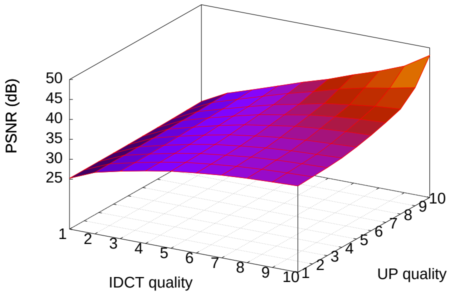
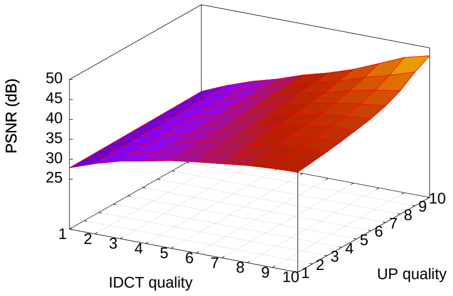
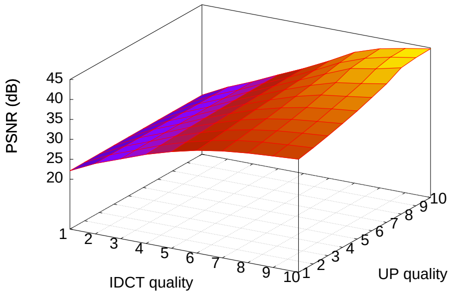
H.263 Quality-Scaling Evaluation



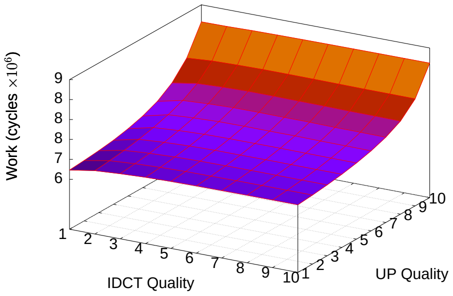
(a) Akiyo PSNR.



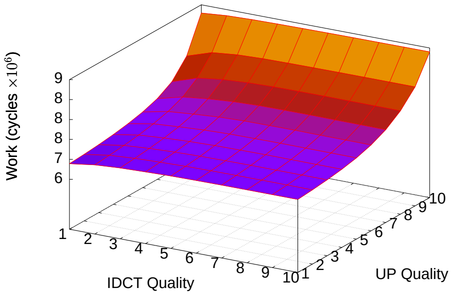
(b) Tree PSNR.



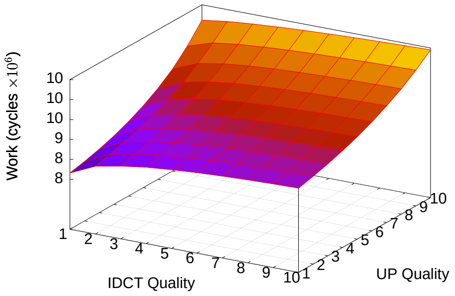
(c) Bus PSNR.



(d) Akiyo work.

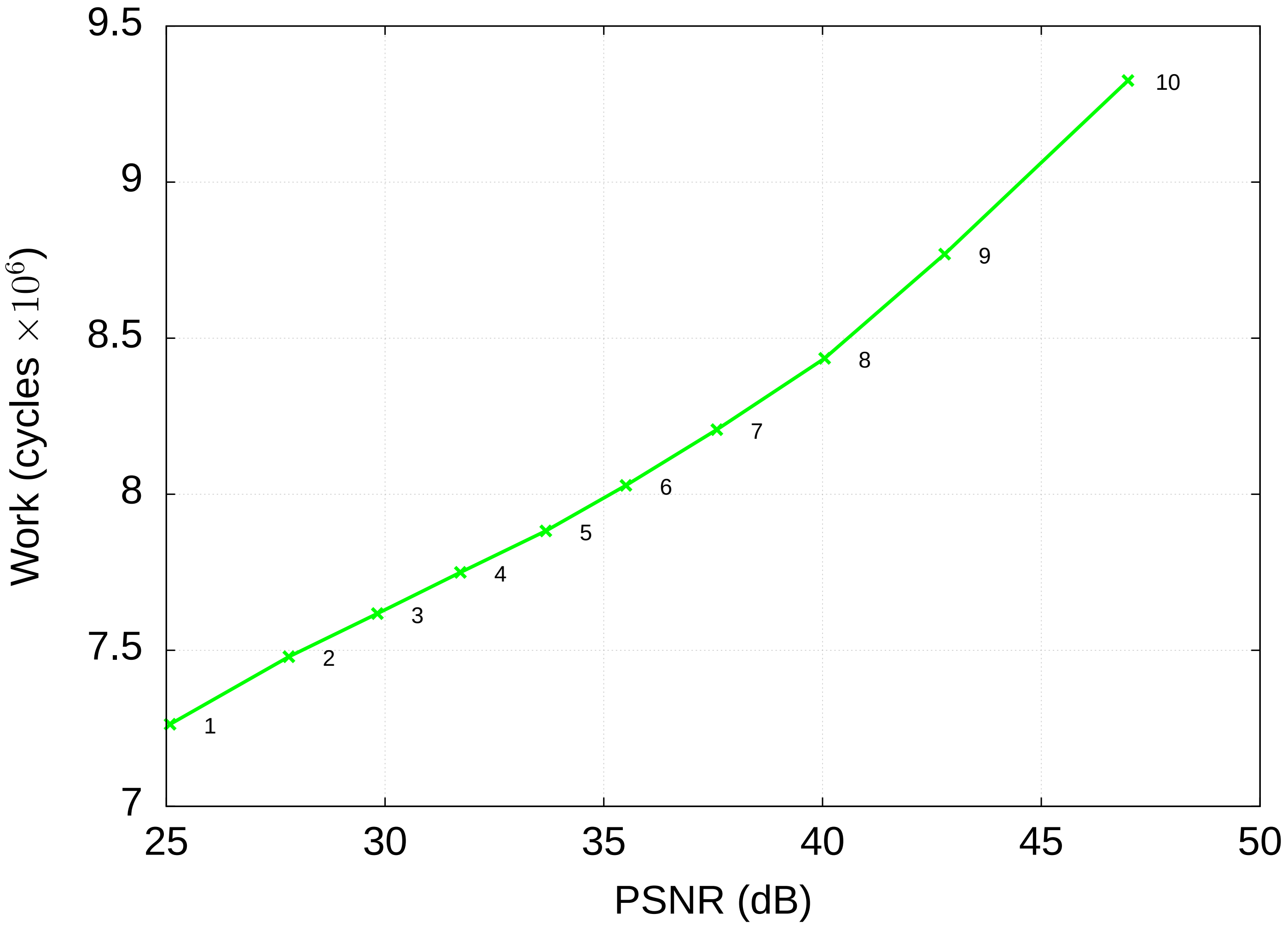


(e) Tree work.



(f) Bus work.

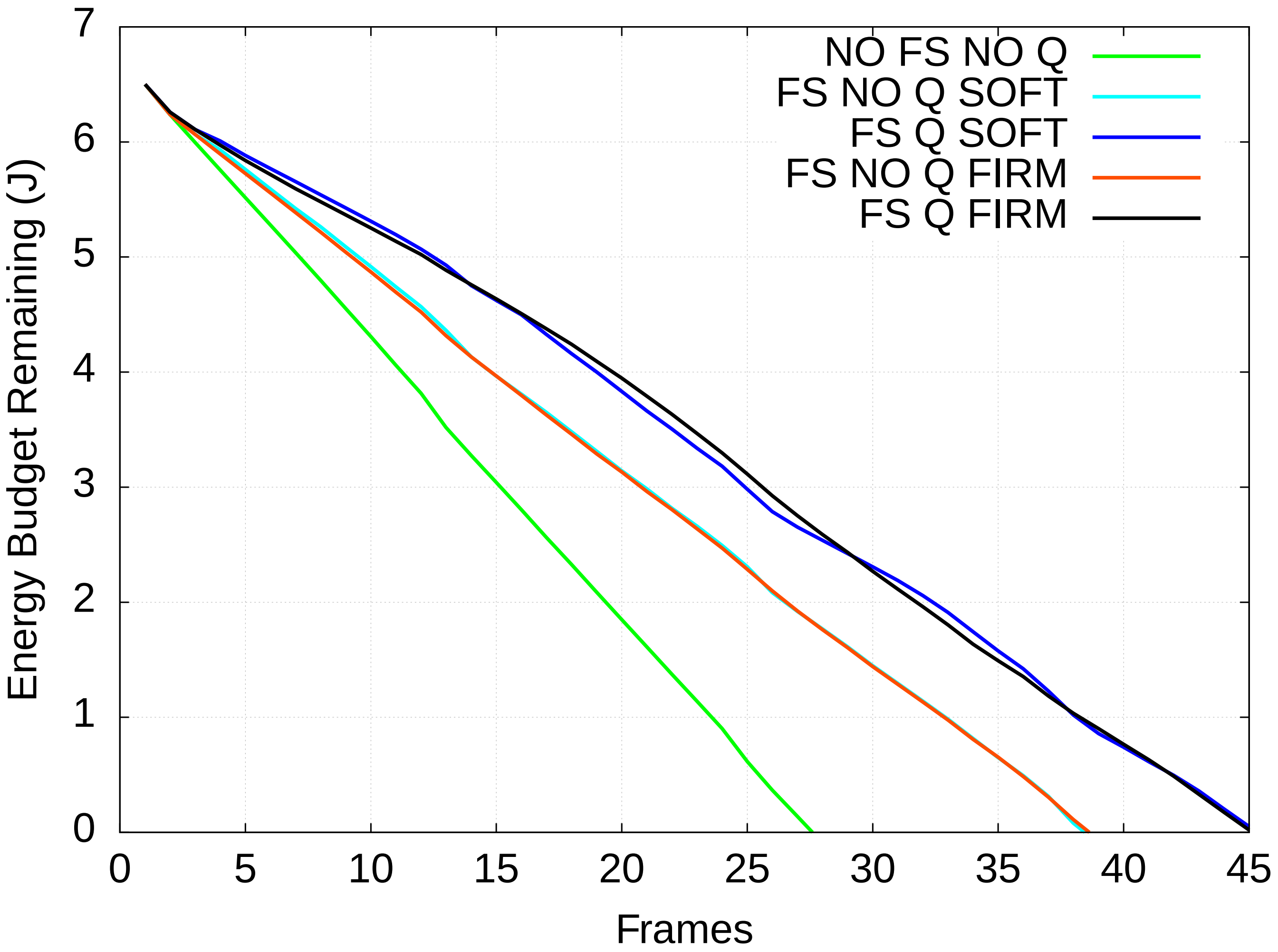
Selected Quality-Levels



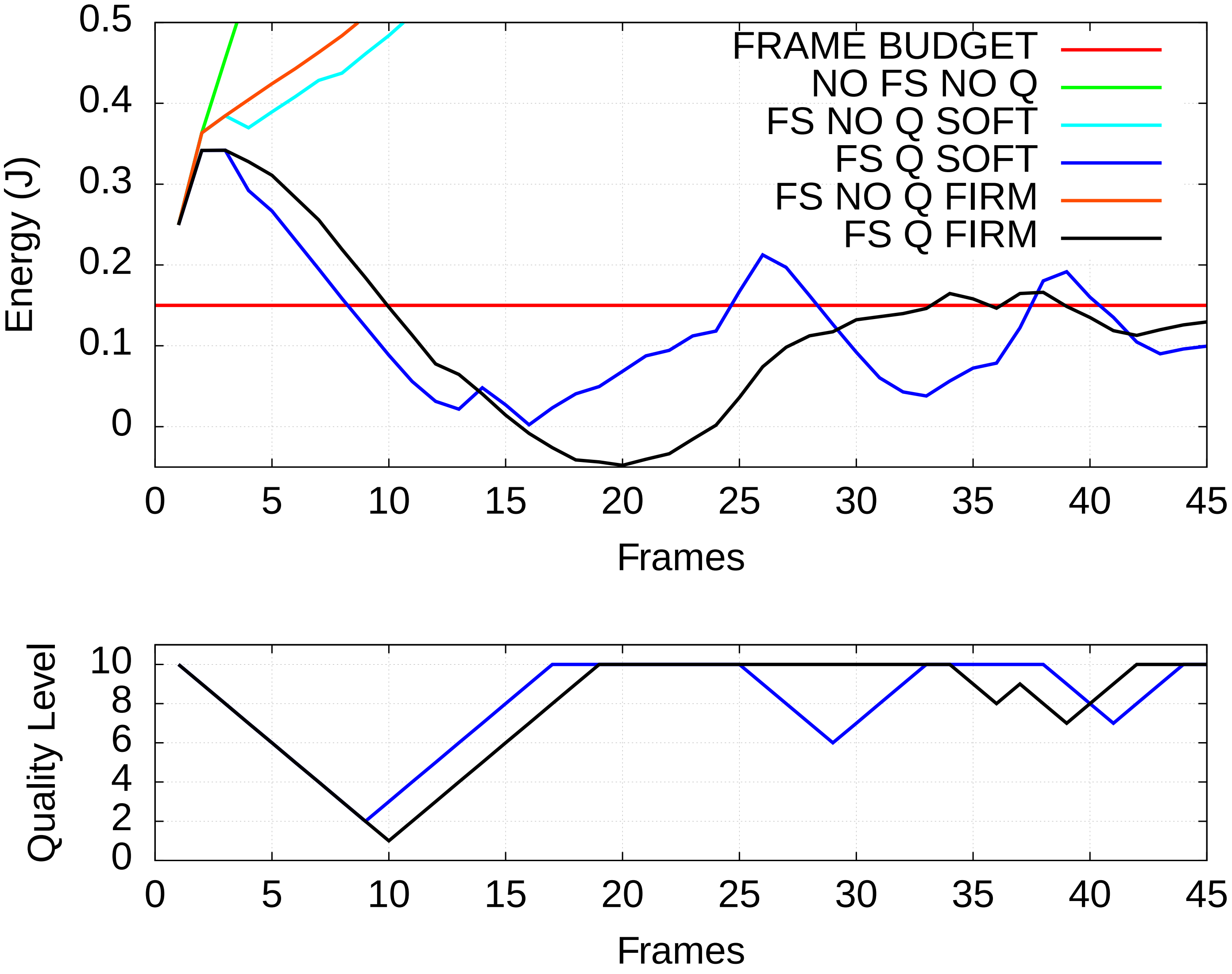
H.263 Energy/Time Constraints

- Energy budgeted as 6.75J for 45 frames
  - Soft energy constraint
- Frame rate of 10fps
  - Max. frequency 120Mhz
  - Work budget of 11.52MCycles
  - Firm and soft temporal constraint

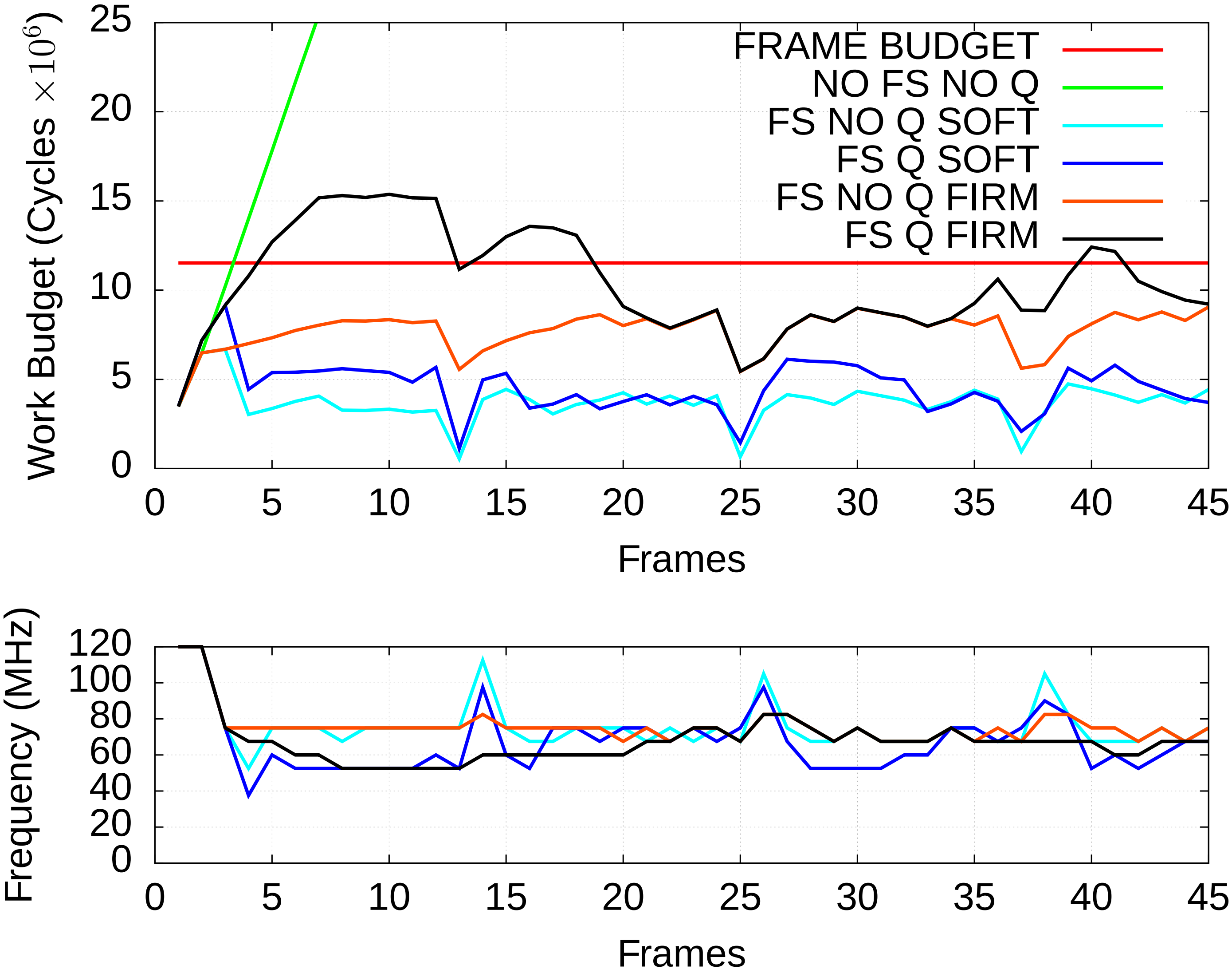
Depleting Energy Budget



Meeting the Energy Budget



Meeting the Work Budget



Conclusion

- We propose a technique that trades quality for a power reduction in adaptive applications:
  - Using independent quality- and power-management
  - Within soft/firm real-time constraints
- We demonstrate our technique for an adaptive H.263 decoder on the CompSOC platform
- Our experimental analysis shows that our simple quality-manager is able to trade quality to assist with meeting temporal/energy/power constraints.

Acknowledgements

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Questions?