Weekly Report

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1 Flow of Journal Paper for Voltage Scaling on Network Processor with QoS

First, we study the *voltage setup problem* for voltage scaling: given the probability distribution of incoming paket rate, design power supply network with the voltage scaling capability where there are total M V_{dd} levels. The inputs of this problem include the pdf of incoming packet rate and the number of cycles to process each packet at a reference V_{dd}. The outputs of this problem are the value of M and the V_{dd} of each level.

Second, we use feedback control to performance dynamic voltage scaling based on the power supply network we design from the voltage setup problem.

2 Voltage Setup Problem

[1] proposes the voltage setup problem to decide the number of V_{dd} levels and the V_{dd} value at each level, for a DVS system. [1] assumes the following known conditions: (1) the total number of tasks, (2) the execution time and deadline of each task, and (3) how often each task is executed. Based on this information, [1] proposes an analytical model to decide the V_{dd} levels for power minimization of a dual-vdd system. When the number of V_{dd} levels is larger than two, no analytical solution is available. Instead, an approximation algorithm is provided to solve the problem in [1]. The method in [1] requires the system workload is fixed during the design time. Therefore it can only be applied to ad hoc systems. In addition, leakage energy is ignore.

We propsed to study the voltage setup problem for systems with variable workloads. We use probability distribtuion function to characterize the workload fructuation, and our method can be applied to general systems, as long as the pdf of workload is known.

In our solution to the voltage setup problem on the packet processing network processor, we assume the pdf of incoming packet rate is a function $p(k)$, where k is the packet rate. The deadline is $1/k$, and the QoS requirement is q, which means the ratio between outgoing packet rate and incoming packet rate is no less than q. We further assume the number of cycles to process each packet at reference V_{dd} is C.

We first look at single-vdd system for packet processing. In this case there is a minimum single V_{dd} determined by the QoS requirement with the following equations:

$$\int_0^k p(k)dk \quad \geq \quad q \tag{1}$$

$$k = \frac{freq}{C} = \frac{(V_{dd} - V_{th})^2}{V_{dd} \cdot C} \tag{2}$$

where k is the outgoing packet rate under the V_{dd}. By solving the two equations we can obtain V_{dd}.

For a dual-vdd system with V_h and V_l for the high and low V_{dd}, V_h should be the same as the one decided for the single-vdd system, for the sake of QoS requirement. Suppose the outgoing packet rate for V_h and V_l are K_h and K_l, respectively, then for incoming packet rate no more than K_l, we apply V_l, otherwise, we apply V_h. Such relationships exist: $k_l = \frac{(V_l - V_{th})^2}{V_l \cdot C}$, and $k_h = \frac{(V_h - V_{th})^2}{V_h \cdot C}$. The total energy is given as:

$$E = \int_0^{k_l} (p(k) \cdot C \cdot V_l^2 dk) + \int_{k_l}^{k_h} (p(k) \cdot C \cdot V_h^2 dk) \tag{3}$$

where k_h, V_h are known. With $\frac{dE}{dk_l} = 0$ we can solve k_l analytically.

A few points: (1) we can assume normal distribution of $p(k)$ or use empirical data to get a formula for such pdf; and (2) we can add in a new voltage-dependent term to consider leakage, or simple use $E = (1 + l(V))CV^2$, where $l(V)$ is the function of V for the ratio between dynamic power and leakage power.

For multiple V_{dd} case, it seems the analytical soluction is hard to get. And some kind of approximation algorithm like that in [1] can be tried.

References

[1] S. Hua and G. Qu, "Approaching the maximum engergy saving on embedded systems with multiple voltages," in *ICCAD*, Nov 2003.