HW/SW Partitioning in Real-Time Systems

- Use HW coprocessors for acceleration to meet deadlines
- Must consider worst case execution behavior of SW and HW for analysis

Example: SW only

T_i	P_i	D_i	C_i	Pr_i
M	33	33	15	2
B	30	12	8	4
X	100	50	3	1
Y	20	18	4	3

$R_B^0 = 8 \qquad 8 \leq 12$ ✓

$R_Y^0 = 4$

$R_Y^1 = 4 + \lceil \frac{4}{30} \rceil 8 = 12$

$R_Y^2 = 4 + \lceil \frac{12}{30} \rceil 8 = 12 \qquad 12 \leq 18$ ✓

$R_M^0 = 15$

$R_M^1 = 15 + \lceil \frac{15}{30} \rceil 8 + \lceil \frac{15}{20} \rceil 4 = 27$

$R_M^2 = 15 + \lceil \frac{27}{30} \rceil 8 + \lceil \frac{27}{20} \rceil 4 = 31$

$R_M^3 = 15 + \lceil \frac{31}{30} \rceil 8 + \lceil \frac{31}{20} \rceil 4 = 39$

$R_M^4 = 15 + \lceil \frac{39}{30} \rceil 8 + \lceil \frac{39}{20} \rceil 4 = 39$ $\qquad 39 > 33$ FAIL

$R_X^0 = 3$

$R_X^1 = 3 + \lceil \frac{3}{30} \rceil 8 + \lceil \frac{3}{20} \rceil 4 + \lceil \frac{3}{33} \rceil 15 = 30$

$R_X^2 = 3 + \lceil \frac{30}{30} \rceil 8 + \lceil \frac{30}{20} \rceil 4 + \lceil \frac{30}{33} \rceil 15 = 34$

$R_X^3 = 3 + \lceil \frac{34}{30} \rceil 8 + \lceil \frac{34}{20} \rceil 4 + \lceil \frac{34}{33} \rceil 15 = 57$

$R_X^4 = 3 + \lceil \frac{57}{30} \rceil 8 + \lceil \frac{57}{20} \rceil 4 + \lceil \frac{57}{33} \rceil 15 = 61$

$R_X^5 = 3 + \lceil \frac{61}{30} \rceil 8 + \lceil \frac{61}{20} \rceil 4 + \lceil \frac{61}{33} \rceil 15 = 73$

$R_X^6 = 3 + \lceil \frac{73}{30} \rceil 8 + \lceil \frac{73}{20} \rceil 4 + \lceil \frac{73}{33} \rceil 15 = 88$

$R_X^7 = 3 + \lceil \frac{88}{30} \rceil 8 + \lceil \frac{88}{20} \rceil 4 + \lceil \frac{88}{33} \rceil 15 = 92$

$R_X^8 = 3 + \lceil \frac{92}{30} \rceil 8 + \lceil \frac{92}{20} \rceil 4 + \lceil \frac{92}{33} \rceil 15 = 100$

$$R_x^9 = 3 + \left\lceil \frac{100}{30} \right\rceil 8 + \left\lceil \frac{100}{20} \right\rceil 4 + \left\lceil \frac{100}{33} \right\rceil 15 = 119$$

$$R_x^{10} = 3 + \left\lceil \frac{115}{30} \right\rceil 8 + \left\lceil \frac{115}{20} \right\rceil 4 + \left\lceil \frac{115}{33} \right\rceil 15 = 119$$

$$R_x^{11} = 3 + \left\lceil \frac{119}{30} \right\rceil 8 + \left\lceil \frac{119}{20} \right\rceil 4 + \left\lceil \frac{119}{33} \right\rceil 15 = 119$$

$119 > 50$ FAIL

1. MPEG2 Encode SAD

SW Kernel:

Cycles: 793,441,912

Execs: 328014

Iters: 5.54

%exec = 65.7%

Cycles = 436 * iters * execs.

HW Kernel:

Cycles = 72 * iters * Execs.

Comm:

Cycles = 99 * execs

$S_{kernel} = \frac{436 * iters * \cancel{execs}}{(72 * iters + 99) * \cancel{execs}} = \frac{436 * iters}{99 + 72 * iters}$

$s(1) = 2.5$ (worst case)

$s(2) = 3.6$

↓

T_i	P_i	D_i	C_i (SW)	C_i (HW/SW)
mpeg(1)	33	33	15	9

$C_i(HW/SW) = \frac{C_i * .657}{2.5} + C_i * (1 - .657)$

≈ 9

2. Brev

SW kernel:

Cycles: 5,136,076

Execs: 16,000

Iters: 4

%exec: 80%

Cycles = 160 * iters * exec

HW kernel:

Cycles = $(2 + iters(2))$ execs

Comm:

Cycles = 3 * execs

$S_{kernel} = \frac{160 * iters * \cancel{execs}}{(5 + 2 * iters) * \cancel{execs}} = \frac{160 * iters}{5 * 2 * iters} = 49$

$iters \Downarrow 4$

T_i	P_i	D_i	C_i (SW)	C_i (HW/SW)
brev (B)	30	12	8	2

$C_i(HW/SW) = \frac{C_i * .8}{49} + C_i * (1 - .8)$

$= 1.7 \approx 2$

HW/SW Response Time Analysis

T_i	P_i	D_i	C_i	Pr_i
M	33	33	9	2
B	30	12	2	4
X	100	50	3	1
Y	20	18	4	3

$R_B^0 = 2 \qquad 2 \le 12$ ✓

$R_Y^0 = 4$

$R_Y^1 = 4 + \lceil \frac{4}{30} \rceil 2 = 6$

$R_Y^2 = 4 + \lceil \frac{6}{30} \rceil 2 = 6 \qquad 6 \le 18$ ✓

$R_M^0 = 9$

$R_M^1 = 9 + \lceil \frac{9}{30} \rceil 2 + \lceil \frac{9}{20} \rceil 4 = 15$

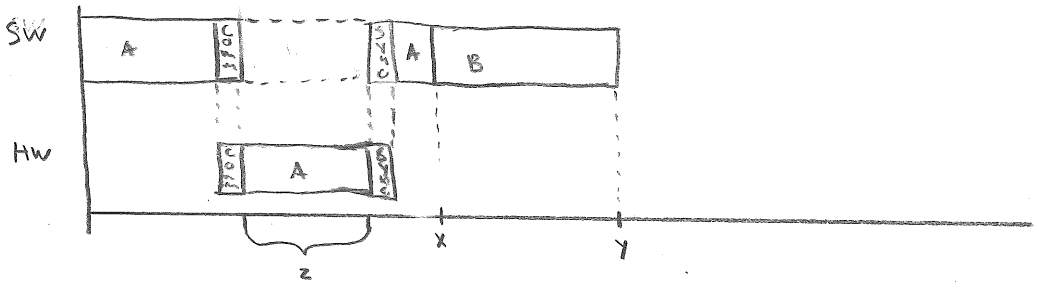
$R_M^2 = 9 + \lceil \frac{15}{30} \rceil 2 + \lceil \frac{15}{20} \rceil 4 = 15 \qquad 15 \le 33$ ✓

$R_X^0 = 3$

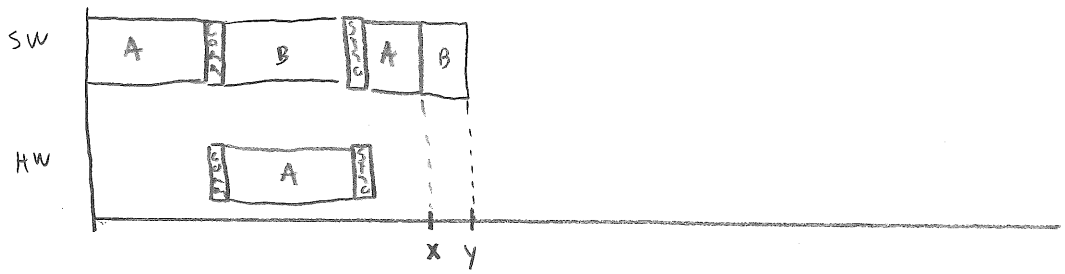
$R_X^1 = 3 + \lceil \frac{3}{30} \rceil 2 + \lceil \frac{3}{20} \rceil 4 + \lceil \frac{3}{33} \rceil 9 = 18$

$R_X^2 = 3 + \lceil \frac{18}{30} \rceil 2 + \lceil \frac{18}{20} \rceil 4 + \lceil \frac{18}{33} \rceil 9 = 18 \qquad 18 \le 50$ ✓

Further Opportunity to Improve Real-tie Performance in HW/SW Implementations



→ Can schedule tasks when HW coprocessor active for another task.



Response Time Analysis with context switch overhead

- Interference I_j from all higher priority tasks. Each distinct interference will incur a context switch overhead twice (pessimistic worst case)

$$\text{Releases} = \left\lceil \frac{R_i}{P_j} \right\rceil$$

$$I_j = \left\lceil \frac{R_i}{P_j} \right\rceil (C_j + 2 * T_{cs}) \qquad T_{cs} = \text{time for each context switch}$$

$$R_i = C_i + \sum_{j \in hp(i)} \left\lceil \frac{R_i}{P_j} \right\rceil (C_j + 2 * T_{cs})$$

Why is this pessimistic? What would be an optimistic estimate?