Optimization of the Highest Entropy First Scheduling Algorithm for Real-time Systems

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Motivation

The original version of the HEF algorithm [1] requires checking the entropy value of the tasks on each unit of time of the scheduling diagram. After a preliminary analysis [2] we found that when the utilization of the task set is higher than 90%, the number of context switches and number of preemptions is higher than EDF [3].

Related Work

Rincon and Cheng [1] defined the mathematical background for using entropy [4] in real-time systems.

Entropy of a single time unit:

$$H_{SingleTimeUnit} = \frac{log_2(hperiod)}{hperiod}$$

Entropy of a task:

$$H_{Tasks} = log_2(hperiod) * \frac{c_i}{t_i}$$

Total entropy of a system:

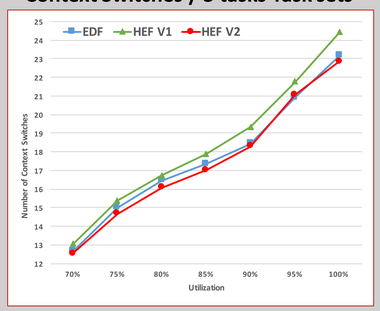
$$H_{System} = log_2(hperiod) * \sum_{i=1}^{n} \frac{c_i}{t_i}$$

Methods

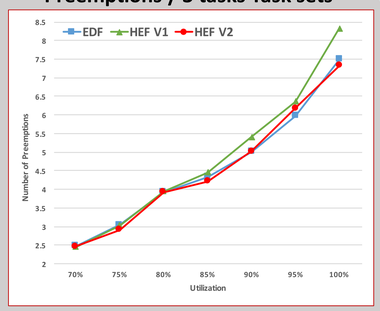
- Hyper-period set at 40
- EDF, Original HEF and Optimized HEF implemented.
- 100 tasks per test file
- 21 Test files
  (Utilization = 70%, 75%, 80%, 85%, 90%, 95% and 100%.
  Tasks per Task set = 3, 4 and 5

Results

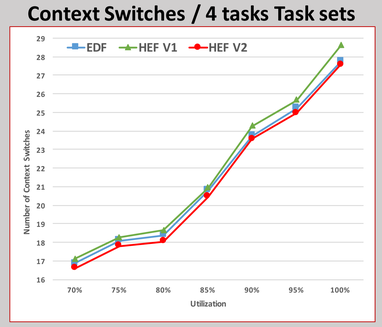
Context Switches / 3 tasks Task sets



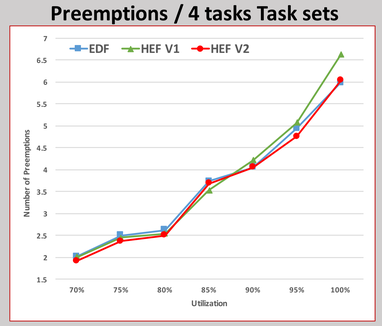
Preemptions / 3 tasks Task sets



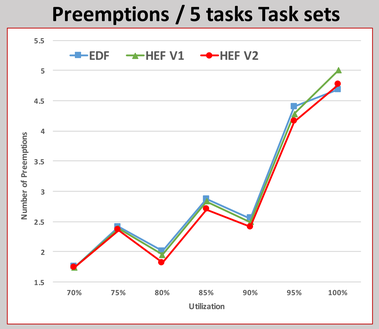
Context Switches / 4 tasks Task sets



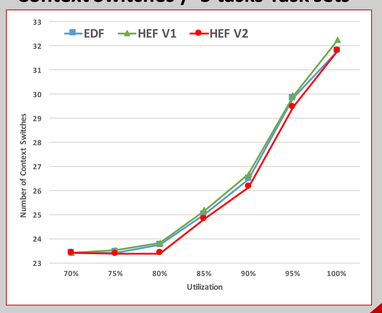
Preemptions / 4 tasks Task sets



Preemptions / 5 tasks Task sets



Context Switches / 5 tasks Task sets



Conclusions

- Optimized HEF improved the performance of original HEF for all the test cases.
- Optimized HEF improved the performance of EDF for U ≤ 95%.
- Optimized HEF performance for U = 100% was similar than EDF.
- Future Work: Using entropy in multi-processors

Proposed Optimization

Because checking the entropy value of the tasks at each unit of time makes the algorithm not suitable for real implementation, we proposed the following changes:

1) Select the task with the highest entropy for the studied period:

$$H(x)=H_{SingleTimeUnit} * \left(c_j * \frac{t_i}{t_j}\right)$$

where t_i=studied period, c_j= WCET of task j and t_j = period of task j.

2) Select the next scheduling point:

If WCET of selected task i < $t_i - \sum_{k=1}^{n,k\neq i}\left(c_k * \frac{t_i}{t_k}\right)$ Then: Next scheduling point= c_i

Else, next scheduling point= $t_i - \sum_{k=1}^{n,k\neq i}\left(c_k * \frac{t_i}{t_k}\right)$

Feasibility

Assuming that we have a task set S with U <= 1 then $\sum_{i=1}^{n,} \frac{c_i}{t_i} \leq 1$

If S is not schedulable by HEF, then the entropy of the scheduled tasks for a period t_i has to greater than the total entropy present in that particular period:

$$c_i * H_{SingleTimeUnit} + \sum_{j=1}^{n,j\neq i}\left(c_j * \frac{t_i}{t_j}\right) * H_{SingleTimeUnit} > t_i * H_{SingleTimeUnit}$$

Then:

$$c_i + \sum_{j=1}^{n,j\neq i}\left(c_j * \frac{t_i}{t_j}\right) > t_i = c_i + t_i * \sum_{j=1}^{n,j\neq i}\left(\frac{c_j}{t_j}\right) > t_i$$

$$\frac{c_i}{t_i} + \sum_{j=1}^{n,j\neq i}\left(\frac{c_j}{t_j}\right) > 1, then: \sum_{i=1}^{n,} \frac{c_i}{t_i} > 1$$

Non-schedulable by HEF = U > 1

References

[1] C. A. Rincon and A. M. Cheng, "Using entropy as a parameter to schedule real-time tasks," in *Real-Time Systems Symposium. WiP Session, 2015 IEEE*, Dec 2015, pp. 375–375.
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[3] C. Liu and J. Layland, "Scheduling algorithms for multiprogramming in a hard-real-time environment," *J. ACM*, vol. 20, no. 1, pp. 46–61, 1973.
[4] C. E. Shannon, "A Mathematical Theory of Communication," *The Bell System Technical Journal*, vol. 27, no. 3, pp. 379–423, 1948.

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