Real Time User-Centric Energy Efficient Scheduling In Embedded Systems

N.SREEVALLI, PG Student in Embedded System, ECE
Under the Guidance of Mr.D.SRIHARI NAIDU ,
SIDDARTHA EDUCATIONAL ACADEMY GROUP OF INSTITUTIONS, NEAR C.GOLLAPALLI, TIRUPATHI-517505, ANDHRAPRADESH,INDIA

Abstract-This paper demonstrates simulation Events, a model based design and simulation tool and its application in assisting a design concept of fair scheduling and governing in embedded system. In this paper a Dynamic Voltage Scaling (DVS) controller is designed for energy efficient scheduling subject to real time processing constraints and also the scheduling of tasks based on timeline is introduced. This proposed design can achieve significant energy gains with improving the quality of user experience also.

Keywords- DVS, Scheduling, Embedded System

I INTRODUCTION

The current growth in embedded systems facilitates the application of control systems in wireless network. On the other hand issues will occur during the design and process of such systems like multi-process scheduling, manage over network and power consumption in real time. In order to support the efficient study of such systems software tools are required. A design based model and associated software tool fits the above needs, normally acknowledged by the industrial and scientific communities. A number of efficient algorithms such as AURA An Application and User interaction Aware and Middle-ware frame work[4], for energy optimization in mobile devices, GREEDY algorithm[3] to minimize energy consumption in heterogeneous systems and also the concept of scheduling in fair manner based on sensitivity analysis [1].

Generally many of them are designed based on pre-emptive scheduling which leads to large number of context switches that require large stack sizes with increased consumption of energy. In this paper, we consider the scheduling of tasks based on schedule timeout and cancel timeout which enforce time limit on entities and a Dynamic Voltage Scaling (DVS) controller is designed based on Infinitesimal Perturbation Analysis (IPA) which is an online gradient estimation technique [5]. Based upon workload the DVS controller can dynamically update the input voltage with application of online gradient estimation technique. By this the power consumption can be reduced and also the average system time of job which was measured as a quality of service is assured. To design the controller we require block sets and libraries. The correlation of these blocks sets (switches, gates, servers, queues) in Simulation events can model the DVS controller. These Simulation events can also be mutually used with Simulink in aid for hybrid system design and simulation. This section first introduces the concept of time limiting for entities and then the online gradient estimation IPA technique as the incentive for DVS is briefly explained as backdrop for the proceeding section that follows.

A. Time Limiting

During multi-process scheduling the arrival rate of entities have to be managed. By using this proposed model the time limit can be imposed on the entities arrival and based on the timeliness the work load can be reduced. The Schedule Time Out and Cancel Time Out are the two blocks that are necessary to impose the time limit.

B. IPA Technique

The main objective in the design of discrete event system is mainly focused on increase in performance along with minimizing cost. In

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general the performance can be considered based on the quality of service (QOS) supplied by the system. The performance metrics in case of discrete event system include average time take by the system, utilization and packet loss rate. While, the cost is measured based on the resources such as time, communication channels, energy used by the system. So, the main aim is in allocating limited resources with gaining maximizing performance of the system. The performance and related cost can be evaluated effectively based on the model based design and simulation tool. As the operation of the system is mainly based on configuration of parameters, a difficult task to perform multiple simulations and to find parameters that matches the design needs. Stochastic input and random noise are two parameters linked to discrete event system. A greater effort is needed to obtain accurate estimation of the system in terms of computational complexity and simulated time. In continuous system the sensitivity information subjected to performance metrics can be easily obtained but it cannot be possible in case of discrete event systems. By using the infinitesimal perturbation analysis, we can verify the sensitivity information and also the parameter configuration problem, on single simulation. Based on this sensitivity information we can obtain the present performance and configurable parameters of the performance metrics through first order derivative

C. Dynamic Voltage Scaling

The incorporation of communication, computation and control had integrated in present technology. Studies shows that the wireless sensor network, collect information about environment, at medium load levels it can work for one to two years without any recharge. So the power consumption should be managed carefully. Figures show that electronic control unit can accounts for about fifty percent. So it has gained a common interest in the case of device engineers and chip manufactures. In general the legacy models include on and off control method by which the proposed technique can achieve more 50% gain in energy compared to on and off control. The technique involved in DVS control is that the controller can lowers the input voltage when the arrival rate of jobs at electronic control unit is low by overwhelming less energy at low rate whereas if the arrival rate of jobs is high then the Dynamic Voltage Scaling system can makes the processor to works at high frequency at high speed. So the design of DVS is made without affecting the performance of the system [2]. The paper is organised as follows, in section II scheduling based on time limit for entities is shown based on scheduler time out and cancel time out blocks. In section III the DVS controller is discussed and in section IV simulation results are revealed.

II SCHEDULING BY TIME LIMIT

In this model we have imposed a time limit on entities by using the schedule time out and cancel time out blocks. The schedule time out block shows how long an each entity can remain in infinite server block and the cancel time out block cancels the scheduled time out and reads the residual timeout for each entity.
The corresponding time limit model as shown in Fig.1

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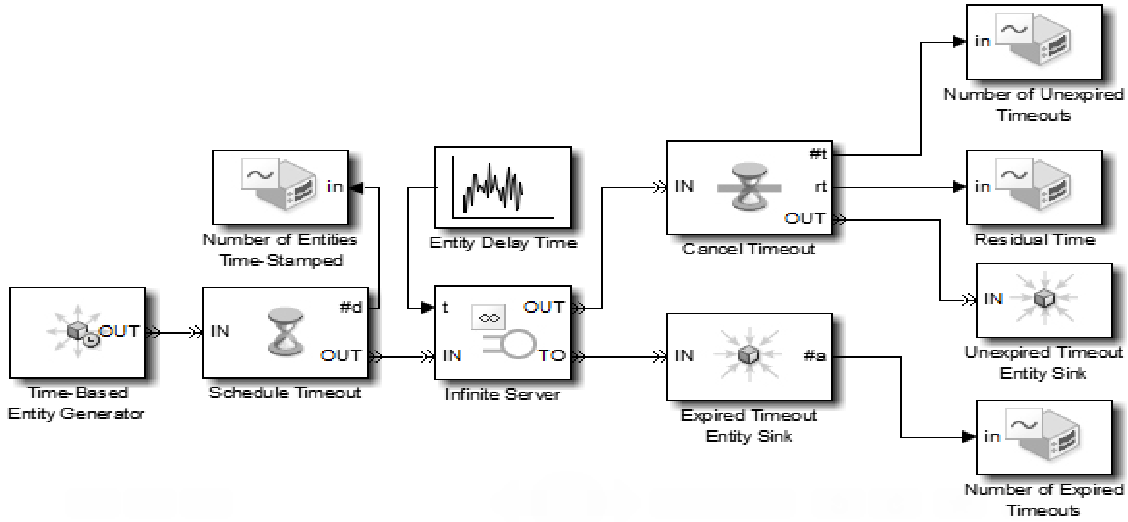

Fig. 1 Model based scheduling time out for entities using Simulation events and MATLAB Simulink

We have considered the entity generation with a period of T=0.5 sec with N=10 simulations .Based on this the entities can be generated for every 0.5 sec and entities generated are shown in Fig 2. The entities that are timed out are shown in Fig. 3 and this model is mainly based on infinite server block.

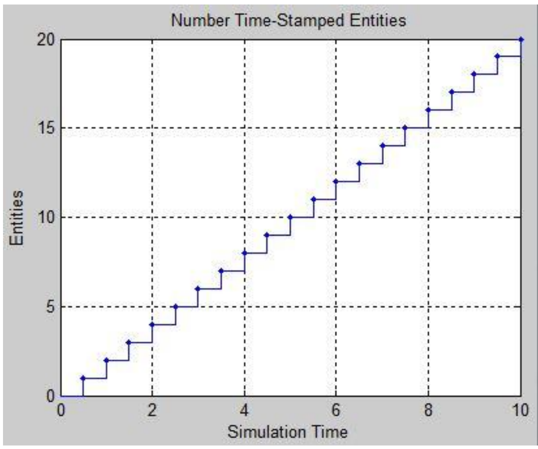

Fig.2 Time- Stamped Entities

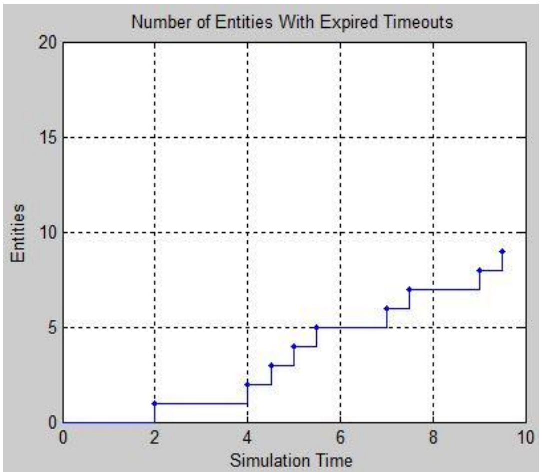

Fig.3 Entities With Expired Timeouts

If the service time in the infinite server block is less than the time out duration of entity then the time out will be cancelled by the cancel time out block upon completion of service. So, finally it allows the entities to process based on the scheduled time interval.

III DVS CONTROLLER

In the design of Electronic Control Unit a single server based queuing system is used. As we have discussed earlier, power management is done by varying input voltage. In this device the processing unit can be controlled based on adjusting the input voltage. Depending on non-pre-emptive scheduling the jobs are stored in the buffer where the arrival rate is stochastic and served as first in and first out queue with infinite capacity. The generated random variables during inter arrival times are independent and identically distributed (i.i.d).

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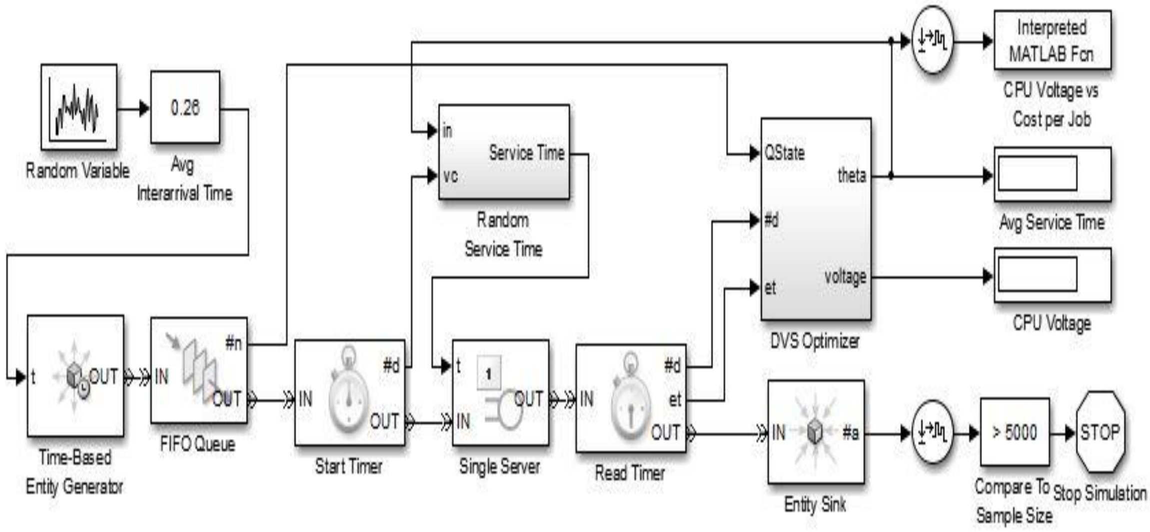

Finally, the proposed design is useful in scheduling the tasks based on the Scheduled time interval. A model based DVS controller is designed as shown in Fig.4. It is modelled using Simulation events in Simulink which contains queues and servers. In this proposed model the entity generation is done by using time based entity generator. The entities will wait in the queue block until the present entity is executed. The Start Timer and End Timer are used to allow the flow of entities from this FIFO queue block to Single Server block which allow the entities to pass one by one. The Service time to this Single Server Block is varied by the Random Service Sub system and also the DVS optimizer can calculate the performance metrics based on the time generated by the timer blocks as this time is used to count entities that are passed to other blocks also. Considering as an example, based on the data sheet of AT90S8535 the

Fig .4 Model based design of DVS controller using Simulation events and MATLAB Simulink

A. Usage of IPA technique

Based on the work load the DVS controller can dynamically adjust the input voltage by the usage of IPA technique is given by,

$$J(V) = \omega P(V) + S(V) \qquad (3)$$

Where,
P(V) is the average energy consumption of job,
S(V) is the average system time of job which

corresponding input voltage and speed of the processor is taken. In this system the voltage is taken as

$$V = V_t / 1 - C_1 f \qquad (1)$$

V - is the input voltage
V_t - is the device threshold voltage
C_1 - device dependent constant

The value of Vt = 2V and C1 = 0.0833 and in order to process a job the energy consumed is given by

$$P = C_2 N V^2 \qquad (2)$$

P - is the energy usage(joules)
V - is the input voltage
C2- constant ($0.4567*10^{-3}$)

measures Quality Of service ω is the weighting parameter.

The performance of the system is calculated using (3) without the use of system time of job i.e., without assuring the quality of service. On combination of equations (1) (2) (3) the performance metric can be known as,

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$$J(\theta) = \omega C_2 \left(\frac{V_t}{1 - C_1/\theta} \right)^2 + S(\theta)$$

(4)

Due to one to one mapping between θ and V, we replace θ with V for mathematical simplification minimizing equation (4) is rewritten as,

$$\frac{dJ}{d\theta} = -\frac{2\omega C_1 C_2 V_t^2 \theta}{(\theta - C_1)^3} + \frac{dS}{d\theta} = 0$$

(5)

If the estimation of dS/dθ is done to derive dj/dθ , then in the process of simulation the gradient method can be applied with constant step size Δ=0.001 we derive the service time as,

$$\theta_{k+1} = \theta_k - \Delta \left[\frac{dJ}{d\theta_k} \right]$$

On applying the gradient estimator equation (5) will become as

$$\left[\frac{dJ}{d\theta_k} \right] = -\frac{2\omega C_1 C_2 V_t^2 \theta_k}{(\theta_k - C_1)^3} + \left[\frac{dS}{d\theta_k} \right]_{IPA}$$

(7)

To find optimal θ and to calculate the average cost of a job, the iterative process is summarized on combining equations (6) and (7).where $[dS/d\theta_k]_{IPA}$ known as gradient estimate generated by the IPA estimator.

B. DVS Algorithm

To analyze the performance of DVS controller the following steps are to be executed

i. Start
ii. Take an subjective input voltage V_0 and average service time θ_0 at time t=0
iii. By simulation we obtain the K^{th} job
iv. Obtain $[dS/d\theta_k]_{IPA}$ depending upon new departure information
v. Derive $[dJ/d\theta_k]$ using an equation (7)
vi. By using equation(6) update the input voltage V_{k+1} and average service time by θ_{k+1}
vii. Recur the process of simulation
viii. End

IV SIMULATION RESULTS

This section shows the corresponding cost taken by the DVS controller on adjusting with input voltage dynamically by itself. By varying the average inter arrival time the arrival of job rate is wide-ranging which are in the form of exponential distribution. The obtained results are tabled based on the different arrival rate by varying the value of λ in equation (4) as the queuing system used is single server we change the equation (4) in terms of λ depending on the job arrival rate for theoretical purpose

$$J(\theta) = \omega C_2 \left(\frac{V_t}{1 - C_1/\theta} \right)^2 + \frac{\theta}{1 - \lambda\theta}$$

(8)

This equation (8)can be reduced into first order differential equation and reduced to (6) higher order equation in polynomial form. Some of the theoretical results are tabulated as shown in table 1

TABLE-1

λ (jobs/sec)	V (volts)	θ (sec)
0.73	3	0.25
3.88	4	0.167
6.85	6	0.125

The values taken for equation (8) are ω=100, C_1=0.0833, C_2=0.4167*10, $V_{T=}$2 the size of the job is assumed to be 1M operations. A comparison table is drawn between simulated and theoretical results and shows that the simulated results consume low voltage value than theoretical results. Based on this we determine that simulated results are suitable to calculate optimal voltage and the exponential curve is obtained between input voltage and the cost consumed is shown in Fig. 5

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TABLE-2

λ (jobs/sec)	V^{SIM}	V^{THE}	θ^{SIM}	θ^{THE}
0.73	3.1	3	0.22	0.25
3.88	3.05	4	0.241	0.167
6.85	3.03	6	0.243	0.125

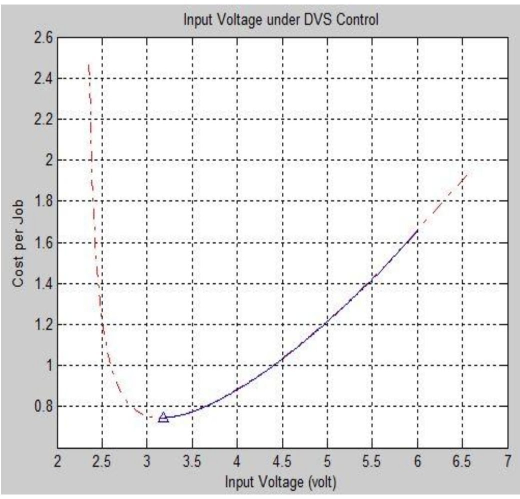

Fig. 5 Input Voltages under DVS Control

Fig. 6 and Fig. 7 show the comparison between jobs generated and input voltage, service time.

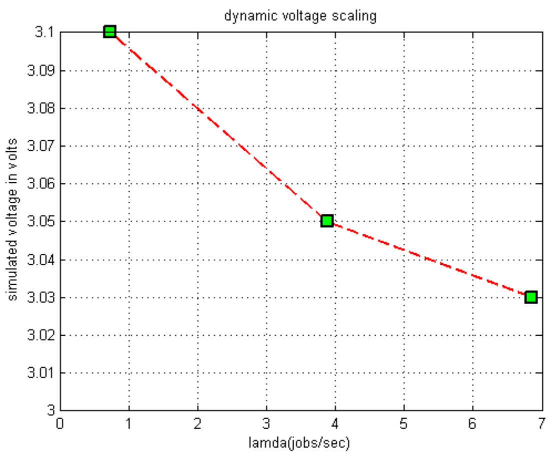

Fig. 6 Dynamic Voltage Scaling

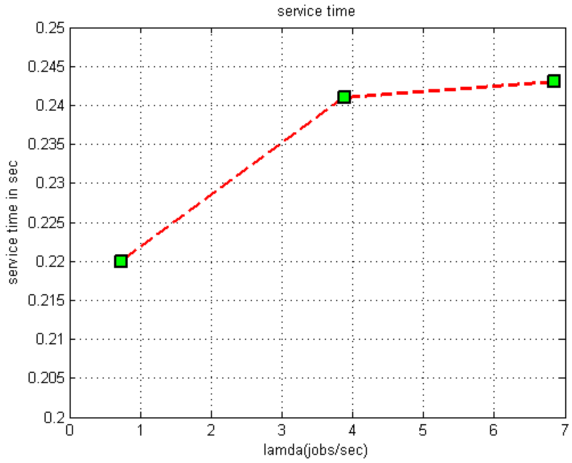

Fig. 7 Service Time

V CONCLUSION

This paper explains that Dynamic Voltage Scaling Controller can be utilized to construct microprocessor controllers that reduces the power handling using the deviations occur by change the time interval of jobs arrival. The time duration of the entities is also minimized by imposing the time condition on the arrival rate of entities. On convergence of simulated results with theoretical values that the IPA can give an unbiased estimate. The IPA technique can provide optimal values that provide energy saving by providing performance metrics based on job service time and also used for complex models.

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