IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 7.39 ⅙ Vol. 11, Issue 1, January 2022

DOI: 10.17148/IJARCCE.2022.11157

Energy Efficient Task Scheduling Algorithms for controlling room temperature in Cyber Physical Systems

Umapathi G. R[1], Dr. Ramesh Babu H S[2]

[1]Department of Information Science and Engineering, Acharya Institute of Technology, Bangalore, India

[2] Sai Vidya Institute of Technology, Bangalore, India

Abstract: The massive growth of energy consumption by buildings and release of huge amount of carbon footprints by resources such as air conditioners motivated to develop eco friendly solutions for room temperature monitoring. As a result task scheduling has drawn attention in which limited resources can be efficiently utilized to consume less energy. In this paper, we compare different scheduling policies in terms of energy efficiency for room temperature monitoring. Finally a solution is provided to efficiently reduce the energy consumption.

Keywords: Scheduling, Cyber Physical Systems, Energy Consumption, Makespan

I. INTRODUCTION

A cyber physical system (CPS) comprises of two key components: (1) the computer portion consisting of the processor operating the control algorithm to measure control inputs and (2) the physical component being operated in the form of a physical system. The scale and complexity of the physical plant will vary from an embedded medical device to a network for regulating a continent wide power grid.

The cyber part-the controller-is in the controlled plant's feedback loop. The operation has two factors that influence the efficiency of the regulation it affords. One is its process response time, the other is the quality of the control algorithm it performs.

A large amount of energy is consumed by buildings in the city. Monitoring room temperature is a growing need due to uncertainties in our weather conditions and climate generally [1-2]. This necessitates the temperature control system for homes and industrial applications. In [3], study on energy efficiency and energy saving potentials on Heating, Ventilation and Air Conditioning (HVAC) systems at the hospitals are presented. The paper consists of review of payback periods of some projects on HVAC including the installation of cogeneration, trigeneration, chiller, new burners, heat exchangers and steam trap systems. In [4], economic models are introduced for Hotelling tax on carbon emissions. It is shown that the least-cost approach to a temperature limit pricescarbon emissions at a rate that increases more slowly than exponentially. Paper [5] investigates the potential impacts of alternative international climate change scenarios based on different policies and technological circumstances on future emission pathways and abatement costs. It also examines if these hypothetical scenarios could result in significant emission reductions required to control the global temperature from rising to no more than 2.5 °C above preindustrial level. Using an integrated assessment model, this paper examines these issues under 12 scenarios derived from four policy perspectives and three technology dimensions. Results show that the no-policy-change baseline scenarios lead to high global average temperatures in the future. M. R. Levine [6] invented an automatic temperature adjusting system for an air conditioner room. The automatic temperature adjusting system for the air conditioner room was made simple in operation and was capable of monitoring the temperature of the human body at any time in the air conditioner room and transmits the corresponding signals to the air conditioner in time, and then the air conditioner conducts adjustment, so that health of people is guaranteed. However, this is also one time programming and it is needed to be interfaced with the computer anytime re-programming is needed, hence, the operation of the system becomes complex. Although a number of similar temperature control system, “do-it-yourself” temperature control designs have recently been published [7, 8, 9, 10, 11, 12, 13, 14, 15, 16], these designs are not easy to use in term of programming and temperature adjustment. The systems work on the benefits of using temperature adjustable and fan temperature control systems. These systems are either one time programmable or need analog adjustment which is not accurate and more difficult to use. Also the problem of efficient servicing in case of limited resources is not addressed.

The structure of this paper is as follows – Section 2 describes system model. Section 3 highlights the scheduling task and Section IV fives performance evaluation.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 7.39 ※ Vol. 11, Issue 1, January 2022

DOI: 10.17148/IJARCCE.2022.11157

II. SYSTEM MODEL

The system is defined according to the requirements outlined in Fig. 1. The modeling targets for the room temperature control are (1) Observe how the rooms are occupied by clients (2) Keeping track of temperature changes.
For room temperature control the system needs the following - Thermal characteristics of the room, Central Manager, Thermal characteristics of the heater/cooler, Task Scheduler
In this model discrete model of AC used in [17] is used. The model relates the inside temperature of the room with ON/OFF state of AC thermostat.

$T_{in}(t) = T_{in}(t-1)+\gamma S_{AC}(t)$

where

$T_{in}(t)$ = Inside temperature of a house during time slot 't'

$S_{AC}(t)$ = Status of AC thermostat during time slot 't'

γ = Time interval duration

The parameters needed for the room temperature monitoring are listed in Table. 1

Table. I Required data or parameteres

Variable	Description
$T_{in}(t)$	Inside temperature of a house during time slot 't'
n	Number of rooms = (5, 10 etc.)
set	Temperature of room set by the client
γ	Time interval duration

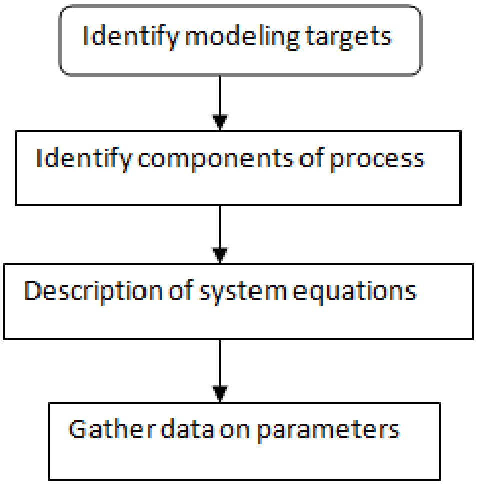

Fig. 1 Requirements for system model

Consider a building which includes 'n' rooms '. The rooms are accommodated by clients. The room temperature is the range of air temperatures that most people prefer when wearing traditional indoor clothes for indoor settings that feel comfortable. Depending on humidity, air calculation and other factors, customers can widen beyond this range. The average summer and winter range is between 23 and 25 degree Celsius, and 20 to 23.5 degree Celsius. Furthermore, the clients are expected to vary the set room temperature in our study. As a result a centralized manager (engineer) is in place to keep track of temperature changes. The time required to bring individual room temperatures up to the set level is modeled as tasks. In this model Fig. 2, incoming tasks are put in a global queue, and the manager is arranging, handling and dispatching them. The problem considered here fits CPS benchmark [18].

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 7.39 ∺ Vol. 11, Issue 1, January 2022
DOI: 10.17148/IJARCCE.2022.11157

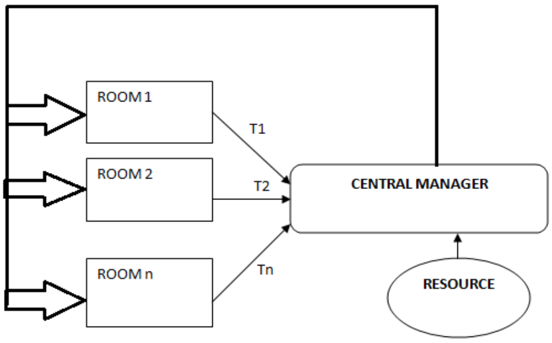

Fig. 2 System model

Here we presume that each client's role is recognizable by the set temperature and resource utilization. We calculate the client task execution time (time required for setting the room temperature) and submit it to the centralized manager. We also presume that the system resource (air conditioner) is related to resource utilization and that there is no interference between tasks for the shared resources described above.
The energy consumption (E) of the resources is mathematically given by
E = (Avg. completion time * task energy) (1)

III. SCHEDULING TASK

Scheduling is the task of choosing the next request to be handled by a server. The execution time (ET) matrix of 'x' task and one resource is shown in (2)

$$ET = \begin{pmatrix} T_1 \\ T_2 \\ . \\ T_x \end{pmatrix} \qquad (2)$$

The primary aim of the problem of task scheduling is to reduce energy consumption. To achieve this different scheduling policies like first come first serve, round robin scheduling are considered.
In these scheduling policies the utilization (completion 'ct') of the resource can be calculated as follows

$$ct = \sum_{i<x} st(i-1) + wt(i-1) \qquad (3)$$

Where 'st' and 'wt' are service times and wait times respectively.

IV. SIMULATION RESULTS AND DISCUSSIONS

In this section, we present the simulation configurations and datasets with various parameters and their interval of generation. Subsequently, simulation results are presented with respect to energy consumption.

The simulations are carried out using MATLAB R2017a. In this model 1.5 ton air conditioner is estimated to consume 1.5kW of energy per hour and roughly one minute is required to bring down temperature by 1.8° Celsius. System sites are not concealed and can be transformed to Markov Decision Process.
The various scheduling policies are implemented, including round robin, first come first serve. The results of the simulation are compared concerning energy consumption. As illustrated in Fig. 3 The first come first serve energy consumption scheme (FCFS) is 78kW and 305kW for round robin scheduling (RR). It is important to mention that the use of resources is directly linked to energy consumption; hence it is not clearly seen.

IJARCCE
ISSN (O) 2278-1021, ISSN (P) 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 7.39 ⋇ Vol. 11, Issue 1, January 2022
DOI: 10.17148/IJARCCE.2022.11157

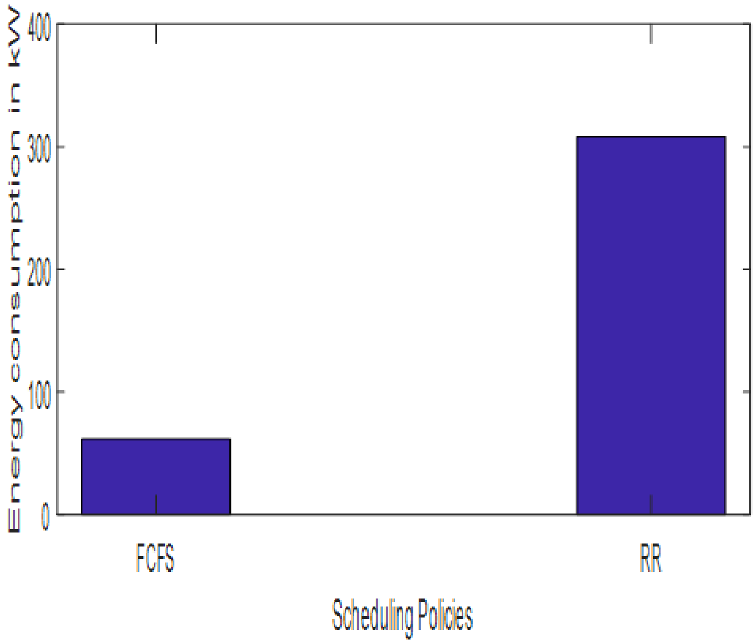

Fig. 3 Energy consumption of FCFS and RR scheduling

We also foresee the random scheduling relation with the above scheduling policies. As shown on Fig. 4 Random scheduling has the potential to cut energy consumption. To do this, the central manager must obtain the incoming job, run random scheduling and find the best possible task combination to begin servicing. The energy consumption is reduced considerably by this stratergy [19]. Three such combinations exist, as shown in Fig. 4

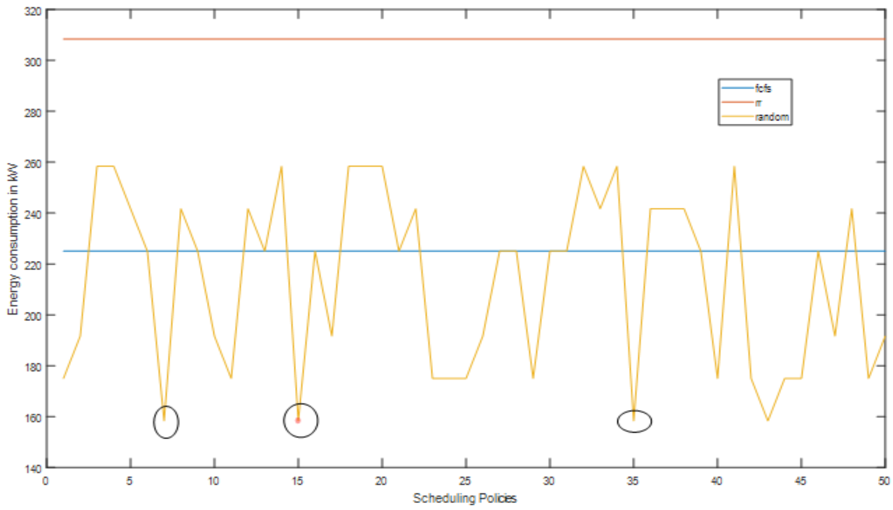

Fig. 4 Comparison of energy consumption for FCFS, RR and random scheduling

Further parametric analysis has been performed with respect to varying room numbers in a building for Round Robin, FCFS and random scheduling individually. Parameters such as Energy efficiency and makespan (completion time) is noted. Fig. 5, 6 and 7 gives makespan (completion time) of FCFS, random and round robin scheduling respectively. Through these statistics we see that as the number of rooms to be serviced increases, the makespan grows linearly. But in the case of random scheduling this calculation is not linear. That is, even though the number of rooms in buildings increases, in the event of random scheduling there is a risk to minimize the completion period.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 7.39 ⵋ Vol. 11, Issue 1, January 2022

DOI: 10.17148/IJARCCE.2022.11157

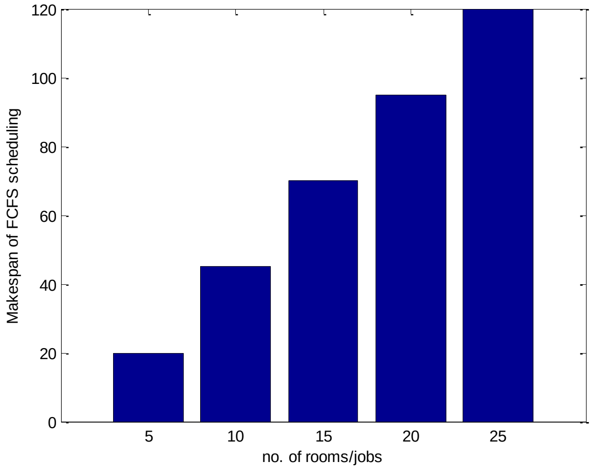

Fig. 5 Makespan of FCFS Scheduling

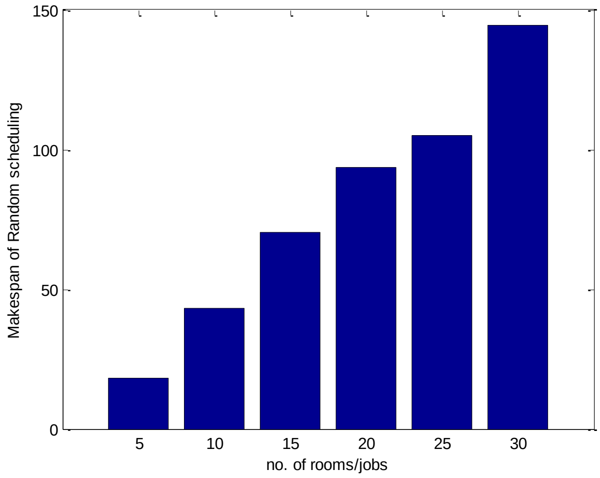

Fig. 6 Makespan of Random Scheduling

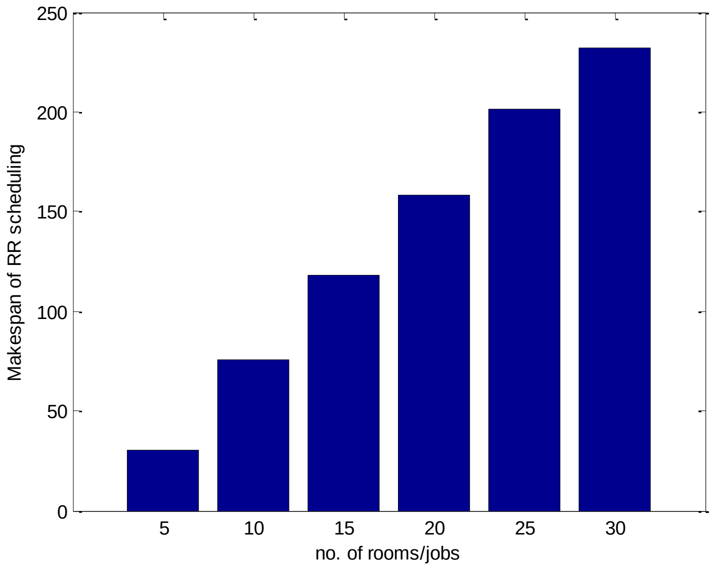

Fig. 7 Makespan of Round Robin Scheduling

DOI: 10.17148/IJARCCE.2022.11157

From Fig. 8 It is seen that the makespan of the random scheduling is less than FCFS or RR scheduling for 25 rooms in a building. This inturns reduces the energy consumption of the system.

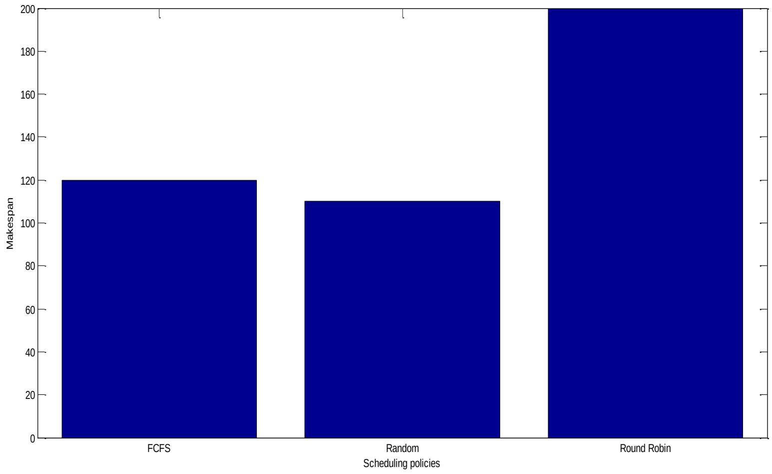

Fig. 8 Comparison of Makespan of FCFS, RR and Random scheduling

Table II. Comparison of energy consumption, makespan for FCFS, Random and RR scheduling

Number of rooms	FCFS		Random Scheduling		Round Robin Scheduling	
	Energy consumption in KW	Makespan	Energy consumption in KW	Makespan	Energy consumption in KW	Makespan
5	500	20	420	16	765	30
10	1125	45	923	36	1967	78
15	1750	70	1680	67	2958	118
20	2378	95	2240	89	3940	157
25	3000	120	2840	113	4962	198

As seen in Table II. The proposed random scheduling gives better makespan and low energy consumption for all instances.

CONCLUSION

We have introduced Energy Efficient Task Scheduling Algorithms for Room Temperature Control in Cyber Physical Systems. Comparison of FCFS scheduling with RR scheduling shows that FCFS consumes less amount of energy compared to RR scheduling. Therefore, FCFS scheduling is economical. By properly selecting the best possible combination using random scheduling the energy consumption can be significantly reduced.

REFERENCES

[1] Ogu, Emmanuel & John, Ekundayo & Olumide, Oyetesu. (2011). Temperature Control System.

[2] Ahmad Faris Bin Zulkifli, A Project on Automatic Room Temperature Control with Security System, University of Malaysia (May 2009)

[3] A. Teke and O. Timur, “Assessing the energy efficiency improvement potentials of HVAC systems considering economic and environmental aspects at the hospitals,” Renewable and Sustainable Energy Reviews, vol. 33, pp. 224-235, May 2014.

[4] D. Lemoine and I. Rudik, “Steering the Climate System: Using Inertia to Lower the Cost of Policy,” Social Science Research Network, July 2014.

[5] Y. Zhu and M. Ghosh, “Temperature control, emission abatement and costs: key EMF 27 results from Environment Canada’s Integrated Assessment Model,” Climatic Change, vol. 123, pp. 571-582, April 2014.

[6]. M. R. Levine, Automatic temperature adjusting system for air conditioner room. China Patent CN103335385 A, 6 June 2013.

Impact Factor 7.39 ⁘ Vol. 11, Issue 1, January 2022

DOI: 10.17148/IJARCCE.2022.11157

[7]. B. G. Tate and R. P. Ries, Wireless thermostat and room environment control system. Unites States of America Patent US4969508 A, 13 November 1990. https://patents.google.com/patent/US4969508A/en.

[8]. S.B Poll, Automatic heater controller. United States of America Patent US4086466 A, 21 June 2006. https://patents.google.com/patent/US4086466A/en?oq=US4086466+A.

[9]. Agarwal T. 17 October 2006. EL PRO CUS.https://www.elprocus.com/arduino-basics-and-design/ [Online]. Available: (Accessed 16 March 2017) [Google Scholar]

[10]. Ogu E.C., Ogunlere S., Ogu C. A control and security system for internal temperature breaches using the ATMEL AT89C52 microcontroller. Int. J. Adv. Stud. Comput. Sci. Eng. 2016;5(1):1–7. http://publication.babcock.edu.ng/asset/docs/publications/COSC/9475/2149.pdf [Google Scholar]

[11]. N. Minoru, Automatic temperature control system. United States of America Patent US3241603 A, 26 March 1996. https://patents.google.com/patent/US3241603A/en.

[12]. Brumbaugh J.E. Vol. 2. John Wiley & Sons; 2004. pp. 109–119. (AudelHVAC Fundamentals: Heating System Components, Gas and Oil Burners, and Automatic Controls). [Google Scholar]

[13]. Fehring T.H., editor. Mechanical Engineering: a Century of Progress. NorCENergy Consultants, LLC; October 10, 1980. p. 22. Technology & Engineering. [Google Scholar]

[14]. Fiedler G.J., Landy J. Multi-loop automatic temperature control system design for fluid dynamics facility having several long transport delays. IEEE IRE Trans. Autom. Control. 1959;4(3):81–96. [Google Scholar]

[15]. Chengxiang L., Zhenhua Y., Xu W., Feng L. Proceedings of the IEEE International Conference on Intelligent Computation Technology and Automation. 2011. Design of automatic temperature control system on laser diode of erbium-doped fiber source; p. 404407. [Google Scholar]

[16]. Fu T., Wang X., Yang G. Proceedings of the IEEE International Conference on Computational and Information Sciences. 2010. Design of automatic temperature-control circuit module in tunnel microwave heating system; pp. 1216–1219. [Google Scholar]

[17]. M. C. Bozchalui, S. A. Hashmi, H. Hassen, C. A. Canizares, and K. Bhattacharya, "Optimal operation of residential energy hubs in smart grids", IEEE Trans. on Smart Grid, vol. 3, no. 4, pp. 1755-1766, December 2012.

[18] Rajeev Alur, Costas Courcoubetis, Nicolas Halbwachs, Thomas A. Henzinger, Pei-Hsin Ho, Xavier Nicollin, Alfredo Olivero, Joseph Sifakis, and Sergio Yovine The algorithmic analysis of hybrid systems. Theoretical Computer Science, volume 138(1),3-34,1995.