Real-Time Scheduling Approach for IoT based Home Automation System

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Abstract. *Internet of Things (IoT) is one of the most disruptive technologies nowadays which can efficiently connect, control and manage intelligent objects those are connected to the Internet. IoT based applications like smart education, smart agriculture, smart health-care, smart homes etc which can deliver services without manual intervention and in a more effective manner. In this work, we have proposed a IoT based smart home automation system using a micro-controller based Arduino board and mobile based Short Message service (SMS) application working functionality. Wi connectivity has been used to establish the communication between the Arduino module and automated home appliances. We have proposed a real-time scheduling strategy that offers a novel communication protocol to control the home environment with the switching functionality. Our simulation results show that the proposed strategy is quite capable to achieve high performance with different simulation sce-narios.*

Keywords: Task scheduling, Real-time, Deadline, Signal, Down counter clock

1 Introduction

Internet of Things (IoT) paradigm is a composition of intelligent and self-configuring devices. It represents the intertwining of physical objects-devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data [1]. The IoT object allows to send and control remotely through the existing network infrastructure. Combination of the current network technology and IoT plat-forms provides a large amount of space and innovative service based on wireless communication. Smart Systems basically incorporate functions such as sensing, actuation and control in order to analyze a situation and also to make decisions in a highly predictive or adaptive manner. In a similar way, smart housing system or home automation will control lighting, climate, entertainment systems and other appliances. When such a system is combined with the internet, it will thereby become an important constituent of the Internet of Things. Home automation systems that integrate an astronomic time clock and performs events in a timed fashion, implements the concept of Real-time Scheduling. So, we need new technologies for handling such devices remotely and to establish communication, we require GSM, mobile technology, SMS(Short Message Services) and certain hardware resources. Since, cellular phone is a recently invented technology, a home automation system based on cellular phone is extremely important for the human generation.

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IoT smart objects configuration and their management as well as their integration with real-time applications are complex challenges which require a suitable scheduling models and techniques. Scheduling is a process by which we can fulfill the users requirement by allocating their request to different processes on the basis of the interest. In this paper we have proposed a priority based real-time scheduling approach Shortest Deadline First - Real-time Task Scheduling (SDF-RTTS) for controlling of smart home automation systems. Arduino based platform has been used to perform proposed work which lies on the inherent irrelevancy of distance or remoteness, in controlling sensor based technologies. Short Message Service (SMS) that triggers the appliances can be sent from any-where regardless of the distance between the source and the appliance. We have not consider the security issues and network related issues in this work. Only our focus is on the scheduling part mainly to optimize the overall execution time.

The organization of the paper is as follows: Related work has been discussed in Section 2. System model and assumptions are described in Section 3. A real-time priority based scheduling strategy has been discussed in section 4. Working strategy explained with an example in Section 5. Results and experimental setup are illustrated in Section 6. Finally, Section 7 concludes the paper.

2 Related Work

The authors in [2], described a home automation system which is composed of smart phones and micro-controllers. Home appliances are control and monitor by the smart phone applications through various type of communication techniques. Different types of communication technique such as ZigBee, Wi-Fi, Bluetooth, EnOcean and GSM has been explore and compared. The advantage of this system is to provide security so that the system is accessible only to the authorized users. In [3], The authors made a survey to understand the topography of devices used in the home automation system. They also compared the proposed programming languages for different systems which are based on ECA structures but presenting subtle differences. The authors in [4], established a connection between a temperature sensor and a miro-controller where the temperature sensor was used to measure the temperature of the room and the speed of the fan varied according to the temperature using pulse width modulation technique. Although, the advantage of the system was that it was simple, cost effective and provided automatic control, it has very specific limitations.

Scheduling algorithms are an important aspect of real time systems. Accord-ing to system environment, real time system can be classified into uniprocessor scheduling, centralized multiprocessor scheduling and distributed scheduling shown in [5]. Real-time scheduling algorithms such as RMS, EDF and LLF are discussed for uniprocessor systems. In multiprocessor systems scheduling thought and strategies are investigated. GRMS and DSr are discussed for the distributed real-time scheduling algorithms. The authors in [6], said that an ideal scheduling algorithm minimize the response time, maximize the throughput, minimize the overhead (in terms of CPU utilization, disk and memory) and maximize fairness.

However, as established by the same paper, there are no such algorithms in existence which meet all the criteria of an ideal algorithm. The authors in [7] further states that the four model tenets are: static table-driven scheduling, static priority preemptive scheduling, dynamic planning-based scheduling, and dynamic best effort scheduling when we talk about the best efforts that are to be used in scheduling. The authors in [16] established a home automation system that operated on the basis of sending Short Message Services(SMS), however, the specific limitation of this work was profound because there were no established scheduling algorithm to regulate the entry of multiple SMSs.

The authors in [35] clearly underscored the importance of the duality of Wireless Security and Home Automation System. The usage of text messages as 'alerts' can be a very important security initiative in domain of Home Automation. This dual was well addressed by the authors. Moreover , IoT based home automation systems serves to mitigate the limitations of existing bluetooth controlled systems as the system can be accessed from anywhere (even from places which does not have Wi-fi or internet connectivity , as only the board is required to have internet connectivity) . Lastly, the authors cited the importance of the flexibility of the system as it does not use any of the tradition user interfaces of smartphones , but a few digits of the keypad of the phone.

3 System Model and Assumptions

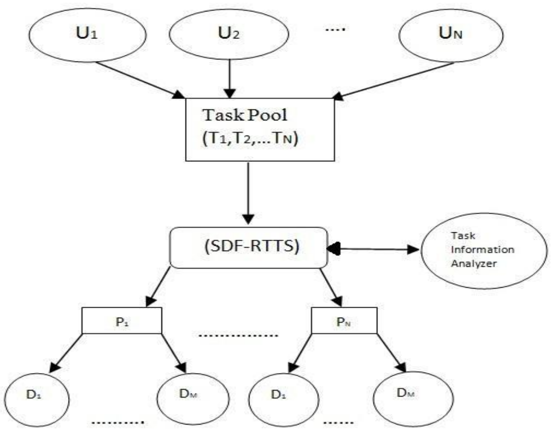

Fig. 1. SDF-RTTS working module

The system model gives a schematic description of the idea presented in this paper. It incorporates multiple users in the system who can send SMSs (tasks). These SMSs are stored in the task pool. We use a priority scheduling algorithm SDF-RTTS based on Shortest Deadline First (SDF) to sort the SMSs. The working of our priority scheduling algorithm SDF-RTTS is later explained in the Working section. Without loss of generality, we are assuming that

- Each user can send one signal which will treated as a task at a time.
- Device actuation time for each home appliances are known to the processors at design time.
- Task to processor mapping are fixed. Each task will be processed by a unique processor which will remain same if that task has multiple occurrences.

The scheduler allocates task to the processing elements based on their priority. Each processor has the control over the appliances connected to it.

4 SDF-RTTS: Working Strategy

Let us assume that at time instance t, N number real-time tasks arrive for possible allotment on the processors. Our proposed SDF-RTTS will attempt to meet timing requirements of all tasks by completing them within their soft deadline. Each task consist two parameters:

{ 1) Signal with ON/OFF value (S)
{ 2) Deadline of the Task (T)

ON/OFF value is a binary number. ON signal indicate by the value "1" and OFF is "0". Deadline of a task can be represented by multiple bits. Assume if deadline is 5 unit, then signal can be represented as "101".

We also assume that M number of home automation appliances are connected to each processor. A down counter clock is maintained to track the deadline. Each appliance or device actuation time in known to its connected processor. First processor check the deadline with the devices actuation time. Devices are partitioned into two categories based on the deadline. One partition let say SET1, consist devices whose actuation time is less than the deadline and second SET2 consist devices whose actuation time is greater than the deadline. Appliances or devices of SET1 ensures that it will be activated with desired condition with the stipulated deadline. On the other side, SET2 devices will be activated but without reaching the desired conditions.

Our proposed algorithm will check if any task has arrived at SET1 or not. If a user request or task arrived then it will start the down counter clock (DL). Each devices connected with the processor have different actuation and it is known in prior. User request or task mapping to the processor is fixed. Down counter clock (DL) starting value will be the deadline and continue up to zero (0). In between that, devices those actuation time matches with the down counter clock (DL), will receive a activation signal. SET2 devices will get activate signal randomly when the processor is free or within the time gap between two consecutive devices actuation time or in between down counter clock (DL) start time and first device activation.

The pseudo-code for the SDF-RTTS scheduling strategy is shown in algorithm 1.

5 SDF-RTTS : an Example

Let us assume that 4 users A, B, C, D want to start their home automation appliances and make the home environment comfortable before they reach home. Hence, user A, B, C and D send a text message which is known as a task to switch on the devices, say D_1, D_2, D_3, D_4 in their respective homes. In text message users has mentioned the deadline or the time within he/she will reach at home. Lets say the deadline for reaching to the destination are 5, 10, 8 and 12 minutes. Devices actuation time is also known to the scheduler SDF-RTTS. Let, say 1, 2, 5, 10 minutes are the actuation time for the devices D_1, D_2, D_3, D_4

Algorithm 1: SDF-RTTS Scheduling Strategy

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Input: N number of signals [S,T ], Number of devices M
Output: Priority based device actuation
Initialize DL = deadline; Detect signals [S,T ] from multiple users;
Set priority of the tasks based on the deadline (T ) given by the user (Smallest deadline
will have the highest priority);
Assign the tasks to the pre-de ned processors based on the priority;
for (each devices in N) do
if (deadline   device actuation time) then
    move device to SET 1;
  else
    if (deadline   device actuation time) then
       Move device to SET 2;

if (SET 1 6= NULL) then
  Set a down counter clock(DL);
  if (T == device actuation time) then
     Send the signal to activate the device;
     Decrement the clock till DL=0;

if (SET 2 6= NULL) then
  if (T 6= device actuation time) then
     Send the signal randomly to activate the devices;

End
```

respectively. Hence, according to the algorithm user A has the highest priority as it has shortest deadline, then C, B and D. Now for first task, overall deadline is 5 minutes but device actuation time for D_4 is 10. Hence, classify the device set into two subsets. One set say, SET1 has devices whose actuation time is less or equal to the deadline and the other set named as SET2 have devices whose actuation time is greater than the deadline. Algorithm will check whether SET1 is null or not, if it has devices in the set it will activate the down counter clock (DL). According to the actuation time processor will send the activation signal to the devices. At down counter clock (DL) 5 processor will activate D_3, at 2 D_2 and at 1 D_1 respectively. SET2 devices will activated randomly by the processor when it is free or there is no request for SET1 device activation. This similar procedure will be followed by the other processors also.

6 Evaluation and Results

We have presented a simulation based results from the solution of our proposed SDF-RTTS strategy for real time scheduling of home automation appliances. We have analyzed the execution time and performance for the proposed solutions. Before presenting the detailed results, we now discuss our experimental setup.

6.1 **Experimental Setup**

Arduino: It is a micro-controller board that happens to be based on the AT-mega328.There is a total number of fourteen digital input/output pins where six of them can be used as PWM outputs. It also consists of six analog in-puts, sixteen MHz ceramic resonator, a USB connection, a power jack , an ICSP header and a reset button[5]. Arduino Uno is the main processing element in this experiment.

GSM SIM 300: Sim300 is well known and is often used in quite a lot of projects and hence various types of development boards with regards to this has been developed. These developmental boards encompasses various features that makes it easily communicable with SIM 300 module[6]. The GSM Module used in this experiment comprises two parts: a TTL interface and RS232 interface. The TTL interface is used for interfacing and communicating with the micro-controller. The RS 232 interface uses a MAX232 IC to allow communication with the PC. It also consists SIM slot. This module in this current application is used as a Data Circuit terminating Equipment and PC as a Data Terminal Equipment.

Relay Drive: Relay can be used an electromagnetic device that is very commonly used to separate two circuits electrically and connect them magnetically. They are very popular and equally useful devices which enables one circuit to switch to another one while they are completely isolated. These devices are mostly preferred to be used while interfacing an electronic circuit (working at a low voltage) to an electrical circuit which works at very high voltage. Henceforth, a small sensor circuit can drive, say, a refrigerator or an electric bulb.

BC 547: BC547 is a Bi-polar junction transistor(NPN) . A transistor, rep-resents a transference of resistance, which is commonly used to increase current many folds.

Wi module: Wi connectivity has been used to established the communication in between the arduino and home automated appliances.

Number of Tasks (T): Total 4 to 20 number of tasks or user request considered with different appliances used for simulation.

Number of Processors (P): As task and processor mapping is fixed i,e. each task has a dedicate processor to perform the execution. Hence, number of processor also varied from 4 to 20.

Number of Devices (D): Total 4 to 16 number of different types of devices have been used for simulation.

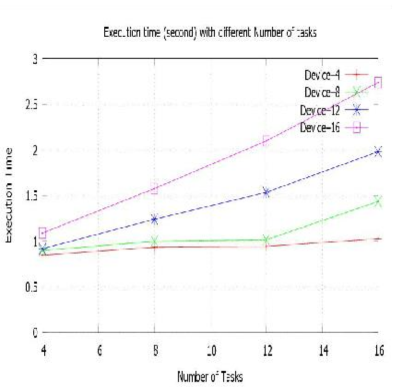
Each result is generated by executing 100 different instances of each data set type and then taking the average over these 100 runs.

Table 1 shows the performance of the SDF-RTTS strategy over a different number of processors, tasks and devices. Runtime of SDF-RTTS strategy is mea-sured in terms of millisecond.

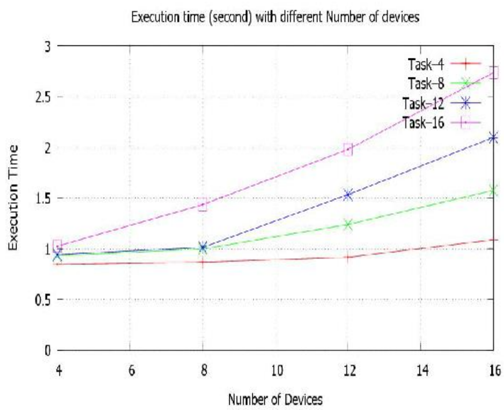
As the number of task increases, execution time of our proposed strategy SDF-RTTS also increases. For each task few verification is done before it gets scheduled to the processor. As task number goes high, it takes more time to verify and schedule it to the appropriate processor. Figure 2(a) clearly depicts

Table 1. Task execution time (second)

D	T	P	runtime	T	P	runtime	T	P	runtime	T	P	runtime
4			0.847			0.932			0.943			1.026
8	4	4	0.896	8	8	0.998	12	12	1.014	16	16	1.435
12			0.917			1.239			1.534			1.980
16			1.089			1.576			2.098			2.737



(a) Execution time varies with number of task



(b) Execution time varies with number of devices

Fig. 2. Performances of SDF-RTTS strategy

that when number of task increases (without increasing the device number) overall execution time also increases.

Figure 2(b) shows that if we increase the number of devices for the same number of task, execution time also increases. As number of device increases, device count in SET1 and SET2 also increases. Hence, it will have to send more number of signals to activate all the devices.

7 Conclusion

In this paper, we presented a strategy for allocating real-time tasks on arduino based platform using mobile SMS application such that we can minimize the overall execution time. Our proposed scheduling strategy SDF-RTTS is based on the "Shortest Deadline First" approach, which ensures that scheduling will fulfill all the real-time constrains and will optimize the overall execution time. Arduino based testbed which provides the exibility of controlling the IoT devices through wi connectivity. We designed, implemented and evaluated the algorithms using simulation based experiments and results are promising. Though there are some drawbacks like security issues, network issues which we have not covered in this work. But in future work we will focus on these issues.

References

1. Byun, J., Kim, S., Sa, J., Kim, S., Shin, Y.T., Kim, J.B.: Smart city implementation models based on iot technology. Advanced Science and Technology Letters 129(41)(2016) 209-212

2. Asadullah, M., Raza, A.: An overview of home automation systems. In: Robotics and Arti cial Intelligence (ICRAI), 2016 2nd International Conference on, IEEE (2016) 27-31

3. Demeure, A., Ca au, S., Elias, E., Roux, C.: Building and using home automation systems: a eld study. In: International Symposium on End User Development, Springer (2015) 125-140

4. Das, A.: Fan speed controlled system by temperature using pulse width modulation (pwm). International Journal of Current Research 10(4) (2018) 68021-68024

5. Jie, L., Ruifeng, G., Zhixiang, S.: The research of scheduling algorithms in real-time system. In: Computer and Communication Technologies in Agriculture Engineering (CCTAE), 2010 International Conference On. Volume 1., IEEE (2010) 333-336

6. Adekunle, Y., Ogunwobi, Z., Jerry, A.S., Efuwape, B., Ebiesuwa, S., Ainam, J.P.: A comparative study of scheduling algorithms for multiprogramming in real-time systems. Int. J. Innov. Sci. Res 12(1) (2014) 180-185

7. Ramamritham, K., Stankovic, J.A.: Scheduling algorithms and operating systems support for real-time systems. Proceedings of the IEEE 82(1) (1994) 55-67

8. Martinez, K., Hart, J.K., Ong, R.: Environmental sensor networks. Computer 37(8) (2004) 50-56
9.
10. Ma, Y., Richards, M., Ghanem, M., Guo, Y., Hassard, J.: Air pollution monitoring and mining based on sensor grid in london. *Sensors* 8(6) (2008) 3601-3623

11. Ghosh, Pramit, Debotosh Bhattacharjee, and Mita Nasipuri. "Automatic System for Plasmodium Species Identification from Microscopic Images of Blood-Smear Samples." *Journal of Healthcare Informatics Research* 1.2 (2017): 231-259.

12. Datta, Soma, Debotosh Bhattacherjee, and Pramit Ghosh. "Path Detection of a Moving Object." *International Journal of Recent Trends in Engineering* 2.3 (2009): 37.

13. Ghosh, Pramit, Debotosh Bhattacharjee, and Mita Nasipuri. "An automatic non-invasive system for diagnosis of tuberculosis." *Applied Computation and Security Systems*. Springer, New Delhi, 2015. 59-70.

14. Bhide, VishwajeetHari, and SanjeevWagh. "i-learning IoT: An intelligent self-learning system for home automation using IoT." Communications and Signal Processing (ICCSP), 2015 International Conference on. IEEE, 2015.

15. Stankovic, John. "Research directions for the internet of things." Internet of Things Journal, IEEE 1.1 (2014): 3-9.F

16. "Understanding the Internet of Things (IoT) ", July 2014. Gubbi, Jayavardhana, et al. "Internet of Things (IoT): A vision, architectural elements, and future directions." Future Generation Computer Systems 29.7 (2013): 1645-1660.

17. Teymourzadeh, Rozita, et al. "Smart GSM Based Home Automation System." Systems, Process & Control (ICSPC), 2013 IEEE Conference on. IEEE, 2013.

18. SubhankarChattoraj: "Smart Home Automation based on different sensors andArduino as the master controller": International Journal of Scientific and Research Publications, Volume 5, Issue 10, October 2015

19. N. Kushalnagar, G. Montenegro and C. Schumacher, "IPv6 over low-power wireless personal area networks (LoWPANs): overview, assumptions, problem statement, and goals", RFC 4919, (2007).

20. Sweatha K N, Poornima M, Vinutha M H – "Advance Home Automation Using Fpga Controller", International Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue 7, July 2013.

21. Takako Nonaka ,Masato Shimano, Yuta Uesugi, and Tomohiro. Embedded Server and Client System for Home Appliances on Real-Time Operating Systems.IEEE (2010).

22. Rakesh K. Deore, Vijay R. Sonawane, Pooja H. Satpute (2015) "Internet of Thing Based Home Appliances Control" International Conference on Computational Intelligence and Communication Networks (CICN), pp. 898-902

23. Shen Bin, Liu Yuan, and Wang Xiaoyi ,"Research on Data Mining Models for the Internet of Things", International Conference on Image Analysis and Signal Processing, pp.127- 132, 2010

24. R. Dickerson, E. Gorlin, and J. Stankovic, Empath: a Continuous Remote Emotional Health Monitoring System for Depressive Illness. Wireless Health , 2011.

25. Amirah Aisha Badrul Hishama, Mohamad Hafis Izran Ishaka, Chan Kok Teika, Zaharuddin Mohameda, and Nurul Hawani Idrisb, "Bluetooth-Based Home Automation System Using an Android Phone," Jurnal Teknologi (Sciences & Engineering), Vol.70, No.3, pp.57–61, 2014.

26. Pavana H., Radhika G., and Remya Ramesan, "PLC Based Monitoring and Controlling System Using WiFi Device," IOSR Journal of Electronics and Communication Engineering, vol. 9, no. 4, pp.29- 34, Aug. 2014.

27. Samuel Tang, Vineetha Kalavally, Kok Yew Ng, and Jussi Parkkinen, "Development of a Prototype Smart Home Intelligent Lighting Control Architecture Using

Sensors Onboard a Mobile Computing System," Energy and Buildings, vol. 138, pp 368-376, Mar. 2017

28. Stefan Matlak, RazvanBogdan, "Reducing Energy Consumption in Home Automation based on STM32F407 Microcontroller", IEEE, November 2016.

29. Lihua Deng, Research of Intelligent Home Control System, International Conference on Electrical and Control Engineering, 2010.

30. Armando Roy Delgado, Rich Picking and Vic Grout Remote-Controlled Home Automation Systems with Different Network Technologies, Centre for Applied Internet Research (CAIR), University of Wales, NEWI, Wrexham, UK http://www.glyndwr.ac.uk/groutv/papers/p5.pdf

31. R.Piyare, M.Tazil" Bluetooth Based Home Automation System Using Cell Phone", 2011 IEEE 15th International Symposium on Consumer Electronics.

32. Sharon Panth, Mahesh Jivani, et al. Home Automation System (HAS) using Android for Mobile Phone, ISSN 2277-1956/V3N1-01-11, IJECSE. 3(1).

33. W. He, G. Yan, and L. Xu. "Developing Vehicular Data Cloud Services in the IoT Environment". In: Industrial Informatics, IEEE Transactions on, pp. 1–1. DOI: 10.1109/ TII.2014.2299233.

34. Honbo Zhou. The Internet of Things in the Cloud: A Middleware Perspective. 1st. Boca Raton, FL, USA: CRC Press, Inc., 2012. ISBN: 1439892997, 9781439892992.

35. Kodali, Ravi & Jain, Vishal & Bose, Suvadeep & Boppana, Lakshmi. (2016). IoT based smart security and home automation system. 1286-1289. 10.1109/CCAA.2016.7813916.