

# 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 scenarios.*

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

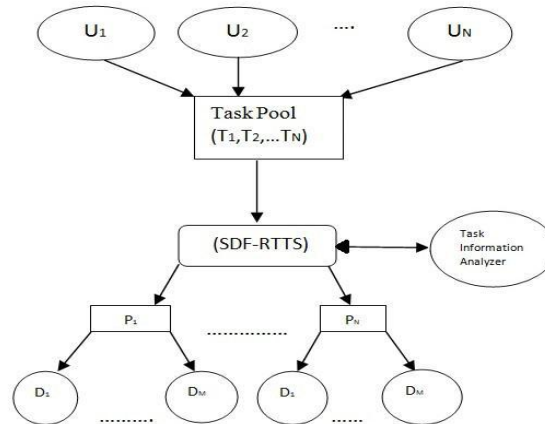


Fig. 1. SDF-RTTS working module

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

The scheduler allocates tasks 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 of real-time tasks arrive for possible allotment on the processors. Our proposed SDF-RTTS will attempt to meet the timing requirements of all tasks by completing them within their soft deadline. Each task consists of two parameters:

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

ON/OFF value is a binary number. ON signal is indicated by the value "1" and OFF is "0". Deadline of a task can be represented by multiple bits. Assume if the deadline is 5 units, then the 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 is known to its connected processor. First, the processor checks the deadline with the device's actuation time. Devices are partitioned into two categories based on the deadline. One partition, let's say SET1, consists of devices whose actuation time is less than the deadline, and the second, SET2, consists of devices whose actuation time is greater than the deadline. Appliances or devices of SET1 ensure that they will be activated with the desired condition within 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 arrives, then it will start the down counter clock (DL). Each device connected with the processor has a different actuation time, which is known in prior. User request or task mapping to the processor is fixed. The down counter clock (DL) starting value will be the deadline and continues up to zero (0). In between that, devices whose actuation time matches with the down counter clock (DL), will receive an activation signal. SET2 devices will get an activation signal randomly when the processor is free or within the time gap between two consecutive device actuation times or in between the 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<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub> in their respective homes. In the text message, users have mentioned the deadline or the time within which he/she will reach at home. Let's say the deadline for reaching to the destination is 5, 10, 8, and 12 minutes. Device actuation time is also known to the scheduler SDF-RTTS. Let's say 1, 2, 5, 10 minutes are the actuation times for the devices D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub>.

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**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

- 1 Initialize DL= deadline; Detect signals [S,T] from multiple users;
- 2 Set priority of the tasks based on the deadline (T ) given by the user (Smallest deadline will have the highest priority);
- 3 Assign the tasks to the pre-defined processors based on the priority;
- 4 for(each devices inN)do
- 5 if (*deadline* >= *device actuation time*) then{
- 6 move device to SET 1;
- 7 else{
- 8 if (*deadline* <= *device actuation time*) then
- 9 Move device to SET 2; }}
- 10 if (SET 1 != NULL) then{
- 11 Set a down counter clock(DL);
- 12 if (T == *device actuation time*) then{
- 13 Send the signal to activate the device;
- 14 Decrement the clock till DL=0;}}
- 15 if (SET 2 != NULL) then{
- 16 if (T != *device actuation time*) then
- 17 Send the signal randomly to activate the devices;}
- 18 End

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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 D4 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 D3, at 2 D2 and at 1 D1 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, represents 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.

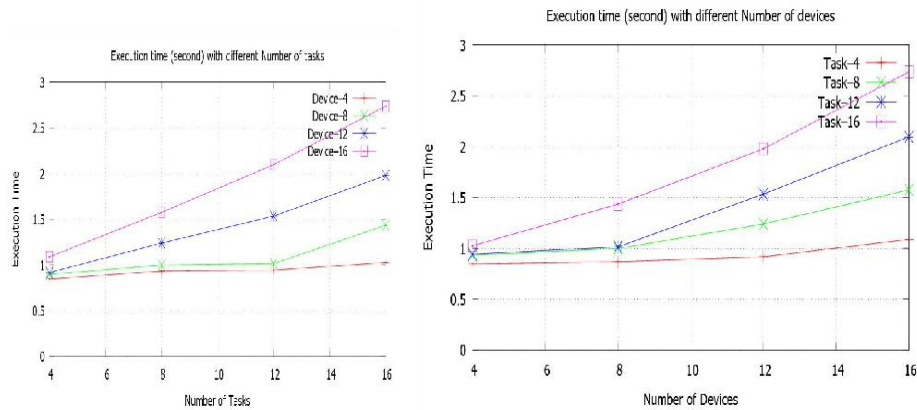
Each result is generated by executing 100 different instances of each data set type and then taking the average over these 100 runs.

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 measured 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	1 2	1 2	1.014	1 6	1 6	1.435
1 2			0.917			1.239			1.534			1.980
1 6			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 constraints and will optimize the overall execution time. Arduino based testbed which provides the flexibility 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.

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