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System Framework for Efficient Resource Utilization by Using Smart Task Scheduling.

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ABSTRACT

Industrial Automation networks needs a gateway to transfer the communication data without any collision and to establish a control operation in timely manner. To resolve the above two requirements intelligent sensor network is designed and implemented in RTOS based architecture. The networks comprises of slave nodes which transmit the data to ARM LPC 2148 is configured as a master node. Based on values received from slave nodes and required control operations are decided. The objective of this paper is to perform the smart task scheduling of the required control operation using adaptive time quantum algorithm with the support of master node. The Master node implementation rely on Vxworks RTOS based architecture to scheduling the tasks and executed under multitasking environment.

Keyword: Intelligent Sensor networks, RTOS, Time quantum, multitasking

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INTRODUCTION

The automation system shall provide a wide communication, scalable architectures and life cycle excellence. It can be deployed into two ways viz wired and wireless automation [1]. In wired automation system,due to fixed infrastructure there is a lack of flexibility in controlling the industrial plant.In embedded wireless automation controlling of industrial plants are flexible [2][3]. The wireless communication in industrial automationfrequently monitoring the environmental condition through sensor nodes and they are battery powered. The sensor nodes are the integration of microcontroller, several sensors and supporting devices[4]. For monitoring purpose the sensors detect the events of interested area and then intimated to the base station. The event may be failure of instruments or machines to taking remedy measures to reduce and prevent the catastrophe of the overall system.

WSN play a major role in monitoring and sensing applications in which small data traffic occurs and the structure of network also arbitrarilychanges[7]. In industrial automation multiple sensor nodes are sensingand the values are transmitted to the masternode[5]. All the critical data,sensed and transmitted to the base station at the same time. So the collision and timing integrity are also major issues that occur during the transmission. For efficient parallel data transmission, specialized algorithms are needed. Even though specialized protocols are used, unwanted disturbances may occur in the data traffic hence, the network lifetime and implementation cost are included in performance computation[6]. But inTDMA scheme, there is no occurrence of collision, every data are transmitted in separate time slots [8]. All the data are scheduled and transmitted in particular time slots. Similarly during dispatch of control operation to various slave nodes TDMA is flexible [4].

RTOS contains a deterministic behaviour that provides time predictable task switching time, task execution time and interrupt latency even when number of task increases. This article proposed embedded platform based industrial automation framework with support of RTOS in ARM processor. Efficient communication usage and effective monitoring and controlling of events are achieved in real time environment. Tasksare scheduled in timely manner and timing integrity is guaranteed by using VxworksRTOS.

Related Work

Advancement in Wireless sensing technology made the low cost industrial automation system that quickly reacts with appropriate actionsbecomes potential. Timing integrity is one of the key factor for efficient multitasking wireless sensor network environment [5][6]. Timing integrity can be realized using TDMA with the drawback of non-tolerable delay when dealing with emergency control operation from the base station. In case of the CSMA when maintaining timing integrity packet loss may occur due to collisions.

CSMA based MAC protocol not ensure the elimination of all collisions and it also stuck against hidden and exposed terminal problem [9]. Another hybrid WSN is based on CSMA – TDMA MAC protocol for reliable delivery of urgent and ordinary data to base station in industrial monitoring system. TDMA is employed to transmit urgent messages by using super frames of fixed time slots assigned to specific sensor nodes in the network [8]. Most of the scheduling schemes employed for reliable transmission in WSN have the relevant features such as centralized network management, avoidance of reuse of channels to sustain the reliability and performance. In multi-channelTDMA transmission, it provides a predictable communication latencies, length of time slot allocated for each and every transmission and hence there is no collision.

Schemes of Packet Scheduling

Scheduling

Packet scheduling is one of the techniques for efficient communication in wireless sensor networks. It deals with several issues such as, energy consumption in node, delay in data transmission from one end to other end etc.. In addition, the data transmission is needed to be synchronized between sensor nodes in the industrial environment and the base station. Therefore ordering of the packets and its transmission should be based on the priority,deadline and network environment.The versatile scheduling techniques [10] are replaced with RTOS framework for industrial automation to coordinate the resource allotment to the users in a systematic and organized manner in embedded multitasking environment.

Deadline

First Come First Serve (FCFS) scheduling, process the data packets from the sensor nodes based on their arrival time. It takes more time to deliver to the pertinent sink node. Also it cannot be guaranteed that the packet has reached base station from the arrival queue before the expiration of deadline. In EDF earliest deadline first scheduling the data packets are collected in a priority queue like structure based on their deadline. So earliest deadline task could be serviced first by the base station.

Priority

The context switching never occur in non-pre-emptive scheduling since the higher priority task in the ready queue executed first , but in pre-emptive scheduling short deadline task are boosted with higher priority if needed, then other tasks are executed based on their pre-assigned priority [11].
Likewise, in this proposed work the scheduling scheme based on time, priority and critical state of environment. The average waiting time and context switches are reduced in this implementation. Proposed Scheduling supports scalability, timely processing in order to realize efficient networks. It also achieves guaranteed real time data processing and execution depends upon the prioritization of task.

SYSTEM FRAMEWORK

Multitasking provides the fundamental framework for industrial application to control and react to multiple and discrete real time events. Multiple tasks that required be coordinating and linking with the subtasks to obtain guaranteed complete execution. Task management depends on intertask communication, task scheduling, interrupt handling, input/output and memory management. Middleware layer is essential to develop complex application easier. Middleware has been ported to embedded platform based on specific libraries, hardware configuration to run any complex operation.It allows portability across the RTOS and hardware. RTOS play a vital role by providing a platform for distributed computing based embedded system.It is highly suitable for more precise and predictable execution of tasks and affords a mechanism to allow real time scheduling of tasks.A device driver issoftware that initiates the device which is connected to specific processor by using various interfaces. ARM 7 Processor is 32 bit processor which is based on RISC architecture, low power consumption, larger register file and instruction cycle are executed in single cycle. The system framework is shown in the below fig.1.

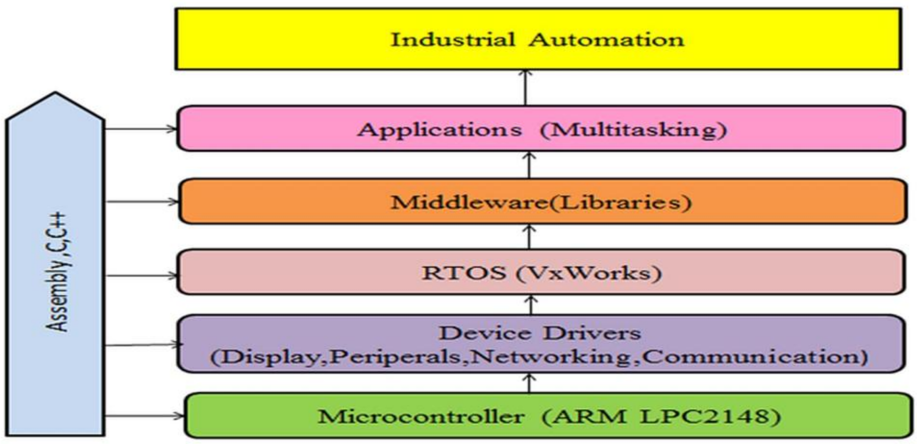

Figure 1: Proposed Framework

In this Suggested Framework, RTOS based scheduling architecture is configured in ARM LPC 2148 which act as a master node. The control commands are send to the slave nodes from the master node if control operation is required. The industrial monitoring, data acquisition, and control operation are performed by the slave nodes. The Bi-directional communication between master node and slave nodes is carried out using XBEE module [12]. In real time multitasking environment, from the information received from the slave nodes the tasks are initiated and scheduled according to the nature of data. Based on the emergency condition priority is assigned and scheduled for execution non-pre-emptively. Though TDMA is adopted under normal situation, emergency tasks are boosted with higher priority range and hence avoiding packet loss. Base station receives the data synchronously without any data loss and viewed to prove the reliable communication between nodes by usage of the proposed algorithm. The main objective of the system is to provide reliable data transmission between nodes for intelligent industrial automation system with VxWorksRTOS.

FUNCTIONAL DESCRIPTION

Numerous sensor nodes are deployed in the industrial area and the changes are continuously monitored. All the nodes are coordinated through the centralized processor (Master Node) for parallel monitoring. The master node,performs the smart task scheduling using adaptive time quantum algorithm when more than one tasks are initiated. The proposed RTOS implementation in sensor nodes as shown in the fig.2

In this prototype implementation two slave nodes are scattered in the industrial region. ThePIC16F877A controller act as a slave nodes consists of gas sensor ,temperature sensor and humidity sensorwhich continuously monitoring and the values are synchronously transmitted to the Master node. Sensed signal are in analog form and LPC2148 has inbuilt ADC which changes the analog signal to digital signal with the help of successive approximation technique. Based on the sensed signal values, master node initiates the control operation tasks and subjected to scheduling.

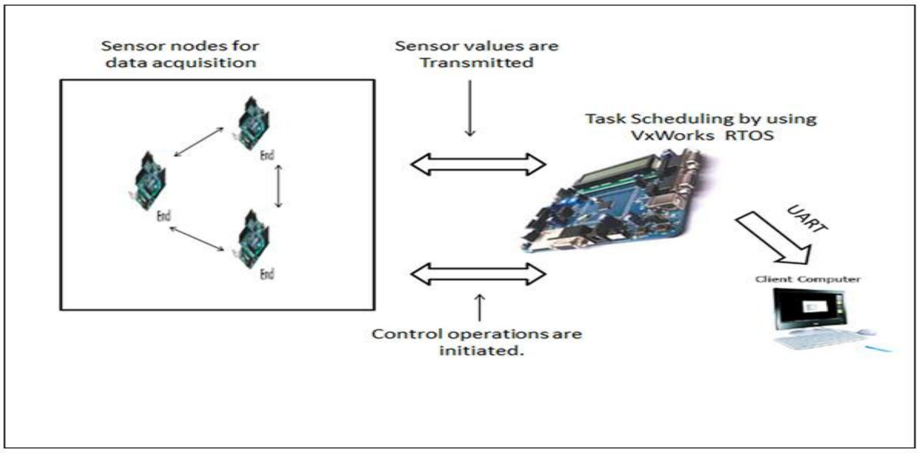

Figure 2: RTOS implementation in Sensor nodes

Multitasking can be efficiently performed with the help of RTOS. Depending on real time demands and its environment RTOS calls the device driversand in turn processor to work accordingly. In fixed timeslots the data is transmitted to the master node from the slave nodes. The Master node receives and processes the data and schedules the appropriate control operation with the support of RTOS kernel.The control operation areaccommodated in the mailbox of the data link layer in the scheduled order. Data link layer is then activated by the kernel for packet parsing and initiates the tasks to execute the control operation. An interrupt signal is generated to trigger slave nodes for each and every 60ms to transmit the data to master node. Similarly RTOS triggers for issuing control signal to the slave nodes.

Proposed protocol stack uses IEEE802.15.4 standard namely ZigBee for efficient data transmission [12]. Master node initiates the radio transceiver for listen the channel within specified allotted time slot for reliable data transmission. In this way data is reliably transmitted within allocated time slot and hence avoiding collision. Also unnecessary delay is reduced this is essential for remote intelligent industrial automation and control system.

TASKS SCHEDULING BY VxWorks RTOS:

In VxWorks RTOS, Task scheduling is the fundamental unit. All the tasks in the kernel are subjected to the scheduler before execution. The tasks are not able to schedule by themselves since they necessarily need inter task communication facilities in order to coordinate their control operation. The ready queues contain number of tasks that needs scheduled and executed based on the scheduling condition.

ADAPTIVE TIME QUANTUM SCHEDULING ALGORITHM (ATQ)

ATQ algorithm decides initial time slice similar to round robin and allocates every tasksin their appropriate time slice[13]. Since fixed time slice is maintained for all types of tasks which are waiting in ready queue, critical tasks are not gaining immediate attention in round robin scheduling. It also leads to more number of context switches, increased average waiting time and turnaround time. Hence the overall system performance is degraded due to the low throughput.

ATQ algorithm includes critical state of tasks, task execution time and deadline in time slice calculation. Time slice is also modified dynamically based on the abovesaid parameters of tasks. Reduction in task overhead and in turn the number of context switches, average turnaround time, waiting time is achieved and it improves the overall performance of the system. If the time quantum is too large then the overall system response time is delayed and in turn the control operations cannot be issued in time. If the time quantum is too small the frequent context switches happens, in such way that more processor time is wasted in switching time. In ATQ scheduling algorithm, time quantum is decided in each round based on the updated parameters computed from the previous rounds and hence too large/small time quantum won't occur.

Pseudo code for ATQ Scheduling Algorithm

```
Pseudo code:
    1.  while (RQ!=NULL)
//Ready Queue(RQ)
    2.  All the tasks in the queue are sorted in ascending order based on execution time.
//Task ID is assigned for each task.
//Execution time is calculated.
//Time quantum (TQ).
//TQ =( (mean+ max execution time)/(no.of tasks +1)).
    3.  Assign TQ to (1 to n tasks)
    4.  Repeat until no other task is pending in the given task set for its time quantum
{
    Assign, TQ for Ti
}
Here TQ denotes updatedtime quantum for each and every round.
    5.  Calculate the residual execution time of given tasks.
   6.  If (task set still have  pending execution time of any task ) then
go to step2
end of if
end of while
    7.   Calculate ATT,AWT,CS
 //ATT=Average Turnaround time //AWT=Average waiting time //CS=Number of context switch
   8.   End
```

EXPERIMENTAL ANALYSIS

Table 1 Sample Task set ID and execution time

TASK ID	EXECUTION TIME
1	70
2	65
3	10
4	15

The task execution time and task ID are assigned for the given tasks set and are to be scheduled by using adaptive time quantum algorithm. The task execution time is theoretically calculated by using the equation given in [Operating System Concepts, 9th Edition]

The tasks in the ready queue are arranged in ascending order sequence initially based on their execution time. TQ is calculated as the ration of summation of average task execution time and maximum task time in task set to the number of tasks + 1.

The first round of execution is performed with above computed TQ for all task in the task set. The same process is repeated with the pending tasks by calculating TQ dynamically based on pending execution times and executed until all tasks have complete their execution. Minimum turnaround time, waiting time and reduced context switches are calculated after execution completion. The time quantum schedule for ATQ algorithm is shown in the fig.3 for the sample set of tasks listed in the Table.1

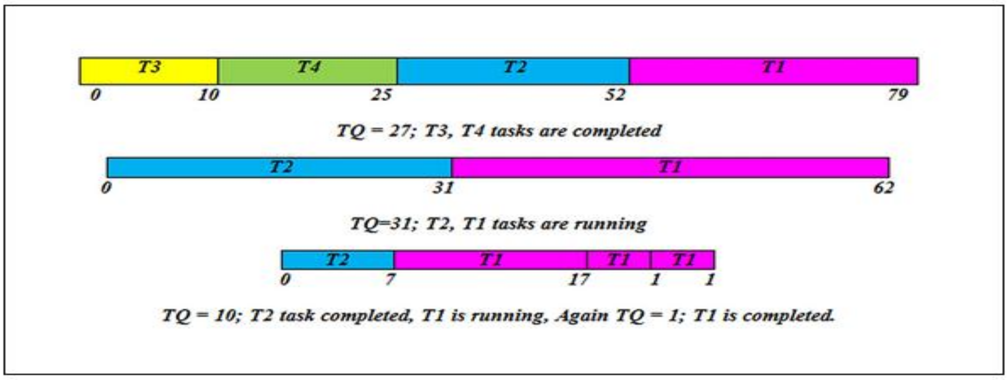

Figure 3: Time quantum diagram

ATQ Algorithm Terminology and calculations:
The waiting time is calculated as,

$$WT_i = TQEt_i - CTQ_i \times TQ$$

$TQEt_i$ Initiation of last time quantum
CTQ_i no. of iterations the task T_i has executed
TQ Time quantum in that round.

Average waiting Time = $(sum\ of\ all\ WT_i)/M$

The turnaround time is calculated as, **Average Turnaround Time,**

$$AVG.TAT = \sum_{i=1}^{M} TAT_i$$

Context Switches are calculated by the following equation,

$$C_s = (\sum_{r=1}^{M} T_r) - 1$$

T_r Total no. of tasks in each rounds.
C_s Context Switches.
M Total no. of rounds

Table 2 shows the turnaround time, average waiting time and contexe switch for the task sets which mentioned in the Table 1.

Table 2: Results for the task sets

Turn Around Time	**98.75**
Waiting Time	**58.75**
Context Switches	**5**

HARDWARE SETUP AND RESULTS

Hardware set up consists of two slave nodes and one master node. Both slave nodes consist of PIC microcontroller, sensor modules and transceivers as shown in Fig.4 and 5. The gas sensor and AC bulb is configured in one slave node, temperature, humidity sensors and DC Fan, DC gear motor are connected in other slave node. The gas sensor, temperature sensor, humidity sensor values are continuously monitored and displayed in LCD. Master node decides the control operations if necessary based on the sensor values and subjected to ATQ scheduling algorithm.

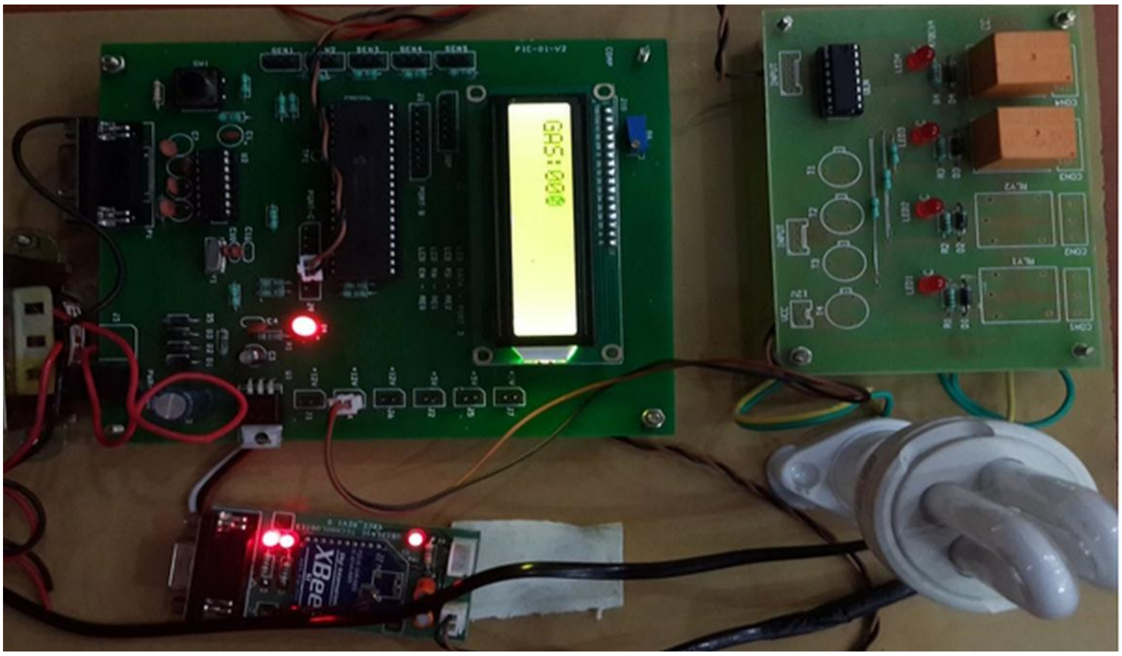

Figure 4: Slave node1

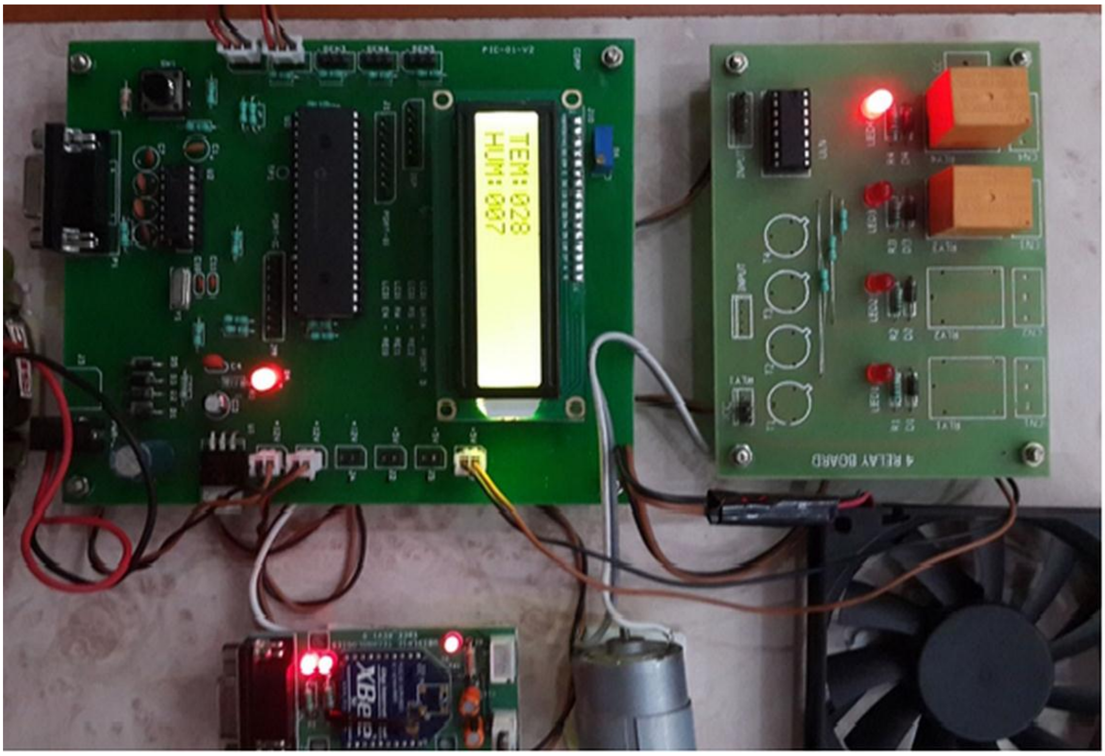

Figure 5: Slave node2

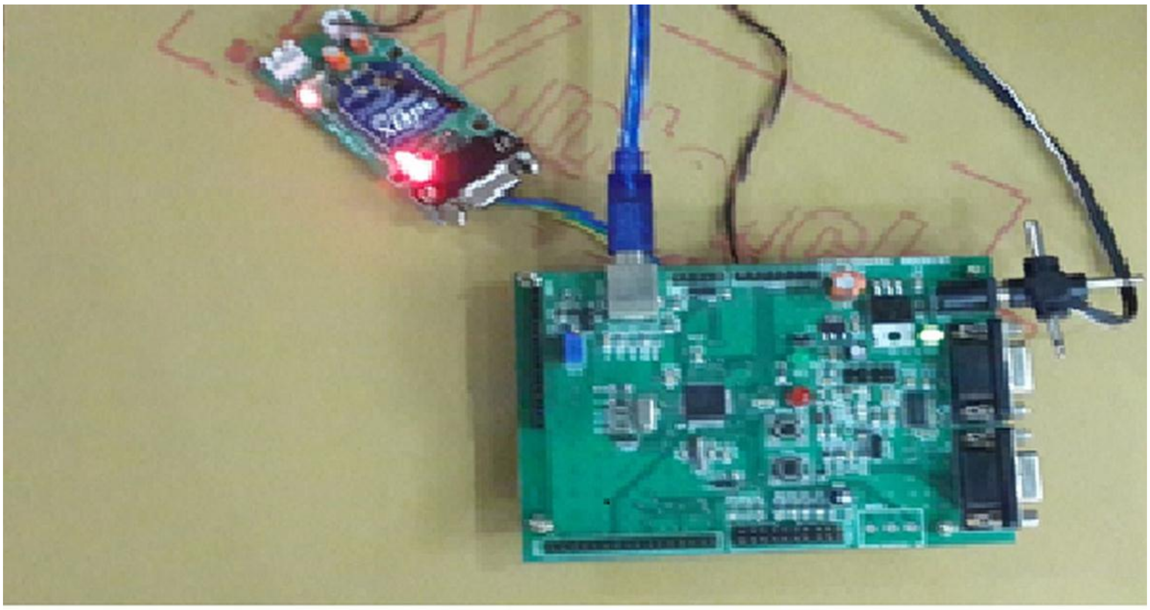

Figure 6: Master node (ARM LPC 2148)

The Master node consists of transceiver and ARM LPC2148 as shown in Fig 6 The master node communicates with the slave nodes and execute the control operations according to the industrial conditions. Scheduling algorithm is implemented in Tornado IDE with the support of Vxworks RTOS. The normal and abnormal range of sensor values are analysed and displayed. If the value of Gas, temperature, and humidity sensors exceeds beyond the threshold value, corresponding control operations are scheduled and generated.

RESULTS AND ANALYSIS

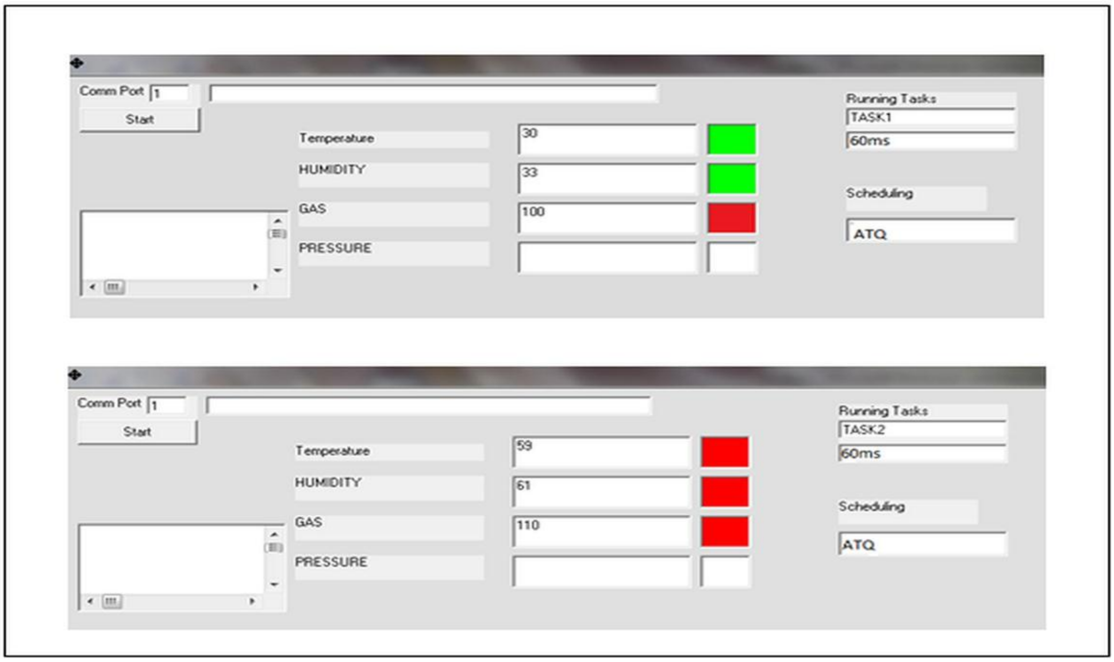

Figure 7(a): Situation analysis

Figure 7(b): Situation analysis

From the above results, Fig.7 (a) & (b) shows that tasks are assigned based on the threshold values and the critical state to perform the control operations. Fig 7(a) indicates that gas sensor values get abnormal, and its specific actuators (L1, L2 turn ON) are activated. If three sensor values are exceeds beyond the onset value, only L3 is turned ON and all other actuators are turned off. Suppose both the temperature and humidity sensor values are abnormal, the L1 and L2 are turned ON. Control operations are in idle state in normal condition i.e., if all the sensor values are in normal (L1, L2 and L3 are turned OFF). L1, L2 and L3 and its corresponding actuators are mentioned in table 3,

Table 3: actuators and their variables

Variable	Actuators
L1	DC Fan
L2	DC Gear Motor
L3	AC Bulb

CONCLUSION AND FUTURE ENHANCEMENTS:

Monitoring industrial region remotely using proposed intelligent embedded system greatly reduces man power and also helps to avoid any major accidents. Critical situations always exist in the industries and it urgesa unmanned intelligent embedded system to monitor and transmit data without delay and collision. So the proposed system involves sensor nodes in IWSN which transmit data to the master node. The control operations are generated based on sensor values with ATQ scheduling and RTOS.The reliable communication is ensured by use of TDMA. Starvation is highly reduced due to less context switches, overall response time is improved due to lesser average waiting time and turnaround time. In industrial environment, dynamic time quantum has proved its timing integrity and the control operations are performed efficiently. In future, the transmission of data over a long distance could be achieved with alternate communication module like Wi-Fi.

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