Real-Time Industrial Automation Process Control using Network -Enabled RFID

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ABSTRACT
The emerging ubiquitous computing technology that belongs to the group of automatic identification technologies and has become popular is the Radio Frequency Identification System involving electromagnetic theory for identifying human beings, animals, and most importantly useful in various fields like drug discovery, tracking and distribution of various materials, and data warehouse management. In recent times, it is found that the ubiquitous technology has been extended to numerous industrial applications involving real-time decisions. This system termed as "networks of RFID systems" helps in controlling various parameters and systems in real-time environment. Scheduling of real-time systems is important since it helps in satisfying the timing constraints where tasks in real-time systems are decided on the basis of deadline, occurrence period and slack time. Few algorithms based on these criteria are Rate Monotonic (RM), Earliest Deadline First (EDF), and Least-Laxity-First (LLF) algorithms. EDF and LLF are considered to be dynamic in nature while RM is static in nature. To judge the efficiency of the algorithms two conditions like "overloaded" and "under loaded" are taken into consideration. In this article, an effort is made to combine the features of both static as well as dynamic algorithms. in order to control the real-time industrial processes. Hence the major issue of concern in this paper is to resolve two issues, one- determine the algorithm in terms of timing performance of different sub-processes so as to properly schedule them and other, how the timing constraints determine the behavior of the system need to be specified and thereby, to ensure that the algorithms meet the constraints under both overloaded and under loaded conditions.

General Terms

Keywords
RFID, Real-time systems, EDF, LLF, RM, Laxity, Success Rate.

1. INTRODUCTION
Radio Frequency Identification system dates back to 1948 as a modification to the radar technology and as a result of research on radio communication during World War II[1]. However, today, Radio Frequency Identification(RFID) System has found applications in logistics and supply chain management system, in mining, in institutions for tracking student's attendance system and tracking books in library, in railways for booking railway tickets and tracking of wagons,[2] in discovery of drugs[3], to name a few. During recent times, however, this mobile and wireless technology is being extended to control the processes in different industries such as chemical, automobiles, etc.

1.1 Real-Time System
A real-time system [4, 12] is a system which reacts or responds to the user queries within a fixed amount of time in order to avoid failures which can be fatal. Processing within a real-time system should be done within a pre-determined deadline, failure of which may cause even loss of life. Examples include real-time systems incorporated in missiles, in chemical plants. etc. In a chemical plant that is automated, when the temperature of the reaction chamber reaches a temperature, say, 200 degrees, the heater gets automatically switched off by the automated system within a deadline or fixed amount of time, say 20 msec.

1.2 Network of RFID System
In most of the industrial automation process [4], access to RFID data in real-time becomes more crucial, especially in a chemical plant such as chemical concentration [4, 5], plant conditions, etc**.** In such cases, for making decisions related to the control mechanism and implementation of these decisions in a real-time environment in order to control the flow of processes so that they meet the deadline becomes an issue of concern. In chemical industries, update about control process parameters, traceability of raw materials such as expensive chemicals throughout, i.e. from starting to finished products must be available within the scheduled time, failure of which may be disastrous. All these benefits are exploited by implementing a network-enabled RFID system.

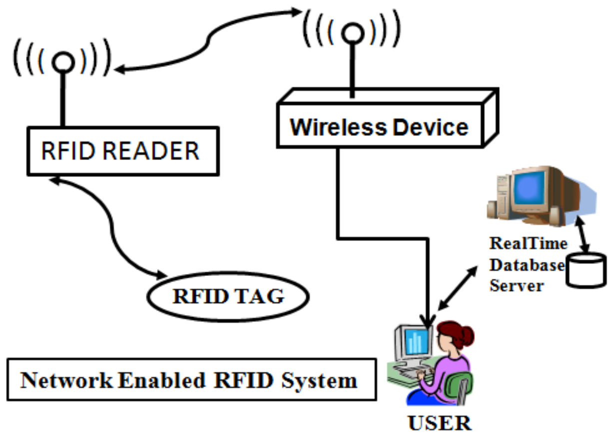


Fig.1. Network-enabled RFID system

1.3 Control System in a Real-Time Environment [6,7]

The control-system, in order to work in a real-time environment, consists of the following components:

1. Sensor: A sensor is a device for converting input from external world into electrical signals. In an industrial process control, varieties of temperature and pressure sensors are used.
2. Some algorithms for managing the control actions like controlling the temperature of the reaction chamber.
3. Actuator**:** An actuator is a component that takes inputs from the output interface of a real-time computer system for converting the signals into some actions occurring physically such as change of thermal, electrical characteristics. Examples include heaters and motors.

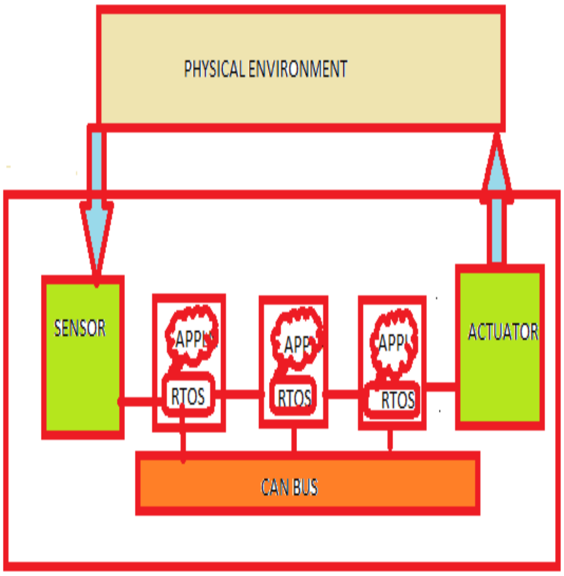
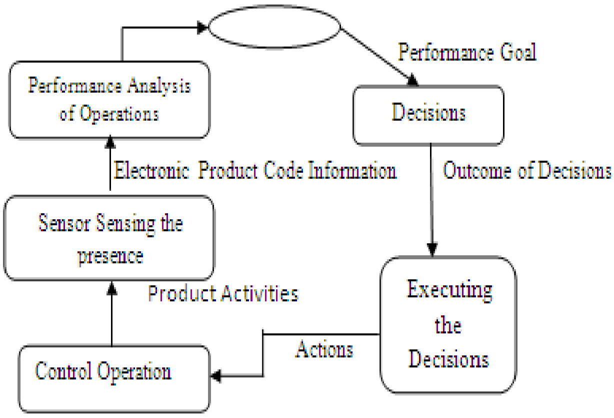


Fig.2. Network Real-time Control System

1.4 Control System Based On Network-Enabled RFID in Real-Time Environment [7]:

The role of network-enabled RFID systems in controlling processes in industries such as a chemical industry can be examined in three phases:

1. *Connection Phase:* In this phase, RFID data is integrated physically with the sensors used for detecting hazardous usf chemicals. This RFID data is used for monitoring different conditions of the chemical plant, based on parameters like temperature, pressure, environment conditions, etc.
2. *Coordination Phase:* In this phase, the RFID data distributed throughout the network is used in enhancing the process of decision making and then executing these decisions related to real-time operations. This enhancement in the decision making process is solely dependent on the availability of data within a fixed time period.
3. *Coherence Phase:* Better information about the availability of rare chemicals, leads to the control of physical operation in a better way. Integration of RFID tagged information of products, lead to the concept of "profound product" – a product capable of storing its own distinct identity and



communicating the same to the RFID network.

Fig.3. Role of RFID in Industrial Process Control

2. RELATED WORK

Lisanne Bainbridge[9] in his paper has recommended the advantages of automating the processes that control the entire industrial system**.** However**,** DunCane McFarlane has focused on the netwok-enabled RFID systems [5,8] which he claimed to be effective in industrial process automation. Wei Wang, Duncan McFarlane and James Brusey have focused more on the timing analysis [7] of the network-enabled RFID systems and its role in automating the process. However, neither a single article has addressed the problem of scheduling the real-time processes in a better way. Hence, in this article, it has been tried to reap the benefits of deploying the algorithms in real-time environment so as to control the industrial automation process as well as to make better decisions.

This article is structured in the following manner: Section III describes the problems or issues arising due to usage of real-time network-enabled RFID technology. Section IV describes the proposed work in the form of algorithms. Section V describes the parameters for measuring the performance of these algorithms and also describes the simulation environment. Section VI concludes the paper and Section VII gives a detailed list of references which completes the article.

3. ISSUES WITH REAL-TIME NETWORK ENABLED RFID TECHNOLOGY

In order to ensure control operability of processes in a real-time environment in industries, especially chemical industry, network-enabled RFID technology is added as an add-on package, which gives rise to issues like the type of system constraint set by the outside environment and the methods by which these constraints should be handled with.

4. PROPOSED WORK

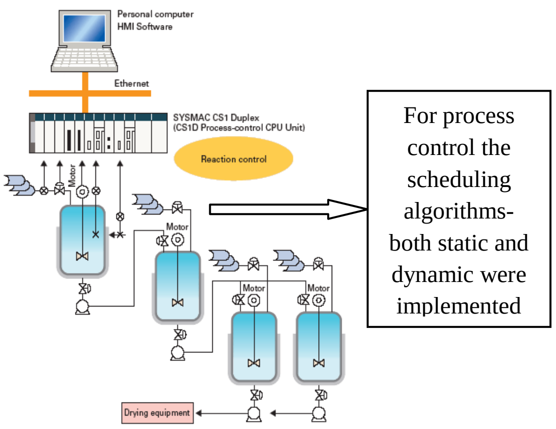


Fig.4. Process scheduling for controlling chemical processes

4.1 SCHEDULING OF REAL-TIME TASKS:

Scheduling of real-time tasks [4, 6, 7] refers to the prime objective of deciding the order in which several tasks are to be executed. To satisfy this requirement, a number of task-schedulers are used, which are classified on the basis of scheduling algorithm that it uses. These task-schedulers ensure that the tasks get executed within the deadline period.. The scheduling strategies can either be static or dynamic. Assignment of priorities to a particular task during the time of design or creation is performed by the static algorithm, which remains constant until the task gets executed completely; whereas, assignment at run-time, i.e., during execution, is performed by the dynamic algorithm, taking into account various execution parameters of the scheduled task.

Scheduling algorithms that are dynamic in nature either uses the strategy of assigning priority during design time or during the time of execution.

Rate Monotonic (RM) and Deadline Monotonic (DM) are dynamic scheduling algorithms that assign the priority to a task during the time of its design. Earliest Deadline First (EDF) and Least–Laxity-First (LLF) are dynamic scheduling algorithms that assign priorities during execution time.

4.2 SCHEDULING ALGORITHMS [6,10]:

4.2.1 *The LLF Algorithm:*

The algorithm gives optimal solution when executed on a single processor and the system is both preemptive as well as under loaded. The algorithm also assigns the highest priority to those tasks that has the nearest deadline or with shortest laxity and selects it for execution.

At a given instant of time, for making decision by the scheduler, the task with the shortest laxity, "l" , is selected for execution and can be found as:

d – c = l (task with shortest value of "l" gets executed)

where, d =deadline interval

c= computation time

Further, Let c_j = remaining computation time of task at time instant "j"

(At the arrival time of a task, "c_j" is the computation time).

d_j = deadline of a task relative to current time instant "j"

Therefore, laxity, $l_j = d_j - c_j$

Here, the laxity of a job can be defined as the maximum amount of time; the job may be forced to wait in order to get executed on a processor within the deadline period. Therefore, jobs with smaller laxity may get high priority, set by the LLF algorithm. Since, the laxity of the job is dynamic, so also the priorities of the job. One of the two jobs with the same laxity can be chosen randomly by the LLF algorithm.

4.2.2 *The RM Algorithm [11]*

Priorities to the tasks are assigned by the RM algorithm on the basis of rate of occurrences of tasks. The algorithm uses the policy of assigning priorities to the tasks during design time, which remains constant until the task completes its execution. The task with the shortest period gets executed first.

Let there be "z" number of real-time tasks, " { T_1, T_2,T_3,……., T_z}" . The utilization of the periodic task "Tz" can be computed as:

$$U_z = \frac{Ex_z}{p_z}$$

Where, Ex_z = execution time of task "T_z"
P_z = period of task "T_z"

or a set of periodic tasks, the total utilization is given by:

$$U = \sum_{z=1}^{n} \frac{Ex_z}{p_z}$$

For RMA, the necessary condition is:

$$U = \sum_{z=1}^{n} u_z \le 1$$

n= No. of tasks to be scheduled
u_z = CPU utilization due to task T_z

In order to get scheduled by the RM algorithm, the utilization factor must be less than or equal to 1, since, for uni-processor systems, the ideal case is u=1.

4.2.3 The LLF-RM Scheduling Algorithm

By exploiting the advantages of both EDF algorithms as well as of RM – based algorithm, a third, yet more advantageous algorithm, called LLF-RM algorithm is designed. It has been explored that the LLF algorithm produces best results when executed in under-loaded conditions, whereas, in overloaded condition, RM algorithm produces an optimum result.

Therefore, the enhancement made in LLF algorithm by exploiting the merits of RM algorithm allows the scheduler to switch between the two overloaded and under loaded conditions using both the algorithms, i.e., LLF and RM.

5. SIMULATION METHODS AND RESULTS

The three algorithms- RMA, LLF and LLF_RMA have been implemented in MATLAB R2009a with periodic tasks. For this purpose, 25 number of task sets (each consisting of five tasks) are generated randomly,out of which 3 task sets are considered as outliers in order to smoothen the graph. The load range of each task set varies between zero and four (0 < load< 4). All The simulations were performed on Intel(R) Pentium(R) Dual CPU T2330 @ 1.60 GHz system with 1GB RAM having Windows Operating Systems. Assuming deadline and period of each task are same and the context switching overhead is zero, the performance of scheduling algorithms for feasible and periodic task sets were measured in terms of Load VS Success Ratio and Load VS Effective Processor Utilization (EPU), which are defined as follows

For a given Task set having n tasks (Here n=5)

Ex_i = Execution time for each task

P_i = Period of the task-i

D_i =Deadline of the task-i

T=Total Time of Scheduling for a task set. Here T is calculated by taking the LCM of all periods of a Task Set.

1. *Success-Rate = Number of jobs completed and scheduled successfully / Total number of jobs arrived*
2. Effective Processor Utilization(EPU)[12] gives the information about how efficiently the processor is utilized and is defined as

$$EPU = \sum_{i-1}^{n} \frac{Vi}{T}$$

Where $V_i = \begin{cases} Ex_i & \text{(if the job successfully executed} \\ 0 & \text{(Job misses its Deadline)} \end{cases}$

3. $$Load = \sum \frac{Ex_i}{Q_i}$$

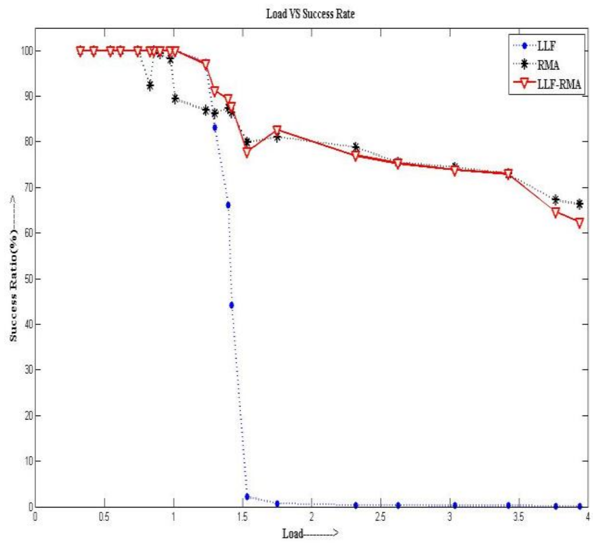
Here $Q_i = P_i = D_i$ (Assumption)

For all the Task Sets Generated Randomly, the avg. success rate and avg. EPU are calculated as:

Average Success Rate = mean(Success Ratio)

Average EPU = mean(EPU)

Fig.5. Load VS Success Ratio



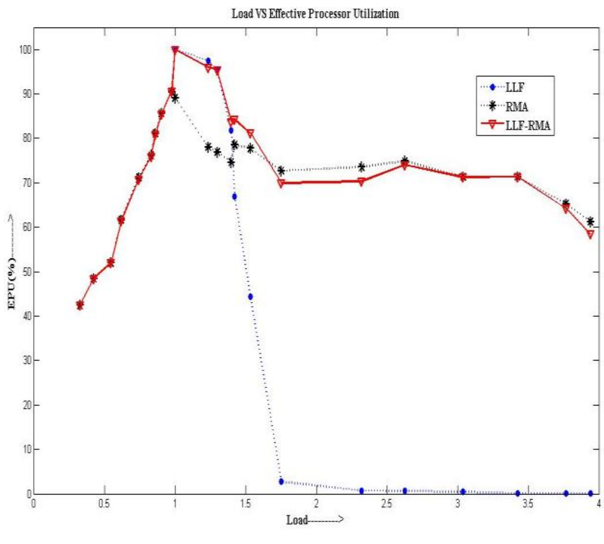


Fig.6. Load VS EPU

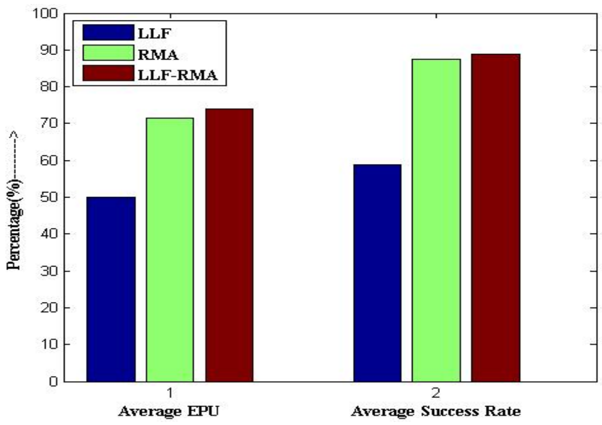


Fig.7. Comparison of Average EPU and Average Success Rate

6. CONCLUSION

In this article, the algorithms which can schedule different task sets having varying load which might be crucial for a chemical plant in real-time, are explored. It has also been tried to show the benefits of using real-time controlled and network-enabled RFID system to ease the process management in chemical plants in a real-time environment. From the results it is clear that The LLF algorithm performs better than RMA in under loaded conditions. However the RMA performs better than LLF in over loaded conditions. In this article, it is tried to design an optimal algorithm by combining the benefits of both LLF and RMA algorithm which can switch from underloaded condition to over-loaded condition and vice-versa. However LLF even performs poorly in underloaded condition if the context switch among the tasks is taken into consideration as the number of context switches among the tasks is more. Similarly RMA also not optimal when the task periods and deadlines are differ. When task deadlines differ from task periods Deadline Monotonic Algorithm (DMA) may be used for optimal scheduling. However if the two assumptions are taken into consideration , then the LLF-RMA algorithm performs optimally for Scheduling real-time controlled and network-enabled RFID system to ease the process management in chemical plants in a real-time environment.

7. REFERENCES

[1] Ahuja S., Pavan P. , "*An Introduction to RFID Technology*", Scientific Research, Communications and Network, 2010.

[2] Das Debashreet, "*RFID Deployment in INDIAN RAILWAYS: A Case-study of E-Transport* Initiative in India", In proceedings of International Conference on Electronic Transport, India, ICET-2011.

[3] Xiao Yang, "Security and Privacy in RFID and applications in Telemedicine", 2006, IEEE Communications Magazine.

[4] Mall Rajib, Textbook on "*Real-time systems*".

[5] McFarlane Duncan, "*Networked RFID in Industrial Control: Current and Future*", Emerging Solutions For Future Manufacturing Systems", Springer, 2005.

[6] Canton Jordi, Nougues M. , "*Reactive Scheduling in real-time operation of Batch Chemical Plants*", Proceedings, Foundations of Computer Aided Process Operations, 2003.

[7] Wang Wei, McFarlane, Brusey James, "Timing Analysis of Real-Time Networked RFID Systems".

[8] Cole H.Peter, Ranasinghe C., "*Networked RFID systems and lightweight Cryptography*", First Edition, Springer, 2007.

[9] Bainbridge Lissane, "*Ironies of automation*", International Federation of Automatic Control, 1983.

[10] Sindhi P., Gupta K. Ravindra, "Enhancement in LLF Real-Time dynamic Scheduling Algorithm using conventional RM algorithm", IJCA, Vol 31, No. 6, 2011.

[11] Deters M, Gill Christopher, "Rate Monotonic Analysis in the C++ Type System".

[12] Kotecha Ketan and Shah Apurva, "Adaptive Scheduling Algorithm for Real-time Operating System", IEEE,2008.