

The Analysis of Crucial Parameter Determining the Performance of Real Time Operating System VxWorks

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ABSTRACT—

The paper presents an overview of VxWorks a Real Time Operating Systems (RTOS). RTOS is defined as a system in which the correctness of the system does not depend only on the logical results of computation but also on the time at which the results are produced. It has to perform critical tasks on priority basis by utilizing resources optimally. VxWorks is one of the most commercially successful RTOS in embedded industry. The features which make it most preferred RTOS are discussed in this paper. Important parameters like memory management, scheduling, runtime performance, development environment are discussed.

KEYWORDS: VxWorks; Microkernel; Workbench.

I. INTRODUCTION

A remarkable rise has been seen in retrospect in the demand of the embedded systems in human affairs. It has made its mark almost in every field varying from domestic purposes to defense. We are very much familiar that the embedded system is the blend of software and hardware and perhaps other mechanical parts too which are directed to perform specific functions. Its contribution has made our life safe and comfortable. Its performance is majorly dependent on the OS used. For such precise task, RTOS comes out to be a better option for embedded designers. [1] and improvised Integrated Development Environment (which included simulation facility) which Versatile Real-Time Executive (VRTX) lacked in. VxWorks gained popularity from its contribution to mars pathfinder project in 1997 in which it helped pathfinder to communicate and control remotely from ground station. Recently VxWorks contributed in successfully implementing EDL (Entry Descent Landing) sequence in Curiosity Mars Rover. Features like SMP (Symmetrical Multiprocessing) and AMP (Asymmetrical Multiprocessing) support, error handling framework, IPv6 networking stack and other make it stand out from other RTOS. According to a survey, VxWorks is an O.S currently used in more than 500 million electronic devices. Latest stable version of VxWorks is 6.9 which was released in 2011.

An operating system is comprises mainly of kernel space and user space. Kernel actually acts like a mediator between user applications and the processing at the hardware level. It also provides the lowest- level abstraction layer for the resources (especially processors and I/O devices). Thus Kernel is a difference making parameter of a RTOS.

VxWorks uses Wind Microkernel since VxWorks 5.0. It provides a lot of real time features which includes advance networking support, fast multitasking, interrupts and both pre-emptive and round-robin scheduling. It has also got a unique feature of supporting unlimited number of tasks.

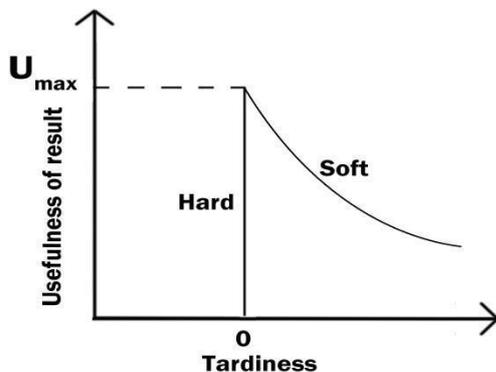
Other benefits of using micro kernel are:

- The program code is shifted from the kernel into —user|| space.
- Communication takes place between user functions using message passing.
- It is easier to extend a microkernel, thus making easier to modify operating system for new architectures.
- It is more reliable, as less code is to be run in kernel mode and more secure as well (due to features like information hiding).

RTOS can be defined as —An operating system which is able to provide a required level of service in a bounded response time.||[2] RTOSs' are broadly classified into two categories, namely, hard

real time and soft real time OS.

The deadline of a job is the instant of time by which its execution is required to be completed. In real time literature, hard and soft timing constraints are often quantitatively differentiated as function of the tardiness of jobs. Tardiness of a job measures how late it completes execution respective to its deadline. Tardiness of a system is zero, if the job completes at or before deadline.



U_{max} – Maximum Usefulness of Result

Fig. 1 Hard Vs. Soft RTOS

If the usefulness of a result decreases gradually as the tardiness of the job/task increases, then that system is called Soft real time system.

Though the requirement of following hard timing constraints puts some restrictions on the design and implementation of (system software) RTOS, VxWorks has been succeeded in adhering to these constraints [3].

VxWorks strikes a balance between supporting a rich feature set and advanced functions to increase its utility in real time applications and its run time performance to meet deadline. [4]

II. RUN TIME ANALYSIS TOOLS IN VXWORKS:

These tools enable a designer to access the performance and analyze the system while it is performing the task. VxWorks workbench provides powerful and dynamic visualization tools for device software applications, this enables the designer to check application code, operating systems and third party libraries. One can monitor variables, detect any memory problem and also enhance the performance of the system even with the continues input of real time data. This saves lots of time and helps to get rid of redundancies more quickly and efficiently. Following have been provided by Wind River systems to check run time analysis of VxWorks.

A. System Viewer:

The tool when utilized on a VxWorks 6.x systems it gives a detailed graphical visualization and the analysis of the complete system. It shows effect of interrupts on the system, interactions between complex tasks. The tool provides graphical visualization of complex tasks such as context switching. System particular events like timers, message queue, signals, tasks, semaphores can also be analyzed graphically using this tool. It helps the developers to detect any anomaly in the system and rectify it in less time.

B. Data Monitor:

It is a data monitoring tool which monitors the real time data. The data can be in any form like memory location or data structures. It enables designer to watch and analyze any value at any instance. It can be peak to peak or out of range values. This tool enables to change the variable during the execution and provides the provision to save the collected data.

C. Memory Analyzer:

Memory plays a crucial role in any application and helps the system to work efficiently. Many times it is seen that improper allocation of memory leads to wastage of memory and task failures. The tool is an instant memory analyzer which gives an insight into the usage of memory. It is designed to check for memory leaks, allocation and

availability of free or unused memory. Memory leaks are often due to third party libraries.

D. Code Coverage analyzer:

The tool analyzes the code to decide which code segments are to be executed during testing periods. It is used to provide test environments to judge the performance of the code. The testing in different environment ensures the production of high quality devices. It also removes any redundant code in the program. All this finally contributes in reducing the memory footprint of the device. [5]

III. PERFORMANCE ANALYSIS PARAMETERS:

A. Portability/ Compatibility:

Designer aims to work on a RTOS which supports number of platforms increasing the degree of freedom to choose hardware according to the application requirements. An RTOS with such a capability can thus be switched between various embedded processor of different architectures.

Prominent platforms supported by VxWorks are ARM 9, ARM 11, ARM Cortex A8, Intel, Pentium family Xenon, core2 duo, atom, MIPS, PowerPC. [6]

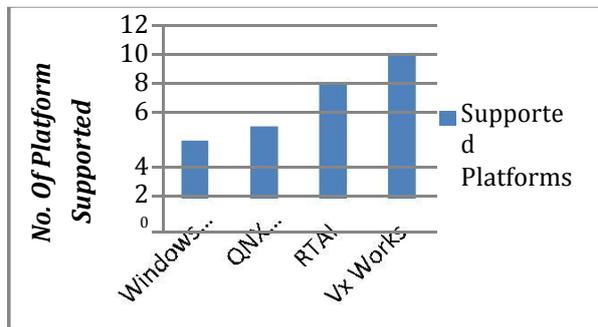


Fig1. No. of Platforms supported by various RTOS

B. Development Suites Provided:

It is necessary to have complete set of development tools in order to reduce debugging time resulting in less time required for development of RTOS. Hence development tools assure a high degree of reliability in code. Advantage of commercial RTOS is that they provide complete set of development tools for analysis and optimization of RTOSs' behavior as against open source RTOSs.

Wind River Workbench 3.3 was developed by Wind River system for developing debugging and monitoring system performance. It uses Eclipse framework. Workbench supports VxWorks 6.x and backward compatible with VxWorks 5.5. Workbench contains editor, GNU compiler, debugger and simulator. The Workbench debugger helps to debug VxWorks 6.x targets. It supports debugging for single and multi-core processors running VxWorks in either SMP or AMP mode. VxWorks introduced a simulator in VxWorks6.x which was one of the most desired features in its predecessor. [7]

VxWorks Simulator:

- VxSim or VxWorks Simulator 6.9 provides a complete simulation solution for VxWorks 6.x applications.
- It supports 64-bit operation on supported 64-bit host platforms.
- It helps in testing applications or a part of it during the development cycle and eliminates the need of hardware for testing.
- It saves the development cost.

C. Memory management:

VxWorks uses microkernel based architecture which differentiates user and kernel space, thus leading to strong MMU protection. It also increases device reliability of the host hardware. This type of kernel model also simplifies application development.

Better memory management leads to reduced memory footprint. Memory footprint is an estimate of RAM and ROM requirements of an RTOS on a specific embedded platform. Effective code, read-only data of the kernel, and any runtime library code are all collectively part of the ROM size. RAM requirements on the other hand are a sum of data structures and global variables and temporary programs.

Memory footprint values depend upon architecture of hardware platform, compiler settings (optimizations) and most importantly OS configurations which include kernel type and size of run-time libraries. Footprint metrics are often an important decision factor when considering an RTOS solution, especially in situations where devices have limited on-chip memory and no possibility of interfacing with external memory. [8] Lower footprint value of RTOS may reduce cost dedicated for storage hardware while planning a project and can also further increase scope of adding more functions in the system keeping the memory size same. VxWorks is known for small memory footprint and thus is most preferred RTOS.

D. Run-time performance:

Interrupt Latency, Context switching time are key factors which affect run time performance of RTOS. These are the parameters used in deciding standard run time performance of an application on given hardware, checking its reliability over performance critical aspects. [9]

1) Interrupt Latency:

Interrupt Latency has been defined as the sum of interrupt blocking time during which the kernel is pending to respond to an interrupt, saving the tasks context, determining the interrupt source, and invoking the interrupt handler. For a particular interrupt, the latency also includes the execution time of other nested interrupt handlers. Since most embedded systems is interrupt-driven, low interrupt latency will drastically increase system throughput.

2) Jitter:

Jitter is a value of latency which is derived from several latency values calculated on different hardware platforms. Accuracy of jitter values depends on correctness of latency values considered.

3) Worst Case Response Time:

Worst Case Response Time is the inverse of the

maximum interrupt frequency obtained. Maximum interrupt frequency is the maximum number of interrupt per second with reliability. It defines ability of RTOS to handle number of interrupts efficiently.

4) Latency:

Latency is defined as difference between an instant at which interrupt is generated and the instant at which its corresponding response is generated. The method used for calculating latency is to test RTOS on a given hardware. [10]

5) Scheduling algorithms:

Scheduling algorithms used in an OS, have a great impact on their run-time performance. Problems regarding multi-tasking and task-priority are addressed by these algorithms. Frequency of context switching is also decided by these algorithms.

VxWorks follows two scheduling algorithms namely Priority Preemptive and Round Robin algorithm.

Base Scheduling algorithm: - Priority Pre-emptive Preemption is the ability of RTOS, which helps it to decide which task needs to be serviced, depending on resources required by the task.

The tasks are done in order of their priorities. A particular task will be pre-empted, only if a task having higher priority is requested. Tasks that have higher periodic requirements should be given higher priority; tasks that make intensive computations should be given lower priority. In RTOS, individual tasks are assigned appropriate priority level for achieving preemption. This means that a priority is associated with each task, ranging from 0 to 255, (0 being the highest priority and 255 being the lowest). It is a feature which makes RTOS different from normal OS in performance.

Round-Robin:

It is a process scheduling method in which when a task of equal priority is competing for CPU time. In this each task is given small piece of CPU time to run, called a quantum, and then allow the next task to run for its quantum. VxWorks has an option to enable the Round-Robin mode, in which every task gets equal CPU, burst turn by turn. Starvation is possible as the low priority tasks may not get CPU. [11]

6) Inter-Process Communication:

Inter Task Communication Mechanism:

Inter Task Communication Mechanism should be reliable and self-sufficient in order to handle multiple tasks. Communication between interlinked functions should be effectively achieved, keeping data integrity and synchronization of data unaffected.

Nowadays real-time applications are created as a set of cooperative and independent tasks. VxWorks enables message queue as a higher-level synchronization mechanism which allows cooperating tasks to communicate with each other this also includes high-speed semaphores. Due to the complexities in this implementation, using this service forces the highest amount of latency and hence it is a key metric to operating system study. [12]

E. Deadlock :

It is a situation in which two or more competing processes are each waiting for other to finish and thus neither ever does. It usually results into resource starvation or lag in execution. [13] As we know any delay in result from RTOS can be catastrophic, so we expect RTOS to preferably avoid situation of deadlock or handle it efficiently.

Conditions for deadlock:

- Mutual exclusion
- Circular wait
- Hold and wait

These four conditions are known as the Coffman conditions from their first description in a 1971 article by Edward G. Coffman, Jr. [14] Probability of RTOS of getting into a deadlock condition depends on the degree of preemption.

- 1) *Avoiding deadlock:* Best approach is to prevent one of the four Coffman conditions from occurring, especially the fourth one. Also methods like acquiring additional information in advance about the process and deciding whether a process should wait or not can also be used by a RTOS to prevent deadlock.
- 2) *Deadlock handling:* If deadlock occurs, RTOS should be able to recover from it, as early as possible. Usually solution for recovery is process termination, which is implemented as:
 - Aborting all the deadlocked processes.
 - Abortion of one process at a time till the deadlock cycle is eliminated.

VxWorks is highly preemptive in nature, hence probability of occurrence of deadlock is less.

F. Security provided:

Until last decade, RTOS had to serve its typical features, but from last few years, due to attacks of malicious software on important systems & network it has to provide complete security. Here security refers to protection which secures system from any unauthorized access inside the system and as well as outside the system. They are expected to follow POSIX standards of security to serve current embedded applications. [15]

IV. PROMINENT CERTIFICATIONS:

VxWorks adheres to the following standards and certifications:

- IEEE Std. 1003.1 (POSIX)
- IEEE Std. 1003.13-2003 PSE52
- U.S. Department of Defense for Joint Tactical Radio Systems (JTRS) Software Communications Architecture (SCA) AEP 2.2.1 and 2.2.2
- IPv6 Ready Logo Program
- IEEE Std. 802.1X, IEEE Std. 802.11i

- IEEE Std. 802.1.AE

V. CONCLUSIONS :

Real time systems have gained popularity due to their ability to resolve highly complex systems. Developers are constantly evolving the real time operating systems to match up with the modern real time systems requirements. Number of RTOS has arrived in market, providing the user a wide variety of options. These can be differentiated on certain parameters like: Power Consumption, Reliability, Cost and Speed.

- VxWorks provide a wide range of supported platforms.
- Due to Round-Robin Scheduling VxWorks supports multitasking.
- VxWorks comes with workbench which is one of the most advance development suites.
- Due to use of micro kernel memory protection is better.
- VxWorks is designed to handle many interrupts comfortably. The applications which are expected to receive more number of interrupts continuously should prefer VxWorks. (Interrupts will tend to increase when number of inputs is applied to the RTOS simultaneously)

- VxWorks is dominant in highly complex and high performance applications.

ACKNOWLEDGEMENT

Authors would like to thank

Prof. Jiterndra Zalke (EDT Dept.)

Prof. Sharmik Admane (EN Dept.)

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