RTEMS CENTRE – Support and Maintenance CENTRE to RTEMS Operating System

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ABSTRACT

RTEMS CENTRE is a project under the ESA-Portugal Task Force aiming to establish a support and maintenance centre to RTEMS operating system.
RTEMS [1], Real-Time Operating System for Multiprocessor Systems, is a full featured Real Time Operating System that supports classical API and standard interfaces like POSIX [5] and Itron [6]. RTEMS provides a high performance environment for embedded applications including multitasking capabilities, multiprocessor systems, event-driven, priority-based, preemptive scheduling, optional rate monotonic scheduling, inter-task communication and synchronization, priority inheritance, responsive interrupt management, dynamic memory allocation, and high level of user configurability [3].
The two main streams in the project are:

- The first one related to design, development, maintenance and integration of tools to augment and sustain RTEMS operating system effective usage and;
- The second linked to the creation and maintenance of technical competences, materialized on RTEMS operating system support site to be located in Europe.

RTEMS CENTRE intends to support companies in the incorporation/integration of airborne and space applications in this Real Time Operating System, allowing the production cost minimization by using the gained technical expertise of RTEMS CENTRE.
RTEMS/Support tools will be developed in the frame of the project, such as:

- A timeline tools for analysing application time utilisation;
- OS management/visualisation tools for configuration;
- Resources status visualization.

A maintenance programme for the below packages will be implemented:

- Flight Board Supported Packages;
- Flight C-Libs.

In addition, the creation of a new support platform (website) will allow the dissemination of technical know-how and developments produced in RTEMS CENTRE. It will include mailing lists and user forums for extended/dedicated technical support, debate ideas, FAQs for the frequently asked questions, repository for the software of this project, bug reporting tools and useful links for community websites.
An agreement with OAR, the founders of RTEMS, is already performed in order to guide and support the production of RTEMS CENTRE.
The RTEMS CENTRE started officially in the 15th of November 2006 and is currently performing the user requirements aggregation and evaluation for the support platform and RTEMS/Support tools. The end date for the project is 30th of May 2008, the support website will be available from third quarter of 2007.

INTRODUCTION

On-board software applications are becoming more and more important contributor to the overall cost of the on-board space systems. This is a consequence of the increasingly complex tasks assigned to software applications and the implicit risks associated to them. To cope with these problems, open source solutions are being slowly introduced. In addition to the cost reduction, the use of open source software ensures long-term maintenance and independence from

the market (in the worst case the source code is available) and allows the space community to benefit from the developments within the overall user's community.
During On-Board Software Harmonisation meeting, March 2003, ESA identifies two areas where dependency is greater, one of them was RTOSs.
The effort to offer support and maintenance in one specific open source RTOS within the ESA members brings important advantages from two points of view: (1) a sustainable use of open sources as RTOS building block for on-board space systems and improving the overall cost-effectiveness of the Agency; (2) the reduction of the technological dependence from the proprietary tools vendors.
The paper is organised as follows: the first section presents the RTEMS operating system, a brief description is provided; next section presents the expected RTEMS CENTRE project improvements to the current RTEMS operating system; ongoing work in RTEMS CENTRE; current conclusions of the project; acknowledgements; and references.

RTEMS (Real Time Executive for Multi-Processor Systems)

Real Time Executive for Multiprocessor Systems (RTEMS) is an open source Real Time Operating System (RTOS) designed for deeply embedded systems that aim to be competitive with closed source and commercial products. Currently it is maintained by the On-Line Research Corporation (OAR) albeit many of the features and platform support for it have been developed by RTEMS users. The first version, of what is today RTEMS, was released in 1988.
RTEMS supports multiple processors, complies with several standards (POSIX, RTEID/ORKID, TCP/IP, µITRON, ANSI C/C++, partially with Ada95), supports basic kernel features, provides networking (FreeBSD TCP/IP stack, UDP, TCP, etc) and filesystem functionalities (IMFS, FAT 32/16/12, etc), and includes debugging features (over Ethernet and serial port). Besides all that, RTEMS was designed to support applications with the most inflexible time frames requirements, making it possible for the user to develop hard real time systems.
The RTEMS kernel supports several features. The most important are multi-tasking, networking and support of file systems.
Multi-tasking allows the software to be more responsive and modular, but brings a lot of issues that must be solved by the kernel. RTEMS makes possible to use multi-tasking, since it implements 3 scheduling features (Event driven, Priority driven and Rate monotonic), which has influence on the system dynamics. The kernel also allows the selection of the modules that are loaded, avoiding unnecessary delays and memory occupation (footprint).
Networking features are also quite valuable, since RTEMS implements several useful networking protocols. This allows loading a kernel or executive from a network, using BOOTP (Bootstrap Protocol). This avoids the need to have a complete operating system running on the target just to load a new executive since it's loaded from the network. Other protocols are useful for the application itself, like TCP, UDP, ICMP, RARP and DHCP. There are also some servers implemented as FTP server, HTTP server that allows file transfer in an easy manner. The PPP server allows the connection via dial-up modems and Telnet to control and configure the target system [4].

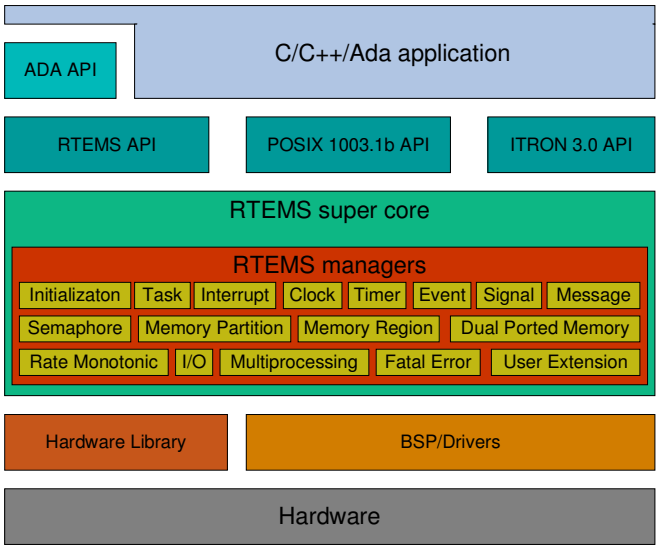

Figure 1: RTEMS Architecture Overview

RTEMS **filesystem** provides features like UNIX, e.g., mountable systems, hierarchical system directory structure, POSIX compliant set of routines for the manipulation of files and directories, individual file and directory support (permissions for read, write and execute, user ID, group ID and access time), modification time, creation time, hard links to files and directories and symbolic links to files and directories.
RTEMS **remote debugging** is very important, since debugging on site is difficult due to board constraints. For development itself, RTEMS can build applications on C and C++, following the ISO standards, and ADA95 (limited). POSIX and µITRON standards are implemented in the system API's.

RTEMS CENTRE

Based on the RTEMS community and users' perspective on the improvements, the RTEMS CENTRE work-plan is being defined and currently consists in the following topics:

- Engineering of a **RTEMS Management/Visualisation tools**;
- Engineering of a analysis tools (**Timeline Tool**) for running applications;
- Tools to sustain the software development cycle**;**
- Configuration tools for software configuration, executives and operating system;
- Considerations on ARINC 653, DO-178B and ECSS E-40;
- Development of a Support website Platform for RTEMS users, to share the technical know-how acquired by the RTEMS CENTRE team;
- Integration of Open Source Tools in RTEMS;
- Investigate current status and evaluate the state-of-the-art;
- Maintenance of flight Board Supported Packages;
- Maintenance of flight C-Libraries.

The **Management/Visualisation tool** envisages providing to the users the capability to easily configure and manage the RTEMS OS in runtime and in configuration/compilation. It provides information of system calls (duration, directive name and arguments), stack size and free stack (on task restart, deletion, exit, etc), system memory usage, message queues (id, name, attributes, number of pending messages, max pending msgs, max msg size), active extensions (id, name, create/start/restart/delete/switch/begin/exited/fatal), device driver table (id, name, init/open/close/read/write/control), system kernel workspace (start/end and size), max tasks/timers/semaphores/msgs queues/partitions/regions/periods/extensions, multi-processor communication interface, CPU usage by each task, RTEMS installation support and RTEMS application configuration tool.

Timeline tool centralizes the temporal information of the running executive on the real time operating system, it is a preferable tool used for validation of the correctness of the scheduling algorithms. Timeline provides information related to task name, id, priority, preempted task, active task, task state, modes, attributes, real priority, current priority, time (number of ticks since boot, at switch task, at any event captured), number of times the task went suspended and went executing and task memory usage.

Figure 2: Sample of Timeline tool

RTEMS CENTRE ONGOING WORK

At the time of the production of this paper, RTEMS CENTRE is performing system engineering activities. An exhaustive study of RTEMS and support tools are currently being defined as also a detailed list of user and system requirements. The following sections provide a high-level description of the work already produced.

RTEMS Overview

RTEMS can be described as a library composed by two modules: board support and programmer's interface.

The Board Support Package (BSP) module includes the startup code, linker scripts (for proper memory addressing of the executive in the target system) as well as the data structures and code to support the specific CPU family (e.g. i386, SPARC) and the remaining integrated circuits (e.g. PIT) on the hardware board. The programmer's interface (API) allows the RTEMS' user to develop his real time application by using his favourite API (C, Ada, POSIX and µITRON are supported). Both the BSP and the API are based on an internal core only accessible to the programmer.

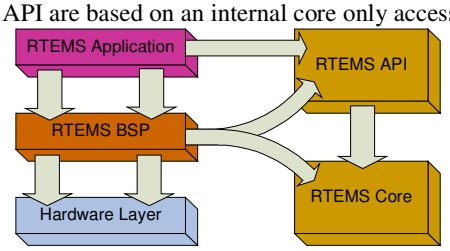

Figure 3: RTEMS architecture overview.

RTEMS, in a development system, produces several system libraries, in which most of them end up wrapped in two main system libraries:

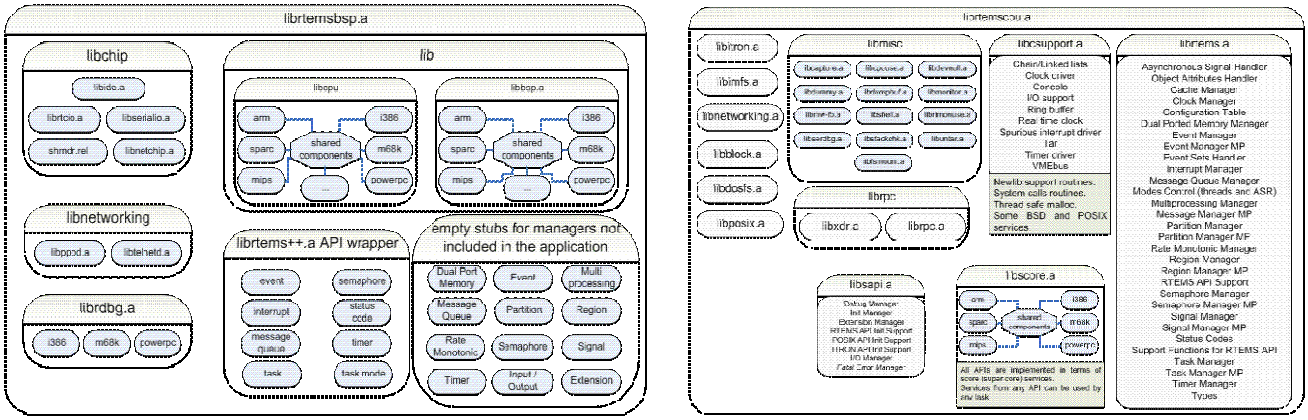

Figure 4: RTEMS librtemsbsp.a and librtemscpu.a components

RTEMS Initialization Manager

After the board's Basic Integrated Operating System (BIOS) finishes its initialization sequence (e.g. on a i386 this means executing POST – Power On Self Test – and then passing control to a boot loader like GRUB, the GRand Unified Bootloader) the execution flow will be transferred to the BSP. The following schematic presents the initialization process of a RTEMS executive, in this case a simple "Hello World" program.

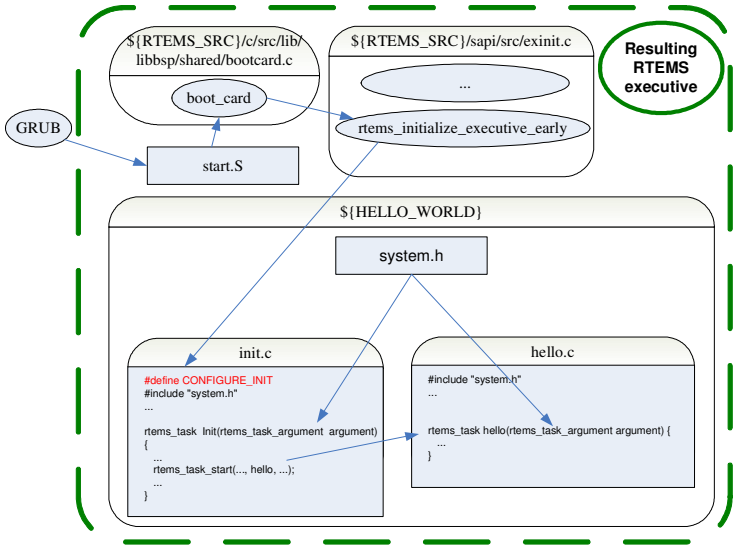

Figure 5: Executive Initialization Process in an i386 environment

RTEMS Managers

RTEMS API for the user is formed by a group of managers. RTEMS CENTRE, in the first phases of development, made a detailed investigation on RTEMS Managers, covering and performing a detailed analysis on the following managers:

Task Manager	Interrupt Manager	Clock Manager	Time Manager	Event Manager
Signal Manager	Message Manager	Semaphore Manager	Rate Monotonic Manager	
Memory Managers, Partition, Region and dual ported			Input/Output manager	
Multi-Processing Manager		Fatal Error Manager	User Extensions Manager	

The following figure displays a sample of the architectural work produced, which consisted on the architectural block diagrams and use cases of each of the Managers listed above, in this case we present the I/O Manager Use case diagram and dual ported memory manager block diagram:

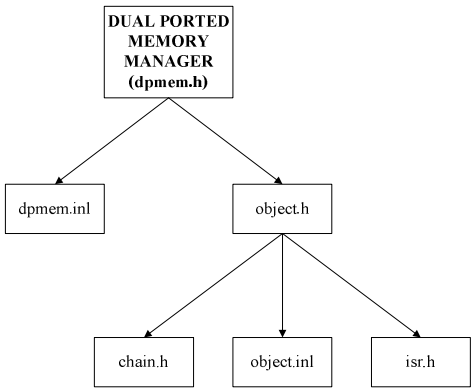

Figure 6: Sample of the Managers architecture

Board Supported Packages C-Libraries and RTEMS tests

The current on-going work of RTEMS CENTRE is being centralized into three main streams, Board Supported Packages, C-Libraries to sustain the development of C applications on RTEMS and the execution of test batteries on top of RTEMS.
Board Supported Packages and device drivers' architectural design is being performed, including a detailed examination of the initialization procedure and compilation of applications. A case study was performed internally for the elaboration of a BSP for SPARC V-9 architecture.
C-Libraries are currently being surveyed, being the C-Libraries analysed the: glibc, newlib, dietlibc, and µClibc.
Test batteries in RTEMS OS were executed, running natively and in sandboxes (Qemu, Bochs, VMWare, etc).

CONCLUSIONS

The RTEMS CENTRE project will establish a knowledge base that can give a significant contribution to the demystification of RTEMS and broader user acceptance. The support provided will help the users to overcome the obstacles encountered, either due to technical issues while integrating different technologies that during the adaptation to new technological fields (e.g. cross-development).
In a near future, RTEMS support tools will be developed and published over internet through the support platform for any interested user[2]. The development of such tools has the unique requisite to help any company or private user to increase its RTEMS OS capabilities. Additionally, a support platform with the technical know-how will be published for RTEMS user. It is our intention to provide added value on the chain-development of RTEMS.

ACKNOWLEDGEMENTS

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