Composability and Adaptability on a Time- and Space-Partitioned Architecture for Spacecraft Onboard Software

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1 Motivation: the AIR Architecture

Space systems of the future demand for innovative computer architectures, enabling reduced size, weight and power consumption (SWaP) and component reuse among the different space missions. A solution being studied concerns the utilization of *time- and space-partitioning* (TSP) concepts, and fosters the interest of space agencies and industry partners [6]. The *AIR (ARINC 653 In Space RTOS) architecture* was designed to fulfil the requirements for robust TSP and allow for mixed-criticality missions [4]. Temporal partitioning is achieved through two-level hierarchical scheduling. In the first level, partitions are scheduled cyclically. Inside each partition, processes compete according to the native process scheduler of each partition's operating system. AIR implements the advanced notion of *mode-based partition schedules*, allowing temporal requirements (and, consequently, partition scheduling) to vary according to the mission's phase or mode of operation. A formal system model of the AIR architecture was defined in the course of the present work [2, 4].

We hereby address our current research work on TSP systems for aerospace applications, laid over the axes of published contributions on composability (and how it enabled component-based analysis of the system) [2] and adaptability (self-adaptability, reconfigurability) [1]. We also introduce the forthcoming research direction of augmenting these properties with support for multicore platforms.

2 Composability and Component-Oriented Scheduling Analysis

The modularity of the AIR architecture design and of its build and integration process enables *composability* of AIR-based systems: the several components that may compose such a system can be developed, verified and validated independently. This eases certification efforts, since only modified modules need to be reevaluated, and allows the introduction of component-oriented, tool-assisted scheduling analysis within both the development of each partition's applications and the integration of all partitions into the complete system. This introduction of TSP-specific scheduling analysis capabilities can be provided through a tool developed from scratch, or by extending an existing tool [2]. We are looking into the possibility of extending Cheddar [5] to this purpose.

* This work was partially developed within the scope of the European Space Agency Innovation Triangle Initiative program, through ESTEC Contract 21217/07/NL/CB, Project AIR-II (ARINC 653 in Space RTOS — Industrial Initiative, http://air.di.fc.ul.pt). This work was partially supported by FCT, through the Multiannual Funding and CMU-Portugal Programs and the Individual Doctoral Grant SFRH/BD/60193/2009.

3 Adaptability, Self-Adaptability and Reconfigurability

The potential to adapt to changing environmental or operating conditions is crucial for space missions. Several failures may be mitigated by software reconfigurability, extending the lifetime of the mission. AIR addresses specific adaptation requirements, namely on the temporal domain (through mode-based partition schedules and process deadline violation monitoring) and on failure detection and recovery (through low-level event overload control). The way in which these requirements are integrated in system design and engineered can be in the form of either adaptive or self-adaptive mechanisms [1].

One reconfigurability aspect being analyzed concerns the possibility to update applications and configuration parameters of the system without interrupting or otherwise significantly affecting its execution [3].

4 The Next Step: Multicore

Multicore processors are paving their way into the realm of embedded systems. The use of multicore architectures in TSP systems and the application of real-time scheduling theory therein has, though, not been addressed in detail.

In the context of TSP, the research problem of applying multicore platforms is threefold. First, the multiple cores can be used to achieve some kind of parallelism. Two dimensions, which may either be mutually exclusive or coexist, can be approached: intrapartition (between processes inside one partition) and interpartition (between partitions) parallelism. This, coupled with AIR's support to mode-based scheduling, brings added temporal adaptability features, such as switching between modes which take varying advantage of parallelism to establish a tradeoff between processing power and energy consumption. On a second degree, core multiplicity adds to adaptability capabilities in the form of fault tolerance. Thirdly, spatial partitioning can be aided by multicore, namely by assigning certain functions (such as partition scheduling and management, timeliness control, or low-level device interface operations) to specific cores.

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