



# Linux Testbed for Multiprocessor Scheduling in Real-Time Systems

Department of Computer Science

University of North Carolina at Chapel Hill

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## About

The LITMUS<sup>RT</sup> project is a soft real-time extension of the Linux kernel with focus on multiprocessor real-time scheduling and synchronization. The Linux kernel is modified to support the sporadic task model and modular scheduler plugins. Both partitioned and global scheduling are supported.

## Goals

The primary purpose of the LITMUS<sup>RT</sup> project is to **provide a useful experimental platform for applied real-time systems research**. In that regard, LITMUS<sup>RT</sup> provides abstractions and interfaces within the kernel that simplify the prototyping of multiprocessor real-time scheduling and synchronization algorithms (compared to modifying a “vanilla” Linux kernel). As a secondary goal, LITMUS<sup>RT</sup> serves as a proof of concept, showing that algorithms such as PFAIR can be implemented on current hardware. Finally, “lessons learned” using LITMUS<sup>RT</sup> may find value as blueprints/sources of inspiration for other (both commercial and open source) implementation efforts.

## Non-Goals

LITMUS<sup>RT</sup> is not a production-quality system (currently). It is also not “stable,” i.e., interfaces and implementations may change without warning between releases. POSIX-compliance is not a goal; the LITMUS<sup>RT</sup>-API offers alternate system call interfaces. While we aim to follow Linux-coding guidelines, LITMUS<sup>RT</sup> is not targeted at being merged into mainline Linux. Rather, we hope that some of the ideas prototyped in LITMUS<sup>RT</sup> may eventually find adoption in Linux.

## Current Version

The current version of LITMUS<sup>RT</sup> is 2010.1 and is based on Linux 2.6.32. It was released on 05/19/2010 and includes plugins for the following scheduling policies:

- Partitioned EDF with synchronization support (PSN-EDF)
- Global EDF with synchronization support (GSN-EDF)
- Clustered EDF (C-EDF)
- PFAIR (both staggered and aligned quanta are supported)

Please refer to the download and installation sections on the LITMUS<sup>RT</sup> web site for details.

Earlier versions, which supported additional scheduling policies, include LITMUS<sup>RT</sup> 2008 (based on Linux 2.6.24) and LITMUS<sup>RT</sup> 2007 (based on Linux 2.6.20).

The first version of LITMUS<sup>RT</sup> (implemented in Spring 2006) was based on Linux 2.6.9.

## Development Plans

There are plans to port LITMUS<sup>RT</sup> to PowerPC and ARM platforms.

## Collaborators

The LITMUS<sup>RT</sup> project is led by Dr. James H. Anderson.

The implementation effort is carried out by students of the Real-Time Systems Group at the University of North Carolina at Chapel Hill:

Björn B. Brandenburg (current maintainer)

Andrea Bastoni (visiting from the University of Rome “Tor Vergata”)

Additional collaborators contributed to the previous LITMUS<sup>RT</sup> 2008 and the LITMUS<sup>RT</sup> 2007 versions.

## Research Support

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## Publications

A. Bastoni, B. Brandenburg and J. Anderson “Cache-Related Preemption and Migration Delays: Empirical Approximation and Impact on Schedulability,” *Proc. of the Sixth International Workshop on Operating Systems Platforms for Embedded Real-Time Applications*, July 2010.

B. Brandenburg and J. Anderson, “On the Implementation of Global Real-Time Schedulers,” *Proc. of the 30th IEEE Real-Time Systems Symposium*, pp. 214-224, December 2009.

B. Brandenburg and J. Anderson “Reader-Writer Synchronization for Shared-Memory Multiprocessor Real-Time Systems,” *Proc. of the 21st Euromicro Conference on Real-Time Systems*, pp. 184-193, July 2009.

J. Calandrino and J. Anderson “On the Design and Implementation of a Cache-Aware Multicore Real-Time Scheduler,” *Proc. of the 21st Euromicro Conference on Real-Time Systems*, pp. 194-204, July 2009.

M. Mollison, B. Brandenburg, and J. Anderson “Towards Unit Testing Real-Time Schedulers in LITMUS<sup>RT</sup>,” *Proc. of the Fifth International Workshop on Operating Systems Platforms for Embedded Real-Time Applications*, pp. 33-39, July 2009.

B. Brandenburg and J. Anderson, “A Comparison of the M-PCP, D-PCP, and FMLP on LITMUS<sup>RT</sup>,” *Proc. of the 12th International Conference on Principles of Distributed Systems*, pp. 105-124, December 2008.

B. Brandenburg, J. Calandrino, and J. Anderson, “On the Scalability of Real-Time Scheduling Algorithms on Multi-core Platforms: A Case Study,” *Proc. of the 29th IEEE Real-Time Systems Symposium*, pp. 157-169, December 2008.

B. Brandenburg and J. Anderson, “An Implementation of the PCP, SRP, D-PCP, M-PCP, and FMLP Real-Time Synchronization Protocols in LITMUS<sup>RT</sup>,” *Proc. of the 14th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications*, pp. 185-194, August 2008. Postscript. PDF.

A. Block, B. Brandenburg, J. Anderson, and S. Quint, “An Adaptive Framework for Multiprocessor Real-Time Systems,” *Proc. of the 20th Euromicro Conference on Real-Time Systems*, pp. 23-33, July 2008. Postscript. PDF.

B. Brandenburg, J. Calandrino, A. Block, H. Leontyev, and J. Anderson, “Real-Time Synchronization on Multiprocessors: To Block or Not to Block, to Suspend or Spin?” *Proc. of the 14th IEEE Real-Time and Embedded Technology and Applications Symposium*, pp. 342-353, April 2008.

B. Brandenburg, A. Block, J. Calandrino, U. Devi, H. Leontyev, and J. Anderson, “LITMUS<sup>RT</sup>: A Status Report,” *Proc. of the 9th Real-Time Linux Workshop*, pp. 107-123, November 2007.

B. Brandenburg and J. Anderson, “Integrating Hard/Soft Real-Time Tasks and Best-Effort Jobs on Multiprocessors,” *Proc. of the 19th Euromicro Conference on Real-Time Systems*, pp. 61-70, July 2007.

J. Calandrino, H. Leontyev, A. Block, U. Devi, and J. Anderson, “LITMUS<sup>RT</sup>: A Testbed for Empirically Comparing Real-Time Multiprocessor Schedulers,” *Proc. of the 27th IEEE Real-Time Systems Symposium*, pp. 111-123, December 2006.

### For More Information

Dr. James Anderson  
Department of Computer Science  
University of North Carolina at Chapel Hill  
CB#3175, Frederick P. Brooks, Jr. Building  
Chapel Hill, NC 27599-3175  
Phone: (919) 962-1757  
Fax: (919) 962-1799  
E-mail: anderson@cs.unc.edu