Development of Fedora Linux Distribution for RISC-V (RV64G) Architecture

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Abstract

The continuous advancement of the RISC-V architecture introduces both opportunities and challenges, particularly for systems that do not include compressed instruction support (RV64G). Current Fedora Linux distributions predominantly target the RV64GC variant, leaving a significant gap in support for RV64G-based systems, which are essential for various research and development applications. The RISC-V community actively contributes to system software development, particularly in the Linux ecosystem. While much of the existing work is focused on enabling Fedora for the RV64GC profile, our research extends this effort by developing Fedora for sub-set profiles like RV64G.

Many startups, academic researchers, and independent developers encounter difficulties in adopting mandated RISC-V profiles such as RV22 due to the complexity and cost associated with designing processors that incorporate multiple extensions. As hardware constraints and development costs rise, access to a functional Linux distribution across all RISC-V variants becomes increasingly critical. Our work addresses this need by delivering a Fedora version optimized for RV64G, facilitating broader adoption among those unable to develop or afford processors with mandatory extension support.

Key aspects of this work involve building a scalable and reliable filesystem hierarchy, creating a cross-compilation toolchain, preparing and bootstrapping the target image, integrating a native GCC compiler, and utilizing the Koji build system to streamline package rebuilding. Additionally, we introduce a custom Python-based tool to enhance automation and reproducibility by efficiently managing Koji builds, ensuring uniformity in package deployment.

Beyond addressing immediate software enablement challenges, this work establishes a solid foundation for advancing High-Performance Computing (HPC) on the RISC-V platform. By enabling a fully operational Fedora Server edition for RISC-V, our contributions support the widespread adoption of RISC-V in both research and enterprise domains. Furthermore, our development methodology follows the upstream-first policy, ensuring long-term maintainability and seamless integration into the Fedora ecosystem. This research not only expands Linux distribution support for various RISC-V profiles but also strengthens the RISC-V community by making Fedora more accessible across diverse hardware configurations.

Introduction

The RISC-V RV64G architecture is gaining traction due to its open-source nature and versatility, but comprehensive Linux distributions for it remain scarce. This gap became evident in our efforts to develop a Fedora Linux distribution for RV64G, distinct from the mainstream RV64GC. We started by building an embedded Linux system with Buildroot, omitting compressed instructions and testing in QEMU, but faced a major limitation—the lack of a native compiler for package installation.

This led us to construct a Linux system for RV64G from scratch using Linux From Scratch (LFS), highlighting the absence of a full-scale distribution. A search for existing solutions yielded none, as Fedora/RISC-V supports only RV64GC. Recognizing this need, we embarked on creating a Fedora Linux distribution specifically for RV64G.

We began by constructing an embedded Linux system, providing crucial insights for further development. Building on this, we expanded efforts to create a full-fledged Fedora distribution, configuring the Koji build system to rebuild Fedora RPMs and porting the Linux kernel with UEFI support. This required both technical expertise and a deep understanding of RV64G's architecture.

Through extensive testing, we successfully developed a Fedora Linux distribution tailored for RV64G, filling a crucial gap. Our work provides a scalable, maintainable solution for those facing similar challenges globally. By sharing our research, we aim to support RISC-V developers, offering insights into building Linux distributions for various RISC-V hardware. This paper details our journey, technical processes, and innovations,

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contributing a valuable resource for those developing Linux systems for RISC-V architecture.

Methodologies

To develop a Fedora Linux distribution for RV64G, we followed a structured, multi-phase process ensuring functionality and scalability.

Filesystem Hierarchy

We established a robust filesystem hierarchy following the Filesystem Hierarchy Standard (FHS), configuring essential system directories (/bin, /boot, /lib, etc.) and key system files (/etc/fstab, /etc/profile) to ensure proper booting and user management.

Cross-Compiler Development

A cross-compilation toolchain was created by setting up host and target variables, installing kernel headers, and building a static GCC compiler, followed by glibc and the final GCC cross-compiler tailored for RV64G.

Target Image Preparation

Using BusyBox for the init process, we cross-compiled and integrated it into the target image. The Linux kernel was configured with required RISC-V extensions, ensuring compatibility with storage and networking modules.

Native GCC Integration

To address the absence of a native compiler, we cross-compiled and integrated GCC and Binutils into the target image, allowing direct package compilation within the RV64G environment.

Koji Build System for Fedora RISC-V

We set up a Koji build system for Fedora package rebuilding. A high-performance x86 PC acted as the Koji hub, with QEMU instances and a StarFive board serving as builders. Around 500 packages were rebuilt to create a bootable Fedora image.

Koji Build Automation with Python

A custom Python application automated Koji build tasks, managing package lists, retrieving source code, and handling build processes, ensuring efficiency and consistency across package rebuilding.

Linux Kernel Configuration

Kernel modifications addressed EFI support and PE32+ header constraints. Adjustments ensured smooth booting using bootefi commands or GRUB, optimizing kernel compatibility with non-compressed instruction sets.

Bootable Disk Image Creation

A Kickstart file and appliance creator were used to generate a bootable disk image, incorporating all rebuilt packages and required configurations for seamless deployment on RISC-V hardware.

Discussion and Future Work

Our testing across QEMU, C-DAC Vega, and StarFive VisionFive boards demonstrated the stability and compatibility of the Fedora Linux distribution for RISC-V (RV64G). Benchmarks like Dhrystone, CoreMark, and HPL validated system functionality and performance, confirming robustness across both emulated and physical environments.

Beyond compatibility, our work enhances the scalability and maintainability of Fedora Linux on RISC-V. The methods used can extend to other Linux distributions, such as AlmaLinux, Rocky Linux, and CentOS, improving adaptability across ecosystems.

Moving forward, we plan to develop a Fedora Server edition optimized for High-Performance Computing (HPC) on RISC-V. This includes rebuilding key HPC RPM packages, optimizing performance, and ensuring seamless integration with RISC-V hardware. We also aim to collaborate with open-source communities to refine our implementation and explore RISC-V extensions like vector processing (RV64GCV).

Through continued research and collaboration, we seek to establish Fedora Server as a viable RISC-V HPC platform, expanding high-performance computing accessibility on open-source architectures.

For additional information, the short paper "Development of Fedora Linux Distribution for RISC-V (RV64G) Architecture" was recently published in the International Workshop on RISC-V for HPC (RISCVHPC) at the SC24 Conference (International Conference for High Performance Computing, Networking, Storage, and Analysis)[1]

References

[1] Surendra Billa et al. “Development of Fedora Linux Distribution for RISC-V (RV64G) Architecture”. In: *SC24-W: Workshops of the International Conference for High Performance Computing, Networking, Storage and Analysis*. 2024, pp. 1685–1689. DOI: 10.1109/SCW63240.2024.00210.