

Wind River VxWorks Platforms 6.9

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The market for secure, intelligent, connected devices is constantly expanding. Embedded devices are becoming more complex to meet market demands. Internet connectivity allows new levels of remote management but also calls for increased levels of security.

More powerful processors are being considered to drive intelligence and higher functionality into devices. Because real-time and performance requirements are non-negotiable, manufacturers are cautious about incorporating new technologies into proven systems. To succeed, companies must optimize their device software across the entire product life cycle: from design through development, from QA to the remote management of deployed devices. The challenge for many device developers is in balancing the need for increased speed, greater efficiency, and lower cost with an acceptable level of development risk.

Wind River VxWorks platforms meet this challenge with an embedded platform solution that combines VxWorks 6.9, the industry's leading 32-bit and 64-bit capable real-time operating system (RTOS); Wind River Workbench, the premier device software development suite; and essential security, device management, and connectivity middleware, including drivers and protocols for connected devices on the factory floor, wireless peripherals, and other devices within the network infrastructure. The VxWorks platforms are backed by Wind River's 25 years of device software industry experience, a world-class support organization, a comprehensive partner ecosystem, and a specialized professional services team.

Wind River VxWorks platforms provide comprehensive multi-core processor support, including asymmetric

multiprocessing (AMP) and symmetric multiprocessing (SMP) operating system configurations as well as hardware optimized multi-core acceleration capabilities.

The VxWorks platforms are optimized develop-and-run solutions for a range of devices, from aerospace and defense (A&D) applications to networking and consumer electronics, robotics and industrial applications, precision medical instruments, and car navigation and telematics systems. The platforms provide a robust foundation for companies that need to leverage their investment in proprietary intellectual property. VxWorks has been deployed successfully in hundreds of millions of devices worldwide.

Available VxWorks Platforms

- Wind River General Purpose Platform:** This versatile platform is used for devices ranging from aerospace and defense, automotive telematics, and small-footprint consumer devices to industrial devices and networking equipment.
- Wind River Platform for Automotive Devices:** Designed for the development of applications that require high reliability, low power consumption, and a small memory footprint, its targets include both vehicle and security control systems (powertrain, engine, ABS, crash and airbag sensors, window/door entry) and in-vehicle systems (digital dashboard displays, navigation systems, telematics systems, and entertainment systems).
- Wind River Platform for Consumer Devices:** This offers a fast-boot, small-footprint run-time environment ideal for memory-constrained devices. Platform targets include digital video, mobile handheld, digital imaging, residential gateways, and broadband customer premises equipment (CPE) devices.
- Wind River Platform for Industrial Devices:** This provides industrial device manufacturers with essential multimedia and connectivity run-time technologies, including drivers and protocols for connected devices on the factory floor, wireless peripherals, and other devices within the network infrastructure. Targets

Development Suite

Wind River Workbench

Software Partners (noncomprehensive)

Ada Support	Advanced Flash Support	OPC
Browsers	CAN	Common Internet File System
DLNA	OSGi	TR-069
Databases	Design Tools	Graphics
High Availability	Java	Others

Additional Middleware*

WLAN	Mobile IPv4/IPv6	802.1Q VLAN	Media Library
SSL & SSH	IPsec	NAT/Firewall	IGMP/MLD
RADIUS and Diameter Client	Wireless Security	Crypto Libraries	EAP
SNMP v1/v2/v3	Web Server	CLI/MIBway	Learning Bridge
VRRP	Web Svcs-Interop/SEC	DCOM	CAN/OPC
IKE v1/v2	MACsec	ROHC	SCTP

Base Middleware**

TIPC	Distributed Shared Memory	USB 1.1, 2.0
dosFs	Flash Support (TrueFFS)	Highly Reliable FS
IPv4/IPv6 Network Stack		PPP

Operating Systems

VxWorks/VxWorks Multiprocessing

Hardware Partners

Reference Designs, Semiconductor Architectures
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Services

Education Services	Platform Customization
System Design	Installation and Orientation
Hardware/Software Integration	

VxWorks platform components

Figure 1: VxWorks platform components

* Included in VxWorks industry-specific platforms
 ** Included in all VxWorks platforms

- include industrial automation, building automation, and medical, transportation, and test and measurement devices.
- Wind River Platform for Network Equipment:** This enables customers to rapidly create, test, deploy, maintain, and manage high-quality network infrastructure devices. The platform offers an extensive suite of security protocols to protect network data. It is ideally suited for wireless infrastructure, enterprise network, core networking, network edge, WiMAX/LTE infrastructure, and broadband access devices.

New in VxWorks Platforms 6.9

The latest release of VxWorks platforms introduces 64-bit VxWorks and Wind River MACsec. It updates and enhances run-time components in VxWorks, Wind River Workbench, and most middleware and networking technologies. These run-time components can be used with the included VxWorks SMP and AMP technologies to exploit the capabilities of the latest multi-core processors.

This release contains the latest versions of the VxWorks operating system, Wind River Workbench, Wind River Diab Compiler, Wind River GNU Compiler, integrated market-specific middleware, and host tools.

Fundamental features of this release include the following:

- Backward-compatible OS
- SMP and AMP capabilities
- Highly scalable, OS-independent network stack
- Updated networking and security products
- State-of-the-art memory protection including real-time processes (RTPs), error detection and reporting, and inter-process communication (IPC)
- Architecture support for ARM/XScale, IA-32, Intel 64, MIPS, and PowerPC
- Middleware integrated with VxWorks and Wind River Workbench
- Evaluation copy of Datalight FlashFX Pro integrated with Wind River Workbench

New features include the following:

- True 64-bit operation using the LP64 data
- Updated configuration interfaces for VxWorks Source Build (VSB) projects and VxWorks image projects (VIP)
- SHA-256 hashing algorithm as the default password hashing algorithm
- Single authentication control used for Telnet, SSH, FTP, and rlogin daemons
- Inclusion of MIPC File System (MFS) and MIPC Network Device (MND)
- Addition of core dump for 32-bit VxWorks SMP
- Wind River VxWorks Simulator 6.9 with 64-bit VxWorks simulation, Network Address Translation (NAT) support, user shared memory, and Intel C++ Compiler for VxWorks support
- Version numbering scheme for Wind River VxWorks platforms aligned with VxWorks RTOS version number
- Broad networking and middleware features
 - Majority of components supporting 64-bit operation
 - Introduction of Wind River MACsec, Wind River's implementation of IEEE 802.1AE
 - Support for the Point-to-Point Protocol (PPP) over L2TP, PPP over virtual local area network (VLAN)
 - Diameter secure key storage

- Updates to Wind River Workbench
 - Enhanced security due to Wind River debugger (WDB) target agent being disabled by default
 - Workbench Debug Mode, a stand-alone solution for debugging
- Updates to Wind River Run-Time Analysis Tools
 - Memory Analyzer
 - Menu options accessible using Session View
 - Performance leak detection mode provided for long running applications
 - Performance Profiler
 - Ability to export analysis data as CSV files
 - Improved event selection
 - Code Coverage Analyzer
 - Additional selection and navigation options
- Updates to Wind River debugger
 - Support for new processor families supported by VxWorks 6.9
 - Ada-specific improvements
 - Improved performance
- Updates to Wind River Diab Compiler 5.9.0
 - Support for additional architectures, optimizations, new options, and new C++ ABI (called Wind River Compiler in previous releases)
- Updates to Wind River GNU Compiler 4.3.3
 - Support for IA-64 and ARM Cortex A9
 - Intel C++ Compiler 12.0 for VxWorks and Intel Integrated Performance Primitives (IPP) 7.0 for VxWorks

VxWorks Platforms Features

VxWorks Real-Time Operating System

VxWorks is the industry-leading commercial-grade device software operating system. Its high determinism, high performance, modular scalability, and small footprint make more than 500 million devices worldwide run faster and more reliably. VxWorks innovation focuses on multi-core technology, openness, performance, reliability, and interoperability.

With VxWorks 6.9, users can do the following:

- Optimize developer productivity through open standards.
- Leverage the power of multi-core silicon to deliver higher performance and more capable devices.

- Increase reliability through memory management unit (MMU)-based memory protection.
- Accelerate time-to-market through enhanced error management.
- Seamlessly migrate existing VxWorks-based IP and other existing software IP, including open source.
- Continue to deliver products that rely on the core attributes of VxWorks, including high performance, high reliability, high determinism, low latency, and modular scalability.

Complementary solution elements include the integrated Eclipse-based Wind River Workbench development suite, extensive middleware components, comprehensive processor and board support package (BSP) support, expert professional services, and the industry's largest partner ecosystem of hardware, software, development tools, middleware, and applications providers.

Compatibility

VxWorks 6.x and VxWorks SMP are designed to ease migration from VxWorks 5.5. To that end, the kernel of VxWorks 6.x supports the VxWorks 5.5 kernel operating environment. Most BSPs, drivers, and kernel applications developed for or ported to VxWorks 5.5 will run in the VxWorks 6.x kernel. By default, the VxWorks 6.x kernel builds like that of VxWorks 5.5. VxWorks 6.9 is backward-compatible with all previous versions of VxWorks 6. With few exceptions, VxWorks SMP is API-compatible with the uniprocessor versions of VxWorks.

The VxWorks technical product documentation includes information about the following:

- Migrating VxWorks 5.5 kernel applications to the current kernel and user modes
- Porting BSPs and drivers
- Migrating code to VxWorks SMP
- Changes in networking and security technologies from VxWorks platforms 3.4 to this release

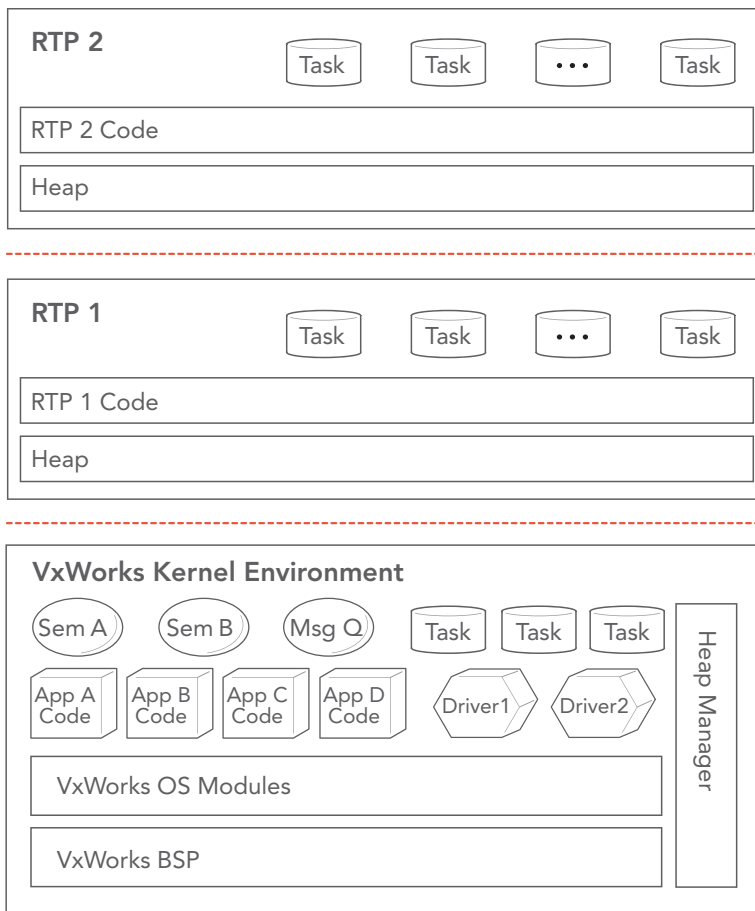


Figure 2: VxWorks kernel environment and two RTPs

State-of-the-Art Memory Protection

VxWorks 6.x enables manufacturers to increase their device reliability through MMU-based memory protection. VxWorks introduces process-based, user-mode application execution in addition to its traditional kernel-mode execution. The kernel is protected from user-mode applications running in VxWorks real-time processes (RTPs). User-mode applications are also protected from each other.

Features of memory protection include the following:

- MMU-based memory protection provides isolation of the kernel from user-mode applications and of applications from each other, increasing device reliability.
- The standard, process-based programming model simplifies application development.

- VxWorks' preemptive, priority-based global task scheduler ensures real-time deterministic behavior.
- The ability to create private or public objects in the kernel and in RTPs offers flexibility to use objects that are protected from manipulation or that can easily be shared among kernel and process tasks.
- The extensible system call interface enables application developers to employ custom-developed kernel services from user-mode execution.
- Support for shared libraries among RTPs improves code efficiency and reusability as well as speeding code development and debugging.

VxBus Framework

VxWorks 6.9 includes the VxBus framework, which device drivers plug into and coordinate device-related operations among device drivers, the BSP, and the VxWorks kernel. It provides a formal interface between device drivers and

hardware. It also provides a uniform set of APIs that can be used by higher-level features such as file systems, network stacks, power management frameworks, and so on. VxBus provides the following:

- Device discovery mechanisms
- Common infrastructure between devices, middleware, and the OS
- Support for different bus topologies

These features allow device drivers to be decoupled from the BSPs they ship with. In turn, this allows drivers to work with minimal or no modifications on many BSPs. The task of writing BSPs for VxWorks is made simpler with the VxBus framework.

Core Dump File Generation and Analysis

Core dump generation is new in VxWorks 6.9 and allows applications encountering exceptions to generate core images, extract core images from the target, and analyze the core file on the host. Core images record the state of the running application at the point of exception. Core files give developers the entire system image for postmortem analysis. Core dump file generation and analysis is supported for both kernel applications and real-time processes (RTPs).

VxWorks 6.9 generates a core image when a fatal system exception, a kernel panic, or a kernel task level exception occurs. Core dump file generation can also be triggered by API calls for this purpose. Interrupts are masked during the core file generation process, and the system reboots thereafter. Core images are stored in persistent memory on the target and are transferred to the host during target reboot. Core file generation components include core file compression, memory filter to exclude memory regions from core images, and APIs for on-demand core generation. With Wind River Workbench, developers can analyze core files in read-only mode at various levels: assembly or C/C++, memory content, variable/value pairs, and so forth. Target Manager, Debug view, Variable view, Kernel Objects view, Stack Trace view, Memory view, Register view, and Symbol Browser fully support core file analysis.

Message Channels and TIPC

With memory protection comes the challenge of segmentation of applications into protected memory spaces. Message channels are a connection-orientated, bidirectional messaging mechanism that allows tasks to communicate across memory boundaries and complement traditional communication mechanisms provided in VxWorks.

Tasks located in different processes or in the kernel can establish connections with each other, independent of their locations. Communication can take place between one task in a process and another in the kernel, or between tasks in separate processes, or between tasks in the same process. In VxWorks 6.1 and later, message channels use the open source, industry-standard TIPC protocol to extend messaging to tasks in multiprocessor systems that can run VxWorks, Linux, or any other operating system that supports TIPC. The VxWorks 6.9–based platforms support TIPC version 1.7.

Features of TIPC 1.7 include the following:

- Open-standard TIPC
 - High-speed, reliable message-passing service
 - Location transparency with logical address and internal address translation table
 - Lightweight, connectionless, or connection-orientated communication modes
 - No message losses
 - No message duplicates
 - Uninterrupted message sequence order
 - Reliable multicast messaging
- OS independence, with interoperability between VxWorks and Linux
- Scalability from single processor to multi-core to cluster of nodes
- Extensible framework for failover
- Suitability for systems where short, real-time critical transactions are performed
- Compatibility with traditional Wind River inter-task communication methods
- Multi-cluster network topology support

Memory Management

Although VxWorks 6.x provides MMU-enabled memory protection, it continues to use the non-overlapped addressing model in all earlier versions of VxWorks. VxWorks 6.9 introduces an overlapped virtual memory model for RTPs, allowing

RTPs to share the same range of virtual addresses. The non-overlapped model is still the default mode. Overlapped mode can be selected through a configuration parameter.

The non-overlapped memory model promotes backward-compatibility with legacy VxWorks code and features the following benefits:

- High determinism and low latency are maintained by not requiring memory to be mapped in or out and by eliminating unnecessary cache flushes.
- Address pointers are unique, enabling reuse of existing VxWorks drivers and applications, as well as simplifying new driver and application development.

The overlapped virtual memory feature closely resembles the traditional user virtual address space used for processes on operating systems such as UNIX, Linux, and Windows. All RTPs in the system get exclusive use of a common range of virtual addresses. Each RTP has a private view of this common virtual memory area. Shared data regions and shared libraries are mapped at other locations. When using the overlapped virtual memory feature, RTP executables can be fully linked and therefore not require symbol relocations at load time that are otherwise necessary in non-overlapped mode. Fully linked RTP executables therefore load

significantly faster than RTPs running in non-overlapped mode.

Other VxWorks 6.x memory management enhancements include the following:

- **Automatic resource reclamation:** Maximizes memory availability and helps prevent memory leaks, improving device robustness
- **Improved memory allocation using a “best-fit” algorithm:** Reduces memory fragmentation and achieves near deterministic memory allocation/free performance
- **User-mode heap and memory partition support:** Enables RTPs and user-mode execution
- **Developer-replaceable user-mode heap allocator:** Maximizes system design flexibility
- **Heap instrumentation for heaps and memory partitions in both the kernel and RTPs:** Assists in diagnosing common memory problems by detecting and reporting memory errors
- **Tight integration with error management:** Maximizes reliability and minimizes time-to-market
- **Compiler-assisted code instrumentation:** Improves static code analysis of memory errors

Error Management

Wind River provides an error management framework to help customers isolate, diagnose, and correct error conditions

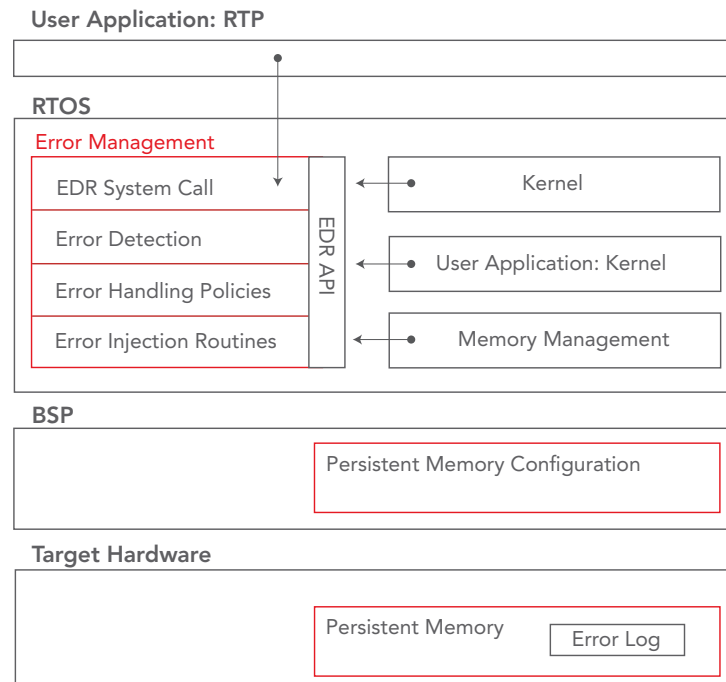


Figure 3: Error management

encountered during development and testing. With this framework, customers can manage failures, minimizing the need to reproduce failures in order to diagnose the device. The error management framework includes memory error detection and error reporting technology and provides a foundation for debugging device software out of the box and is extensible to enable customers to design reliable devices.

Error management capabilities are available in both the kernel and in RTPs and include the following:

- ISR and task stack overrun and underrun detection
- Code corruption detection
- Null pointer usage detection
- Heap block overrun and underrun detection
- Heap usage tracking and leakage detection
- RTP error detection
- API support for kernel application errors
- API support for user-defined application errors
- Customizable error-handling policies
- Comprehensive error records with common headers, key OS information, hardware information, and user-defined optional string
- User-defined memory storage of error records
- Integration and coordination with Wind River device management tools

Processor Abstraction Layer

With VxWorks 6.x, the processor abstraction layer (PAL) provides the capability to extend OS support to similar architecture families. An architecture-specific PAL defines the functional interconnects for each architecture family and, to a degree, abstracts the functionality of that hardware feature from the operating system. While this is transparent to the application, the presence of a PAL for an architecture family facilitates the quick adoption of processor variants, improving time-to-market for VxWorks 6.x customers. The PAL also supports VxWorks SMP for the supported SMP-capable processors.

Operating System Scalability and Performance Tuning

VxWorks 6.7 introduced a new kind of project named VxWorks Source Build (VSB) projects. VSB projects are set up to build VxWorks from source by applying key options to optimize performance and scale footprint. VSB projects can be set up for any BSP, using the kernel configurator in Wind River Workbench.

Predefined VSB build options are available for users to select or unselect from their VSB projects. A given set of options can be combined into a profile. A maximal performance profile has been defined, which excludes RTP support, Wind River System Viewer instrumentation, and some error checks. This profile allows kernel-only systems to be built, providing up to 20 percent kernel performance improvement over a default VxWorks image project build.

VxWorks Source Build and the kernel component configuration, together with an appropriately written BSP, can allow VxWorks image footprints to be significantly reduced to fit the needs of memory-constrained devices.

Small-Footprint Profile

VxWorks 6.9 introduces a new small-footprint profile for resource-constrained devices that need a smaller memory footprint and reduced capability real-time operating system (RTOS). The small-footprint profile is built using the VSB mechanism and results in a VxWorks kernel that supports multitasking, clock interrupts, and mutex and binary semaphores, at a minimum. The small-footprint profile achieves a footprint of 75KB for a fully linked image on a TI OMAP L137 BSP. Additional components can be added to suit users' needs. Scalability down to smaller footprint sizes is determined by the number of components needed to support a given processor and BSP combination, and different BSPs may result in different sizes for the same overall level of functionality.

File Systems

VxWorks includes a FAT-compatible file system called dosFs. VxWorks versions 6.2 and later also include the transaction-based highly reliable file system (HRFS) that enhances the capabilities, performance, and reliability of VxWorks-based file systems.

Features of the file system framework include the following:

- Complete power-safe reliability (except for the case where a write action is interrupted)
- Support for multiple file systems, removable media, and automatic file system detection
- Cache write-through option for dosFs, ensuring data is committed to the file system, enhancing reliability
- Improved CheckDisk for dosFs using the "clean bit," allowing the file system to skip CheckDisk for improved boot-up performance
- Unicode filename support
- Configurable commit policies for fine control of file system performance and reliability

In VxWorks 6.9, HRFS is optimized to provide faster write performance.

Wind River Network Stack

Wind River Network Stack is a full-featured dual IPv4/IPv6 stack specifically designed for embedded real-time systems. Wind River Network Stack incorporates Wind River Advanced Networking Technologies, which provides IPv4/IPv6 networking, security, wireless, and mobility capabilities for compatibility with a wide range of networking environments. It provides rich networking features with high-performance, scalable implementation and a small footprint. It conforms to relevant industry standards and provides a clean code structure for easy integration and faster implementation. In order to ensure high quality, conformance to standards, and interoperability with other network devices, Network Stack has undergone extensive third-party testing and external test lab validation. As a result, Network Stack is

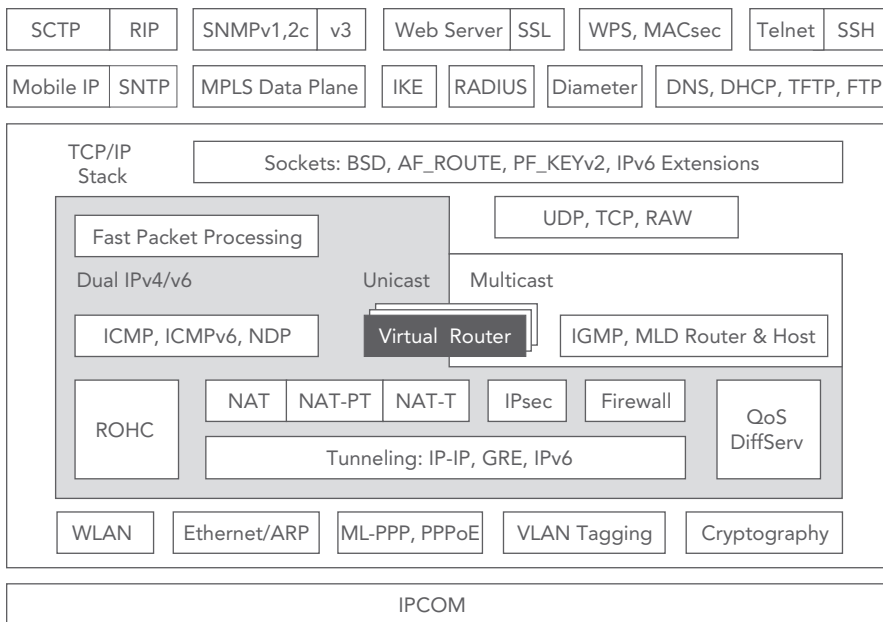


Figure 4: Wind River Network Stack and related components

one of the first few TCP/IP stacks in the industry to receive the IPv6 Ready Phase II logo.

Wind River Network Stack includes a socket wake-up hook feature that is similar to the capability provided by a signals I/O implementation (SIGIO). The stack also supports FIPS 140-2 for the following protocols:

- DHCP v6 (both client and server)
- TCP
- RIP
- SCTP

Wind River Network Stack 6.9 adds the following functionality:

- Support for 64-bit
- Support for 31-bit
- Traceroute command made similar to UNIX traceroute
- Robust header compression (ROHC) enhancement
- IPLITE network stack
- Stacked VLAN
- VLAN priority
- Dynamic domain name server client
- Network time protocol (NTP)
- Relay agent information option (option 82)
- TFTP security

Figure 4 depicts how Wind River Network Stack is integrated with all the relevant networking technologies.

IPv4/IPv6 Dual Stack

Network Stack offers greater flexibility in configuring the stack to support IPv4 and/or IPv6. The stack may be built for IPv4 only, for IPv6 only, or for both protocol versions.

64-bit Support

The following network stack modules support 32-bit and 64-bit hardware platforms:

- IPv4/v6
- IPCOM
- SCTP
- RIP/RIPng
- VLAN
- DHCPv4 client and server
- DHCPv6 client and server
- DNS
- FTP
- NTP
- RLOGIN
- RPC
- RSH
- SNTP
- Telnet
- TFTP

Support for 31-bit Addressing

Wind River Network Stack 6.9 supports the use of 31-bit addressing for point-to-point links on IPv4 networks.

Traceroute Command

In Wind River Network Stack 6.9, the traceroute shell command has been updated to conform to the UNIX implementation of this command.

IPLITE Network Stack

Wind River Network Stack 6.9 includes support for IPLITE. IPLITE is a small-footprint variant of Wind River Network Stack that is suitable for systems based on the ti_omap1137evm BSP.

Stacked VLAN*

Wind River Network Stack 6.9 supports stacked VLAN processing as defined in IEEE Std 802.1ad. IEEE Std 802.1ad amends Std 802.1Q by inserting another service VLAN tag before the customer VLAN. The service VLAN tag is added to provide network service providers the flexibility to configure and administer the service network independently of the customer networks.

VLAN Priority*

The 802.1p priority mechanisms as found in the 802.1q VLAN header have been implemented in the network stack for stacked VLAN. This mechanism allows network administrators to map the user priority indicated in a VLAN tag to network priority so the provider's network can direct user frames to the correct transmission queue according to the user priority bit. Priority mapping is performed at the provider's edge node for each configured customer VLAN ID (C-VID).

Dynamic Domain Name Server Client

The current Domain Name Server (DNS) client module is enhanced with Dynamic DNS. Dynamic DNS is a network service that allows a client to notify a domain name system name server to change the active DNS configuration of its configured host names, addresses, and other information.

Network Time Protocol*

Network Time Protocol (NTP) is supported in Wind River Network Stack 6.9. NTP is a superset of the Simple Network

*These components are included in the networking stack of industry-specific platforms only.

Time Protocol (SNTP) and is compatible with SNTP. NTP conveys timekeeping information from primary servers to secondary time servers and clients over private networks and the public Internet. NTP is widely used to synchronize computer clocks on the Internet. SNTP is still supported.

Hardware Forwarding and Cryptography*

For Cavium OCTEON 38xx and 58xx, Wind River Network Stack 6.9 continues to include an option to dedicate one or more processor cores to fast-forwarding of IPv4 or IPv6 packets. A single forwarding core can be used to process packets from all Gigabit Ethernet interfaces, or multiple forwarders can be configured to work together.

Most devices that support hardware forwarding also support hardware cryptography. Using the hardware cryptography capability of Cavium OCTEON, the forwarding cores can also perform IP Security (IPsec). Typically the forwarding cores do both forwarding and IPsec in one stage. Since IPsec requires much more processing power than plain IP forwarding, more forwarding cores are usually required to reach a certain bandwidth. Using hardware forwarding together with hardware cryptography can significantly increase performance. The IP forwarder in Wind River Network Stack 6.9 supports IPsec in security gateway (SG) mode.

Sockets Compatibility

Sockets in the AF_INET and AF_INET6 family are supported for applications using the network stack. Routing and netlink sockets are also supported.

Stream Control Transmission Protocol*

Wind River VxWorks platforms include support for the Stream Control Transmission Protocol (SCTP) as defined in RFC 4960. Originally used for PSTN signaling, this transport protocol has gained popularity as an alternative to TCP. Using a four-way handshake and multi-homing, SCTP provides a more robust layer-four protocol that increases availability, unlike TCP and UDP. Voice over IP (VoIP) networking often employs SCTP.

MPLS Data Plane Support*

Multi-protocol label switching (MPLS) brings the speed of layer 2 switching to layer 3. It allows routers to eliminate the complex lookup process based on the destination IP address and to make forwarding decisions based on the contents of a simple label. In addition to speed, MPLS offers two key advantages: It supports quality of service (QoS) and virtual private networks (VPNs).

The MPLS data plane support provides the following benefits:

- MPLS over Ethernet devices
- Generic MPLS labels
- IPv4 and IPv6 over MPLS
- Label stacking
- Common label operations
- Delivery of PDUs to Network Stack
- Ingress, transit, or egress node

Quality of Service*

Differentiated Services (DiffServ) is a standards-based priority mechanism for organizing different QoS categories. Network Stack includes DiffServ for egress traffic as a built-in feature of the dual-mode IPv4/IPv6 stack.

The DiffServ classifier can be applied to forwarded traffic. DiffServ markers can be attached to the classifier, so a packet that belongs to a specific traffic flow is passed to a specific marker. The marker can then mark the packet by updating the DS (Differentiated Services) field (or TOS for IPv4 and traffic class for IPv6). The egress interface queues can be configured to use the DS field as selector, which effectively turns them into the shaper stage of the DiffServ machinery.

Policy-Based Routing

Policy-based routing in Wind River Network Stack makes it possible to base the route lookup decision on more than just the destination address. Each virtual router can have one or more forwarding information base (FIB). The default FIB is created when the virtual router is created. The default FIB cannot be deleted unless the whole virtual router is deleted.

Equal-Cost Multipath Routing

Implementing equal-cost multipath (ECMP) routing enables network load sharing by using multiple paths to the same destination. Wind River Network Stack includes two different algorithms, both defined in RFC 2991 "Multipath Issues in Unicast and Multicast Next-Hop Selection," that can be used to select which routes to use when two or more routes have an equal cost. ECMP routing also means that if a certain network path becomes unavailable, the flow of packets will be switched rapidly to an alternative path.

Virtual Router Redundancy Protocol*

Using the Virtual Router Redundancy Protocol (VRRP) implementation in Wind River Network Stack allows a higher availability default path without the configuration of dynamic routing or router discovery protocols on every end host. You can configure VRRP to provide redundancy and load-sharing by defining multiple routers as default gateways and sharing traffic between them. VRRP is the protocol that makes sure that only one router serves the address. If you have a statically configured router on a local area network (LAN), you can use VRRP to assign backup routers using virtual IP addresses. This practice allows failover if the master router fails. VRRP support is currently defined for IPv4 only.

GRE and IPIP Tunneling*

Wind River Network Stack includes drivers for the creation of Generic Routing Encapsulation (GRE) and generic tunnel interface (GIF). GRE is used to tunnel IPv4 and IPv6 packets over IPv4 or IPv6; GRE can tunnel IPv4 or IPv6 packets in a point-to-point tunnel between two IPv4 or IPv6 hosts.

Robust Header Compression*

Robust header compression (ROHC) compresses packet headers transmitted over a wireless link between a mobile terminal and a base station, thus reducing the overhead required for packet headers. The mobile terminal compresses the packet headers before

*These components are included in the networking stack of industry-specific platforms only.

transmitting them over the wireless link, and the base station decompresses them on receipt. Similar processing occurs in the reverse direction. Wind River Network Stack currently supports the uncompressed profile (profile 0x0000) and the IP compression profile (profile 0x0004). ROHC is required for WiMAX and long-term evolution (LTE) networks. ROHC is integrated with MIP4 and MIP6. In Wind River Network Stack 6.9, ROHC has been enhanced with two additional compression profiles, UDP/IP and ESP/IP.

Dynamic Host Configuration Protocol

Dynamic Host Configuration Protocol (DHCP) is an Internet protocol that automates the configuration of computers that use TCP/IP. You can use DHCP to automatically assign IP addresses, deliver TCP/IP stack configuration parameters such as the subnet mask and default router, and provide other configuration information, such as the addresses for printer, time, and news servers. Wind River Network Stack includes server, client, and relay agent for both DHCP and DHCPv6.

Layer 2 Tunneling Protocol*

Wind River L2TP 6.9 is Wind River's implementation of the Layer 2 Tunneling Protocol (L2TP). L2TP allows end devices to connect over a network and thus retain the advantages of a private network while using the public network. A tunnel typically consists of a control connection between two L2TP peers and one or more data sessions. The packets of data sessions are encapsulated in L2TP data messages and exchanged between the two L2TP peers. Wind River L2TP 6.9 can run on a 64-bit platform. In addition, support for PPP over L2TP has been added in the form of L2TP Network Server (LNS) version 2.

ifLib and Route APIs

Wind River Network Stack includes support for the ifLib and if6Lib interface configuration libraries. These libraries enable interface configuration and routing routines available in the Network Stack before release 6.5.

IPv6 Scoped Address Architecture

You can set the IPv6 address scope and zone for a node. You can either assign the default zone for a scope, such as a node, link, subnet, admin, site, or organization, or you can assign a particular interface to a zone.

Gratuitous ARP

Wind River Network Stack supports gratuitous ARP. When gratuitous ARP is enabled, the system sends an ARP request for every new address added to a network interface. The ARP request is sent to verify that no other node on the link uses the address.

Cryptographically Generated Addresses

You can generate and validate cryptographically generated addresses (CGAs) and generate CGA parameters. CGAs are IPv6 addresses for which the interface identifier is generated by computing a cryptographic one-way hash function from a public key and auxiliary parameters. Systems can verify the binding between the public key and the address by recomputing the hash value and by comparing that hash value with the interface identifier.

Secure Neighbor Discovery

Wind River Network Stack supports the Secure Neighbor Discovery (SEND) protocol. This protocol is used in IPv6 networks to counter threats to the Neighbor Discovery Protocol (NDP) that can occur in environments where physical security on the link is not ensured (such as over wireless).

Netlink

Wind River Network Stack supports netlink and RTNETLINK. Netlink is a network service that enables communication between the kernel and user-space processes. Netlink enables a bidirectional communication link so that either a user-space process or the kernel module can initiate communication.

RTNETLINK is a protocol extension to netlink that implements management and information retrieval for links, addresses, rules, routes, and neighbors.

MIB-II Support

Wind River Network Stack supports MIB-II (RFC 1213), using the M2 library m2Lib. Applications developed with this library can allow an SNMP agent to access MIB information, bypass the SNMP agent to access MIB information directly from a device, and access hardware statistics counters.

Routing Engine

Wind River Network Stack contains a high-performance routing engine that uses highly optimized Radix trees that allow both static and dynamic routes. A standard BSD routing socket interface enables the use of standard routing daemons and also allows for dedicated routing devices to cooperate with the TCP/IP stack.

Virtual Routing

VRRP is the protocol that makes sure that only one router serves the address. If you have a statically configured router on a LAN, you can use VRRP to assign backup routers using virtual IP addresses. This practice allows failover if the master router fails. Wind River Network Stack supports full virtualization with multiple independent routing tables used in virtual routers. This means that one network stack can act as multiple routers, enabling a massive reduction in router hardware. The virtual routing support includes a number of BSD socket extensions to manage the additional routing tables.

IPv4 and IPv6 Autoconfiguration

Wind River Network Stack supports both IPv4 and IPv6 autoconfiguration.

Wind River Mobile IPv4/IPv6*

Mobile IP provides an efficient, scalable mechanism that allows users to roam seamlessly among wireless networks. Using Mobile IP, applications such as Internet telephony, media streaming, and virtual private networking can be supported without service interruption when users move across network boundaries.

*These components are included in the networking stack of industry-specific platforms only.

Wind River Mobile IP products are compliant with WiMAX Forum standards for mobility in WiMAX networks, as well as the 3GPP2/3GPP standards for next-generation cellular networks, including LTE. In addition, these products implement fast handover (“make-before-break”) for the support of Voice over Internet Protocol (VoIP) and other real-time applications. Wind River Mobile IP 6.9 can run on a 64-bit platform.

Wind River Mobile IP 6.9 implements a mobile node, home agent, foreign agent, and proxy mobility client for IPv4 and a mobile node, home agent, and mobile access gateway agent for IPv6.

Wind River PPP

Wind River PPP is a source-code product written in C with an object-oriented design. With Wind River PPP, you can implement a dynamically configured PPP stack for diverse remote access applications. These applications can have a variety of network interface types, network stack types, link speeds, control protocols, framing techniques, and so on.

Wind River PPP 6.9 can run on a 64-bit platform. In addition, Wind River PPP adds support for PPP over L2TP and PPP over VLAN.

Wind River PPP already supports the PPP over L2TP protocol in the form of an L2TP Access Concentrator (LAC) client as defined by RFC 2661 where the PPP and L2TP endpoints are on the same host and no Public Switched Telephone Network (PSTN) interface is required or supported. In this release, support for PPP over L2TP has been added in the form of an L2TP Network Server (LNS). Support for PPPoE over a virtual LAN pseudo-interface has also been added.

Wind River USB

Wind River USB enables developers to quickly incorporate standard Universal Serial Bus (USB) connectivity in VxWorks-based embedded devices and their attached peripherals.

Wind River USB 2.6 supports version 2.0 of the USB specification, providing support for the universal host controller interface (UHCI), the open host controller interface (OHCI), and the enhanced host controller

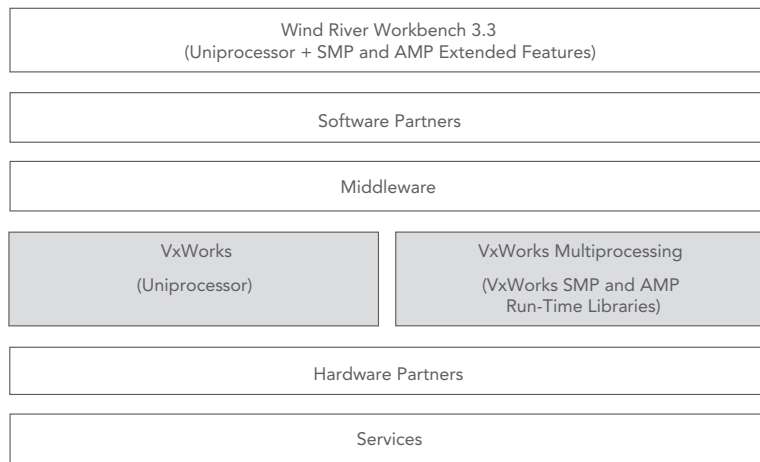


Figure 5: VxWorks multi-core installation with VxWorks platforms

interface (EHCI). The USB host controller drivers are fully integrated under the VxBus device driver framework. Wind River USB includes the most common set of USB 2.0 host class drivers and device emulation drivers. A framework for handling non-conformant USB devices makes it easy for applications to handle USB compatibility issues.

Wind River USB 2.6 in VxWorks 6.9 has improved handling of faulty connections, bad data, sudden non-response from devices, and other corner error cases. For boards that do not support the RS-232 connection, the USB port can be used for serial console I/O. For boards that do not provide an Ethernet port, the USB port can be used for the booting and debug connection. This version of Wind River USB introduces the USB show command-line tool for listing information about connected devices.

VxWorks Multi-core Technologies

Multi-core technologies (i.e., both SMP and AMP) are included in the standard platform to all users of VxWorks. These technologies are an evolution of the VxWorks RTOS to provide both SMP and AMP capabilities, not a new operating system. VxWorks SMP leverages multi-core processors to achieve true concurrent execution of applications, allowing applications to gain in performance through parallelism. VxWorks AMP technologies allow users to construct systems running multiple operating systems, handling different tasks and communicating within themselves. Users can develop on both VxWorks uniprocessor

(UP) and SMP and use the AMP technologies according to their project needs.

VxWorks SMP

Multi-core systems include two or more processors in a single system. SMP is an operating system technology in which one instance of an operating system controls all processors in the system and memory is shared between all processors in the system. SMP differs from AMP in that an AMP system has a separate instance of an operating system executing on each processor (and each instance may or may not be the same type of operating system).

The VxWorks SMP configuration allows a single instance of the operating system to use multiple processors in a single system. At the same time, it maintains the same key RTOS characteristics of performance, small footprint, high reliability, and determinism as the uniprocessor configuration of VxWorks.

The VxWorks SMP-enabled platforms allow you to do the following:

- Deliver higher-performance multi-core-powered products with reduced risk and development investment.
- Speed time-to-market by using the commercially available and supported run-time platforms and developer tools for multi-core.
- Increase productivity by using the same development environment and process available for uniprocessor development by using the SMP extension to existing development tools.
- Enable a flexible design approach using Wind River’s expertise and broad technology support for multi-core.

Terminology

The terms *CPU* and *processor* are often used interchangeably in computer literature. However, it is useful to distinguish between the two for hardware that supports SMP. In this document, particularly in the context of VxWorks SMP, the terms are used as follows:

- **CPU:** A single processing entity capable of executing program instructions and processing data (also referred to as a *core*, as in *multi-core*)
- **Processor:** A silicon unit that contains one CPU
- **Multiprocessor:** A single hardware system with two or more processors
- **Uniprocessor (UP):** A silicon unit that contains a single CPU
- **Multi-core processor:** A silicon unit that contains two or more CPUs

For example, a dual-core processor has two CPUs. A quad-core processor has four CPUs.

UP code may not always execute properly on an SMP system, and code that has been adapted to execute properly on an SMP system may still not make optimal use of SMP. The following terms are therefore used to clarify the state of code in relation to SMP:

- **SMP-ready:** Runs correctly on an SMP operating system, although it may not make use of more than one CPU (i.e., does not take full advantage of concurrent execution for better performance)
- **SMP-optimized:** Runs correctly on an SMP operating system, uses more than one CPU, and takes sufficient advantage of multitasking and concurrent execution to provide performance gains over a uniprocessor implementation

VxWorks SMP Operating System Features

VxWorks SMP is designed for symmetric target hardware. That is, each CPU has equivalent access to all memory and all devices. VxWorks SMP can therefore run on targets with multiple single-core processors or with multi-core processors, as long as they provide a uniform memory access (UMA) architecture with hardware-managed cache coherency. VxWorks implementation of SMP does not have core 0 limitation so multiple SMP systems can run next to each other in a multi-core environment.

Multitasking and Concurrency

SMP changes the conventional UP paradigm of the system being in a single state at any given point in time (e.g., task level vs. interrupt level). VxWorks SMP is also a priority-based preemptive kernel. It allows true concurrent execution of multiple tasks or handling of interrupts on more than one CPU.

Scheduling

VxWorks SMP provides a priority-based preemptive scheduler, just as in VxWorks UP. However, VxWorks SMP schedules the N-highest priority tasks in the system, where N is the number of CPUs. In contrast, VxWorks UP schedules only the single highest priority task in the system. In both VxWorks UP and VxWorks SMP, tasks are scheduled—and RTPs are not.

Mutual Exclusion

Because SMP systems allow for truly concurrent execution of both tasks and ISRs, the UP mechanisms for disabling (masking) interrupts and for suspending task preemption in order to protect critical regions are inappropriate for—and not available in—VxWorks SMP. Enforcing interrupt masking or suspending task preemption across all CPUs would defeat the advantages of truly concurrent execution and severely degrade performance.

VxWorks SMP therefore provides specialized mechanisms for mutual exclusion between tasks and interrupts. In place of UP task and interrupt locking routines—

such as `taskLock()` and `intLock()`—VxWorks SMP provides spinlocks, atomic memory operations, and CPU-specific mutual exclusion facilities.

CPU Affinity

By default, any task can run on any of the CPUs in the system (which generally provides the best load balancing). Sometimes it is useful to assign specific tasks or interrupts to a specific CPU, usually for the purpose of tuning performance or guaranteeing that critical tasks in the system have enough CPU availability to finish their processing requirements. VxWorks SMP provides this capability, which is referred to as *CPU affinity*. For example, once task A has its affinity set to CPU 2, task A will henceforth run only on CPU 2. Other tasks may also share CPU 2, but task A will not run on any other CPU.

While the default SMP operation in which any task can run on any CPU often provides the best overall load balancing, there are cases in which assigning a specific set of tasks to a specific CPU can be useful. For example, if a CPU is dedicated to signal processing and does no other work, the cache remains filled with the code and data required for that activity. This saves the cost of moving to another CPU—which is incurred even within a single piece of silicon, as the L1 cache is bound to a single CPU, and the L1 must be refilled with new text and data if the task migrates to a different CPU.

Another example is a case in which profiling an application reveals that some of its tasks are frequently contending for the same spinlock and a fair amount of execution time is wasted waiting for a spinlock to become available. Overall performance could be improved by setting task CPU affinity such that all tasks involved in spinlock contention run on the same CPU. This would free up more time on other CPUs for other tasks.

RTP Tasks and CPU Affinity

By default, RTP tasks inherit the CPU affinity setting of the task that created the RTP. If the parent task has no specific CPU affinity (i.e., it can execute on any available CPU and may migrate from one

CPU to the other during its lifetime), the RTP's tasks have no specific CPU affinity either. If the parent task has its affinity set to a given CPU, by default the RTP tasks inherit this affinity and execute only on the same CPU as the parent task.

CPU Reservation

CPU reservation is a stronger form of affinity in which a task and CPU are dedicated to each other. Using the previous example, if task A has reserved CPU 2, it will not only always run on CPU 2 but CPU 2 will not schedule any other tasks in the system even if they are ready. While running, task A will not be preempted by any other tasks, regardless of priority. Any interrupts routed to CPU 2 will still be serviced. CPU reservation is typically used to fine-tune and increase the performance of critical, compute-intensive tasks in the system that have a significant impact on system performance and throughput. CPUs can be reserved and unreserved through API calls.

VxWorks SMP Hardware

The hardware required for use with VxWorks SMP must consist of symmetric multiprocessors—either multi-core processors or hardware systems with multiple single CPUs. The processors must be identical; all memory must be shared between the CPUs (none may be local to a CPU); and all devices must be equally accessible from all CPUs—that is, targets for VxWorks SMP must adhere to the UMA architecture.

Regardless of the number of CPUs (typically two, four, or eight) in an SMP system, the important characteristics are the same:

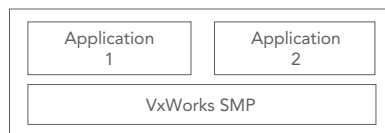
- Each CPU accesses the very same physical memory subsystem; there is no memory local to a CPU. This means it is irrelevant which CPU executes code.
- Each CPU has its own memory management unit that allows concurrent execution of tasks with different virtual memory contexts. For example, CPU 0 can execute a task in RTP 1 while CPU 1 executes a task in RTP 2.

- Each CPU has access to all devices. Interrupts from these devices can be routed to any one of the CPUs through a programmable interrupt controller. This means that it is irrelevant which CPU executes ISRs when handling interrupts.
- Tasks and ISRs can be synchronized across CPUs and mutual exclusion enforced by using spinlocks.
- Bus snooping logic ensures the data caches between CPUs are always coherent. This means that the operating system does not normally need to perform special data cache operations in order to maintain coherent caches. However, this implies that only memory access attributes that allow bus snooping are used in the system.

Comparison of VxWorks SMP and AMP

The features of VxWorks SMP may be highlighted by comparison with the way VxWorks is used in AMP, using the same target hardware in both cases.

In an SMP configuration (Figure 6), the entire physical memory space is shared among the CPUs. This memory space is used to store a single VxWorks SMP image (text, data, bss, heap). It is also used to store any RTPs that are created during the lifetime of the system. Because both CPUs can potentially read from, write to, and execute any memory location, any kernel task or user (RTP) task can be executed by either CPU.



Software

Hardware

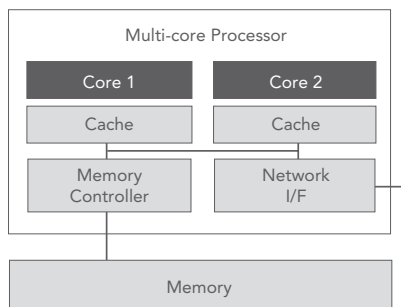


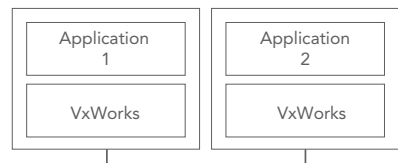
Figure 6

In an AMP configuration there is one copy of the VxWorks image in memory for each CPU. Each operating system image can only be accessed by the CPU to which it belongs. It is therefore impossible for CPU 1 to execute kernel tasks residing in VxWorks CPU 0's memory, or the reverse. The same situation applies for RTPs. An RTP can only be accessed and executed by the instance of VxWorks from which it was started.

In an AMP system (Figure 7), some memory is shared, but typically the sharing is restricted to reading and writing data—for example, for passing messages between two instances of VxWorks. Hardware resources are mostly divided between instances of the operating system so that coordination between CPUs is only required when accessing shared memory.

SMP and Mutual Exclusion

The use of mutual exclusion facilities is one of the critical differences between UP and SMP programming. While some facilities are the same for VxWorks UP and VxWorks SMP, others are necessarily different. In addition, reliance on implicit synchronization techniques—such as relying on task priority instead of explicit locking—do not work in an SMP system.



Software

Hardware

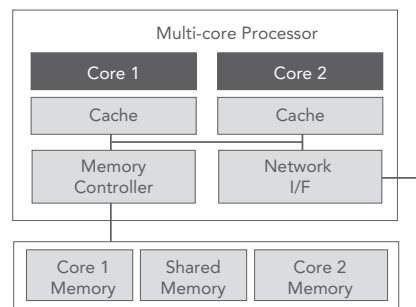


Figure 7

Figures 6 and 7: Comparison of the relationship between CPUs and memory use in SMP and AMP systems

Unlike UP systems, SMP systems allow for truly concurrent execution, in which multiple tasks may execute and multiple interrupts may be received and serviced, all at the same time. In most cases, the same mechanisms—semaphores, message queues, and so on—can be used in both UP and SMP systems for mutual exclusion and coordination of tasks.

The most basic differences for SMP programming have to do with the mechanisms available for mutual exclusion between tasks and interrupts executing and being received (respectively) on different CPUs. In place of UP task and interrupt locking routines—such as `taskLock()` and `intLock()`—VxWorks SMP provides the following facilities:

- Spinlocks for tasks and ISRs
- CPU-specific mutual exclusion for tasks and ISRs
- Atomic memory operations
- Memory barriers

As with the UP mechanisms used for protecting critical regions and global variables, spinlocks and CPU-specific mutual exclusion facilities should only be used when they are guaranteed to be in effect for very short periods of time. The appropriate use of these facilities is critical to making an application SMP-ready.

Note that both spinlocks and semaphores provide full memory barriers (in addition to the memory barrier macros themselves).

RTP Applications

As in VxWorks UP systems, RTP (user-mode) applications have a more limited set of mutual exclusion and synchronization mechanisms available to them than kernel code or kernel applications. In VxWorks SMP, they can make use of semaphores and atomic operations, but not spinlocks, memory barriers, or CPU-specific mutual exclusion mechanisms.

Types of Spinlocks

- **ISR-callable spinlocks:** These are used to address contention between ISRs—or between a task and other tasks and ISRs. They disable (mask) interrupts on the local CPU. When called by tasks, they suspend task preemption on the local CPU as well.
- **Task-only spinlocks:** These are used to address contention between tasks (and not ISRs). They suspend task preemption on the local CPU. The *local CPU* is the one on which the spinlock call is performed.

Spinlocks for Mutual Exclusion and Synchronization

Spinlocks provide a facility for short-term mutual exclusion and synchronization in an SMP system. Spinlocks must be explicitly taken and released. While semaphores can also be used for mutual exclusion and synchronization, spinlocks are designed for use in situations comparable to those in which `taskLock()` and `intLock()` are used in VxWorks UP. Semaphores should be used in an SMP system for the same purposes as in a UP system. (Note that both spinlocks and semaphores provide full memory barriers.)

One of the unique characteristics of VxWorks spinlocks is that they are implemented with algorithms that ensure that they are fair, meaning that they are deterministic in the time between the request and take, and they operate in as close to FIFO order as possible.

Note: Spinlocks are not available to RTP (user-mode) applications.

Memory Barriers

A memory barrier is a class of instructions that cause a CPU to enforce ordering of memory operations. CPUs and compilers often reorder instructions that can cause

out-of-order execution, which causes unpredictable behavior in concurrent programs and device drivers in SMP systems. If code depends on the order in which another CPU writes to memory, a memory barrier should be used. Note that both semaphores and spinlocks provide full memory barriers on their own.

Atomic Memory Operations

Atomic operations make use of CPU support for atomically accessing memory. They combine a set of (architecture-specific) operations into what is effectively a single operation that cannot be interrupted by any other operation on the memory location in question. Atomic operations thereby provide mutual exclusion for a simple set of operations (such as incrementing and decrementing variables). Atomic operations can be useful as a simpler alternative to spinlocks, such as for updating a single data element. For example, you can update the *next* pointer in a singly linked list from NULL to non-NULL (without interrupts locked) using an atomic operation, which allows you to create lock-less algorithms. Because the atomic operations are performed on a memory location supplied by the caller, users must ensure the location has memory access attributes and an alignment that allows atomic memory access—otherwise an access exception will occur. Restrictions, if any, are specific to the CPU architecture.

Interrupt CPU Affinity

SMP hardware requires programmable interrupt controller devices. VxWorks SMP makes use of this hardware to allow assignment interrupts to a specific CPU. By default, interrupts are routed to the bootstrap CPU (CPU 0).

Interrupt CPU affinity can be useful for load balancing (e.g., if there is too much total interrupt traffic for one CPU to handle). It can also be used as an aid in migrating code from VxWorks UP.

Run-time assignment of interrupts to a specific CPU occurs at boot time, when the system reads interrupt configuration information from the BSP. The interrupt controller then receives a command directing that a given interrupt be routed to a specific CPU.

Developer Tools for Debugging SMP Code

A multi-core platform is of little value unless the software applications that will run on it make effective use of multi-core. The Wind River Workbench development environment is based on the Eclipse framework and integrates a broad range of capabilities. The Workbench development environment and associated tools offer extensive capabilities to meet the challenges of multi-core device software development.

VxWorks AMP Technologies

The ultimate goal for Wind River AMP technologies is to facilitate the construction of multi-OS systems involving more than one type of OS. These technologies have been designed to be portable across different operating systems and can be used with minor porting effort in other operating systems such as Wind

River Linux. VxWorks AMP technologies support the construction of multi-core systems comprising two or more VxWorks RTOS instances.

Inter-node Communications Using MIPC

MIPC is a high-speed message-passing protocol designed for inter-node communications in multi-core AMP systems. MIPC uses shared memory as a fast, efficient communications medium between OSes running on different cores. Messages are passed between nodes without copying (i.e., zero-copy) on shared memory busses. The network topology is statically defined at configuration time. Programmatically, a familiar socketlike interface allows TCP/IP- or TIPC-based software to be ported easily and then run at hardware speeds. MIPC is supported in both VxWorks and in Wind River Linux. Failed nodes can reliably rejoin an MIPC network. APIs offer the facility to install callback functions on significant MIPC protocol events such as connection requests and the receipt of new messages. MIPC communications can also be used from real-time processes (RTPs) via the socket and related APIs. VxWorks 6.9 with MIPC 2.1 adds support for 64-bit processing.

Shared Memory and Hardware Partitioning

Shared memory between nodes is the most commonly found medium by which nodes in an AMP system may share data and pass messages. In a multi-core system, the total physical memory in the system must be split into dedicated memory regions for each node and its OS and shared memory regions used for inter-node communications. Devices available in the system must also be cleanly divided between the different nodes that control them. This system-level hardware configuration is different for each system and must be carefully done to avoid conflicts.

Booting AMP Systems: The wrload Utility

AMP systems need to boot nodes in a controlled order. This is controlled by the wrload utility. Boot images in the form of fully linked ELF files can be loaded by

wrload in a configurable sequence. One CPU with VxWorks—the primary CPU—boots first and then uses the wrload utility to load and boot VxWorks on the other CPUs—the secondary CPUs. The paths of boot images are passed to boot images, along with other boot options—for example, the VxWorks boot line. Wrload can be invoked either programmatically, such as from a script, or via the VxWorks kernel shell. Multiple invocations of wrload are used to define the boot order of nodes in an AMP system.

Shared Devices, Virtual Consoles

AMP systems using multi-core CPUs often have fewer physical peripheral devices than the number of nodes present in the system. A case in point is the console serial port, of which there is usually only one or a couple. It is thus necessary to set up the sharing of one physical console port across more than one node. This allows resource-constrained systems with a limited number of physical devices to be shared among more than one node in an AMP system.

MIPC Serial Devices

Nodes that do not have access to a physical serial port can use a virtual serial-port driver that uses MIPC to communicate to a node that does. This is called an MIPC serial device (MSD). The output from a node with an MSD is sent to the physical serial console and can be prefixed with a configurable tag to identify the node it originated from. Alternately, if the terminal supports it, a different color can be assigned to the messages for easy identification.

The VxWorks tip utility provides full duplex communication between a host and the nodes on a multi-core target system. The VxWorks tip utility resembles the tip utility for UNIX and the Linux screen utility. Using the VxWorks tip, commands can be sent to individual nodes in a multi-core system. MSD and the tip can also be used to interact with shells running on one or more VxWorks nodes in an AMP system.

Terminology: Nodes and CPUs

In this document, the term *node* applies to an instance of an operating system on one or more cores and does not necessarily correspond to a CPU itself. A node is a single processor computer in its own right, yet only part of a larger system comprising more than one node.

The simplest example of this is when an operating system runs on one core; that core with its OS is called a *node* in an AMP system. If VxWorks SMP is running on four CPUs (CPU 0 through CPU 3), the four CPUs constitute a single node. In this case if CPU 4 is used for AMP, it counts as node 2. In a multi-core context in which all CPUs have a single VxWorks image without SMP, node and CPU are equivalent.

MIPC Network Device

MIPC network devices (MND) allow nodes in an AMP system to communicate among themselves and the outside world over an MIPC-based network device abstraction. MND uses MIPC busses as virtual Ethernet segments, with nodes attaching and detaching dynamically. Different MIPC busses can serve as different virtual multi-drop Ethernet segments to provide traffic separation. An MND interface is visible to the VxWorks programmer as a standard END device, which can support both TCP/IP, TIPC, or other protocol stacks requiring Ethernet semantics. A node with a physical Ethernet device can serve as a gateway to other networks. Additional IP-based network services such as Telnet, NFS, and so forth can work seamlessly over an MND interface.

MIPC File System

The MIPC File System (MFS), which is modeled on the well-known Network File System (NFS), provides access to file systems on nodes in a VxWorks multi-core environment. As does NFS, MFS implements a client-server architecture. An MFS server on a given node can export file systems and make them available to other nodes. An MFS client can mount an exported file system and access files on the remote node as if the files were local.

AMP Spinlocks

Spinlocks can be used between VxWorks nodes in an AMP system. As their name suggests, spinlocks let two or more AMP nodes synchronize mutually exclusive access to a region of shared memory accessible by both OSes.

AMP Debugging

AMP system debugging relies on a combination of a local debug agent in each node and a “proxy” agent in one of the nodes (usually Core 0 of a multi-core processor) to route debug commands

and information back to the debugger running on the host machine. This allows the debugger to connect to use one host-target network link to debug either individual nodes or the whole system. Wind River ICE 2 can also be used to debug supported processors running an AMP system. The debug operations themselves, such as step, continue, step-over, and so on, are the same ones used in a single-OS environment.

Legacy AMP Systems Using VxMP

VxWorks 6.9 continues to support VxMP as a means of constructing AMP systems. VxMP and the new AMP technologies can coexist in the same system. However, the newer technologies are both more efficient for multi-core systems and more robust. In contrast, VxMP was designed to work over a shared memory back-plane, such as on VME busses and so forth, which are less efficient than shared memory on multi-core systems. A single node that suffers failure does not need the whole system to be rebooted, as was the case with VxMP. It is encouraged for users to adopt the newer AMP technologies as soon as convenient.

Programming AMP Systems

Programming AMP systems is fundamentally no different than programming a set of single-OS systems. Each node is a single-OS programming environment in its own right. Except where specifically noted, all software facilities, features, and restrictions for the single-OS or SMP configurations of VxWorks are applicable to nodes of an AMP system.

Users should note, however, that there is still true concurrency of different actions happening in an AMP system, though the concurrent execution is happening in other OSes. Therefore, AMP programs should not assume any specific order of execution or timing characteristics of actions happening on other nodes.

Access to data items should be subject to lock-free algorithms or there should be a block on receipt of a message.

Wind River Hypervisor Support

VxWorks 6.9 can be used as a guest OS on Wind River Hypervisor 1.0, 1.1, or 1.2^{U2} on Power Architecture, IA-32, and Intel 64 hardware. Wind River Hypervisor enables virtualized solutions by allowing more than one “guest” operating system to execute on the same hardware. VxWorks and Wind River Linux are supported as guest OSes on Wind River Hypervisor.

A virtualized multi-OS system can be considered to be another kind of AMP system, one that runs the guest OSes under the supervision of Wind River Hypervisor. A hypervisor-based AMP system is called a “supervised” AMP system, in contrast with an AMP system in which the OSes run natively.

With this in mind, the Wind River AMP technologies described previously are also supported in hypervisor-based systems and are portable to both VxWorks and Wind River Linux. This allows AMP programs to work transparently in either a hypervisor-based “supervised” AMP system or one that runs natively.

For more information on the Wind River Hypervisor, see <http://www.windriver.com/products/hypervisor/>.

Development Challenges and Solutions

Multi-core Enabled Tools

A multi-core situation requires the ability to physically control multiple processors or processor cores. The tools enabled for this task are included in the Wind River Workbench development environment, which is included in the platforms, and the Wind River on-chip debugging tools, which are an optional add-on product.

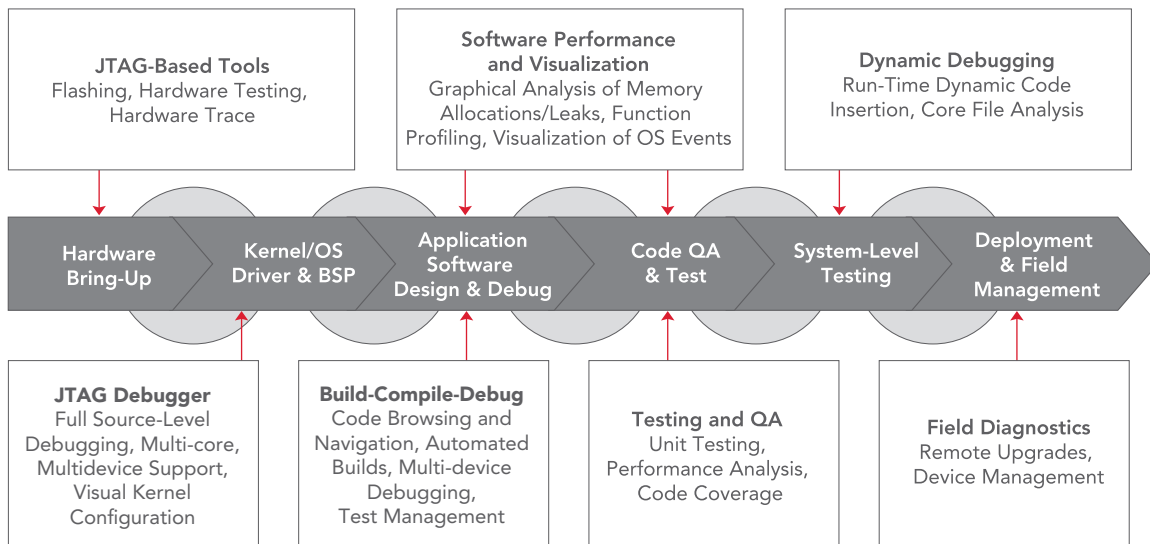


Figure 8: Wind River Workbench development environment integrates a broad range of capabilities

Workbench provides multi-core-enabled capabilities that span the entire development life cycle (Figure 8).

Wind River Workbench includes a target manager to coordinate multiple processor systems. In order to be useful, debuggers and other developer tools must be able to connect to a processor of interest. In many multiple processor systems, there may be processors that do not sit on the same network as the developer's desktop computer. In cases where a processor of interest during debug is not on the same network as the developer's desktop but can be reached through an intermediate processor that does share the network, the proxy included in the Workbench debugger can make the connection—and even translate the protocol if needed.

When using on-chip debugging, a single Wind River ICE 2 can be used to control multiple processors or processor cores. Many other on-chip debugging solutions require a separate debugging hardware unit for every single processor or core, significantly increasing cost and complexity. Wind River's support for multi-processor on-chip debugging also includes synchronized run-control across multiple processors when they are supported by the capabilities of the underlying hardware.

Identifying Overused and Underused Processors

New multi-core-specific enhancements have been included in Wind River System Viewer. For example, System Viewer can display the utilization or number of pending tasks for each processor core over time. For SMP systems, the data for every processor core will be integrated in a single, time-correlated display. In addition, the VxWorks commands can be used to determine the amount of CPU time used by each task, the amount of time spent at interrupt level and in the kernel, and the amount of time the CPU was idle.

Identifying and Diagnosing Race Conditions

Wind River System Viewer supports the visualization of user-defined events. Developers can identify event sequences that represent possible race conditions by logging appropriate events to a file then processing the data in that file with a script or program.

Debugging Thread Interaction Across Multiple Processors

The Workbench debugger works simultaneously on multiple contexts. It assigns each thread its own debug context that includes a source/assembly view, a register window, and a stack back-trace view. Each thread can also be controlled independently using

thread-qualified breakpoints that further extend the developers' ability to debug multiple processor interaction.

Debugging Multiple Processors Without Breakpoints

In AMP systems, it may not be possible to debug certain problems using breakpoints. Stopping one of several processors can cause the system to malfunction or change the system's behavior so much that it hides the problem that's being sought. Wind River Test Diagnostics enables dynamic interaction with a running application—adding diagnostic code, collecting data, and modifying program execution. Providing these capabilities without requiring the processor to be stopped or the application code to be rebuilt makes Test Diagnostics a much less intrusive solution for an AMP system than a traditional debugger.

Tracking Data Values Systemwide

Understanding the operation of a multiple processor system often depends on understanding the changes in the state of the system created by the interaction of multiple processors and having the ability to track data values over time. Wind River Data Monitor (formerly StethoScope) is an easy way to track key data values in an SMP system, or the value of data shared between multiple processors in an AMP system. Workbench target agent and on-chip

debugging support for processors with hardware breakpoint capability provide another way to track data values, by setting breakpoints that trigger on data accesses at a specified address.

Identifying the Best Functions to Speed Up

To increase performance by applying parallelism, begin with the parts of your program that consume the most CPU cycles. The Wind River development environment for VxWorks and Linux provides several ways to collect this information. The VxWorks Spy() capability and the top command available in a Linux environment provide one alternative. Wind River Performance Profiler (formerly ProfileScope) and System Viewer make it easy to identify which functions in an application are consuming the most CPU cycles. In an SMP system, additional threading will help to increase system performance. In an AMP system, these are the functions that may benefit from decomposition or reassignment to a processor with a lighter load.

Uncovering Shared Resource Contention

The rich data collection capabilities of Wind River System Viewer can be used to log information that can later be analyzed to expose a range of resource contention-related issues.

Tracking Inter-processor Communication and Synchronization

In multiprocessor systems, the interaction of processors is at least as important as what happens on any single processor. Spinlocks are commonly used to provide synchronization in multi-core systems. Spinlocks are supported with VxWorks SMP, and spinlock activity is trackable in System Viewer visualization. System Viewer instrumentation of TIPC messages also provides insight into the interaction between processors.

Displaying Static or Dynamic Routing of Interrupts to Processors

The assignment of hardware resources, including interrupts, to specific processors is an important multi-core design decision. The ability to query the state of VxWorks kernel objects allows

developers to see how interrupts are assigned to processors. This will apply to static and dynamic assignment.

Middleware Technology

Security

Wind River IPsec and IKE

Wind River IPsec is a scalable implementation of IPsec, as specified by the IETF. It provides authentication, data integrity, encryption, and replay protection of any network traffic on the IP layer. It is implemented as a tightly integrated software module for Wind River Network Stack, for both IPv4 and IPv6 operations. Wind River IPsec is interoperable with other IPsec implementations and conforms to the IPsec RFCs, as specified by the IETF.

Features of Wind River IPsec 6.9 include the following:

- 64-bit support
- Updates to the PF_Key v2 management interface
- New keyadm commands and options
- RFC 4301, 4308, 4835, and others
- Support for IP forwarding with IPsec on Cavium Networks CN38xx and CNN58xx processors
- Support for IPsec ESP cryptographic offload to Cavium Networks CN38xx and CN58xx processors
- Addition of new commands and parameters as well as changes to existing keyadm shell commands
- Tunnel and transport mode in any security association (SA) combination
- Support for AH and ESP modes
- IP in IP tunneling
- Bypass/apply/discard IP packet filtering with both input and output selectors
- Support for IPsec monitoring MIB
- Key and SA management with PF_Key Management API v2 with openbsd extension
- Support for all required authentication transforms and encryption algorithms
- Validated with Common Cryptography Interface (CCI)
- Extended Sequence Number (ESN) Addendum to IPsec
- Integrated and validated with optional security coprocessors, demonstrating significant performance improvement over software processing
- VPN-A and VPN-B suites
- Traffic flow confidentiality (TFC)

- IPsec offloading with SMP systems
- Support for FIPS 140-2 mode

Wind River IKE is a scalable implementation of IKE versions 1 and 2, as specified by the IETF, and it provides for secure key exchange for IPsec.

Features of Wind River IKE 6.9 include the following:

- Support for IKE v1 and IKE v2
- Support for address and port ranges in the IPsec SA configuration (IKEv2 only)
- Support for listening on any address (0.0.0.0 for IPv4, or :: for IPv6)
- Support of Online Certificate Status Protocol (OCSP) extensions to IKEv2, as defined in RFC 4806
- Ability for IKEv1 and IKEv2 to verify the validity of a given certificate against a certification revocation list issued by an appropriate certificate authority
- IKE v1 support of accepting both ESP and AH negotiation in the same proposal for a given IPsec flow configuration, required for interoperability with Windows Vista and Windows Server equivalents, which allow such policy specifications
- NAT traversal of ESP packets over UDP
- Integration with Wind River Network Stack
- Authentication based on X.509 certificates and preshared secrets (passwords)
- Passive and active establishment of IPsec connections
- Secure, interoperable communication with other IPsec endpoints
- Plug-and-play integration with Wind River IPsec
- VPNC certification for Basic, AES, IKE v2, IPv6, and certificate interoperability
- Support for FIPS 140-2 mode
- IKE SA rekeying
- 64-bit support
- Support for Section 2.24: Explicit Congestion Notification (ECN) of RFC 4306 Internet Key Exchange (IKEv2) Protocol
- Support of RFC 4718 IKEv2 Clarifications and Implementation Guidelines
- Support for secure key storage
- Enhanced dead peer detection (DPD)
- Enhanced IKE daemon to renegotiate proposals in the IKE stack if the first specified group is not accepted
- ipike_identification-extract() routine optimized to avoid unnecessary malloc() calls to enhance memory usage
- Fetching certificates using HTTP
- Matched delete sequence during rekeying for IKEv1 and IKEv2

Wind River Wireless Security

Wind River Wireless Security is a suite of security protocols implemented by Wind River that includes a supplicant and authenticator for the 802.1X-2001 standard and Wi-Fi Protected Setup (WPS). The Wireless Security authenticator is integrated with the Wind River RADIUS and Diameter, Wind River Learning Bridge, and Wind River Wireless Ethernet Driver, providing all the core functionality for typical authenticator products, such as wireless access points. Both supplicant and authenticator can be used in the same product, allowing greater flexibility and a range of application support. Wind River Wireless Security works together with Wind River EAP that supports multiple Extensible Authentication Protocol (EAP) types. Integration with Wind River SNMP is included to interface with the 802.1X MIB.

Also part of Wind River Wireless Security is Wind River's implementation of WPS. WPS simplifies the setup and management of wireless networks by automating the configuration of access points and peripheral devices. Wind River Wireless Security comprises the following components:

- COMPONENT_DOT1X
- COMPONENT_8021X
- COMPONENT_WPS

Features of Wind River Wireless Security 6.9 include the following:

- Support of WPS for the enrollee, AP without registrar, and AP with registrar models
- Capabilities including 802.1X, Wi-Fi Protected Access (WPA and WPA2), 802.11i, Temporal Key Integrity Protocol (TKIP), AES, preshared keys
- EAP types and EAP type combinations added with use of new independent EAP module (IPEAP), allowing EAP to be used by other Wind River modules
- Full integration and testing with Wind River Wireless Ethernet Driver (station and access point modes), easily portable to other wireless driver solutions
- Support for both authenticator and supplicant modes
- Support for wide range of encryption and hashing algorithms
- Support for dot1xPaeConfigGroup supplicant MIB

- New commands to support run-time configuration of multiple port access entity (PAE) instances
- Support for the coexistence of WPS and 802.1X in a single image, allowing parameters to be supplied through WPS, followed by 802.1X authentication with an authentication server

Wind River EAP

Extensible Authentication Protocol (EAP) allows a client and a server to negotiate an authentication method and establish client and, optionally, server authentication. The protocol defines a packet structure that contains commands and attributes used by the client and server during an authentication session. A number of EAP types and EAP type combinations are available to implement an authentication method.

EAP is a separate module based on the IPCOM EAP (IPEAP). EAP is used by the Wind River Wireless Security supplicant to negotiate an authentication method.

EAP supports the WPS EAP method (EAP-WSC). EAP-WSC is used for registrar and enrollee discovery and for credential establishment in a WPS environment.

Wind River EAP 6.9 supports 64-bit operation. In addition, EAP includes VSB configuration enhancements, support for the use of the secure key database to store EAP passwords and private keys, and EAP Session-Id.

The following are the EAP types supported in Wind River EAP 6.9:

- EAP-AKA
- EAP-GTC
- EAP-LEAP
- EAP-MD5
- EAP MS-CHAPv2
- EAP-PEAPv0
- EAP-PEAPv1
- EAP-SIM
- EAP-TLS
- EAP-TTLS
- EAP-WSC

Wind River Firewall and NAT

Wind River Firewall supplies a powerful filtering engine that allows device manufacturers to optimize their software to provide advanced features that protect valuable data. This engine is ideally suited to a wide range of products, including SOHO routers, broadband access devices, and small to medium-size enterprise devices.

Features of Wind River Firewall 6.9 include the following:

- Ability to run on a 64-bit platform
- IP filtering with stateful inspection for IPv4 or IPv6 packets
- MAC (media access control) filtering
- Logging at the network (L3) and data link (L2) layers
- HTTP content filtering for URLs (both specific and by keyword), proxy traffic, Java applets, ActiveX controls, and cookies
- Nonvolatile (NV) storage of firewall rules
- Input and output filters
- Stateful inspection
- Rate limiting
- Filter on network interface
- Support for the pktflags keyword that's used to filter IPsec, NAT, and tunneled packets
- Rule grouping
- Simplified procedure for excluding Wind River Firewall from a VxWorks Image Project

Wind River NAT is a full-featured implementation of the industry-standard Network Address Translation Protocol (NATP) for use in routers, firewalls, DSL and cable modems, and residential gateways. A device running Wind River NAT can connect an entire department or a small office to the Internet using a single global IP address. Address mapping effectively conceals the size and topology of the private network from the outside, providing a basic level of security.

The chief advantage of NAT is that addresses on the private network are hidden from the public Internet, providing a measure of security. A second advantage, realized with certain varieties of NAT, is that scarce IP addresses are conserved, reducing network administration costs.

Wind River NAT supports the two most widely used NAT modes. Basic NAT performs one-to-one mapping of private IP addresses to a preallocated block of external IP addresses. The more commonly used NATP maps port numbers as well as IP addresses. NATP allows multiple private addresses (up to 64,000 address/port combinations) to be multiplexed on a single public address, offering the full benefit of address conservation and security.

NAT provides basic security by blocking all incoming connection requests that don't map to recognized address translations.

Wind River NAT supports the following features:

- Ability to run on a 64-bit platform
- Basic NAT
- Network Address Port Translation (NAPT)
- Bidirectional NAT
- Network Address Translation-Protocol Translation (NAT-PT)
- Demilitarized zone (DMZ) host
- Application-level gateways (ALGs)
- Port triggering
- Support for the Session Initiation Protocol (SIP) Application-Level Gateway (ALG), allowing simple SIP UDP sessions to pass through a NAT device

Wind River Cryptography Libraries

Wind River Cryptography Libraries 6.9 is an implementation of standard cryptographic algorithms and supporting utilities that can be used in developing secure applications. It is based on the cryptographic portions of the open source project OpenSSL. It is also used by other components requiring access to crypto functions. Wind River Cryptography Libraries can run on a 64-bit platform.

Wind River Cryptography Libraries includes the following:

- Software implementations of cryptographic algorithms
- An API for creating interfaces to hardware cryptographic devices for offload of computationally intensive cryptographic algorithms
- An implementation of a hardware interface for Freescale SEC devices
- An implementation of a cryptography offload engine that is supported and included for Cavium OCTEON CN38xx and CN58xx processors
- X.509 certificate support
- Support for AES key wrap and AES CMAC algorithms

Wind River Cryptography Libraries continues to provide support for the Federal Information Processing Standard (FIPS) 140-2. The set of available cipher suites is reduced when building VxWorks in FIPS 140-2 mode because some security algorithms are not FIPS-approved.

When VxWorks is compiled in FIPS mode, the affected algorithms are compiled out. The MD5 hash algorithm is not compiled out, but it is disabled in run-time if the system is running FIPS 140-2 mode. Since these algorithms are not FIPS-approved and are compiled out, it is not possible to select components that use them in your VSB when you enable the FIPS 140-2 option. Some components will not be possible to enable, for example, Mobile IP v4. This exception applies to specifications that mandate the use of non-FIPS-approved algorithms, such as MD5. There are also some modules that will simply compile out features that use non-FIPS-approved algorithms. For example, in TCP the MD5 checksum option will be compiled out. When FIPS mode is turned off, the MD5 hash is enabled.

Customers have the ability to build a non-FIPS image that includes all components and a FIPS image including the encryption library and SSL. In order to configure FIPS 140-2 mode, the VSB option needs to be enabled.

The following are included algorithms:

- AES
- Blowfish
- CAST
- DES
- RC2
- Arcfour
- RC5
- AES key wrap
- SHA-1
- MD2
- MD4
- MD5
- RIPEMD-160
- HMAC
- AES CMAC
- Diffie-Hellman
- DSA
- RSA

Wind River Security Libraries

Wind River Security Libraries continue to be deprecated. New development should use Wind River Cryptography Libraries, which provides enhanced functionality.

Starting with VxWorks 6.6, cryptographic services are provided by the Wind River Cryptography Libraries. Wind River Security Libraries is also included for backward-compatibility with prior versions of

VxWorks. This includes a library of cryptographic algorithms, the common crypto interface (CCI), used by other components requiring access to crypto functions, and the crypto provider interface (CPI), which supplies a mechanism for developers to add other crypto libraries or hardware-based crypto functions.

Wind River SSL and SSH

Wind River SSL is a client server technology used to secure any higher layer protocol that uses sockets. A typical application is to secure HTTP connections (HTTPS) for e-commerce.

Security is provided by the following:

- Privacy, using data encryption
- Authentication, using digital certificates
- Message integrity, using message digests

Features of Wind River SSL 6.9 include the following:

- Support for FIPS 140-2 (the set of cipher suites is reduced when running SSL in FIPS 140-2 mode due to not all algorithms being FIPS approved; customers can only use cipher suites using AES, 3DES, and SHA1 when running in FIPS 140-2 mode)
- Operation in VxWorks 6.9 for both 64-bit and 32-bit modes
- Support for AES-GCM (Advanced Encryption Standard in Galois Counter Mode), including AES-128-GCM and AES-128-CCM
- SSLv2, SSLv3, TLSv1, and DTLSv1 support
- HMAC-SHA-1 and HMAC-MD5
- DES, 3DES, and AES
- RSA public-key cryptography
- Implementation of OpenSSL APIs to allow for easy porting of existing applications
- Advanced Encryption Standard (AES) Ciphersuites for TLS (RFC 3268)
- Datagram Transport Layer Security (RFC 4347)
- Updated version of OpenSSL

Wind River SSH (Secure Shell) is an implementation of the Secure Shell protocol that provides secure remote login, file transfer, and port forwarding over an unsecure network. This means embedded systems can communicate at the application level over a connection that is encrypted and provides data integrity and replay protection. This

effectively eliminates eavesdropping, connection hijacking, IP spoofing, and other network-level attacks.

In addition, embedded SSH provides several secure tunneling capabilities that may be used to create VPNs. A variety of authentication methods is also supported.

Features of Wind River SSH 6.9 include the following:

- SSH server mode
- SFTP client support
- SSH versions 1.5 and 2.0
- Support for key-exchange/regeneration as defined in section 9 of RFC 4253
- Support for arcfour128 encryption algorithms
- Support for the diffie-hellman-group14-sha1 key exchange algorithms
- Operation in VxWorks 6.9 for both 64-bit and 32-bit modes
- Support for SSHv1 RSA fingerprints and calculating in a way that matches OpenSSH fingerprints generation

Wind River RADIUS and Diameter

Wind River RADIUS Client is a full-featured implementation of the industry-standard remote authentication dial-in user protocol. Wind River RADIUS Client supports a complete set of functions for authentication, accounting, and security, and it has been verified against several commercial RADIUS servers, ensuring compatibility with a wide range of applications.

Wind River RADIUS Client 6.9 allows the network to determine whether a user is allowed access (authentication). Authentication is also used to determine that a message has not been fabricated or altered in transit. Authorization determines which network resources a user may access, and the accounting functions provide a record of usage. The RADIUS tunneling protocol and roaming chargeable user identity (CUI) is supported.

The Diameter authentication, authorization, and accounting (AAA) protocol provides support for peering AAA transactions across the Internet. The Diameter base protocol provides the minimum requirements needed for AAA protocol, Mobile Internet Protocol

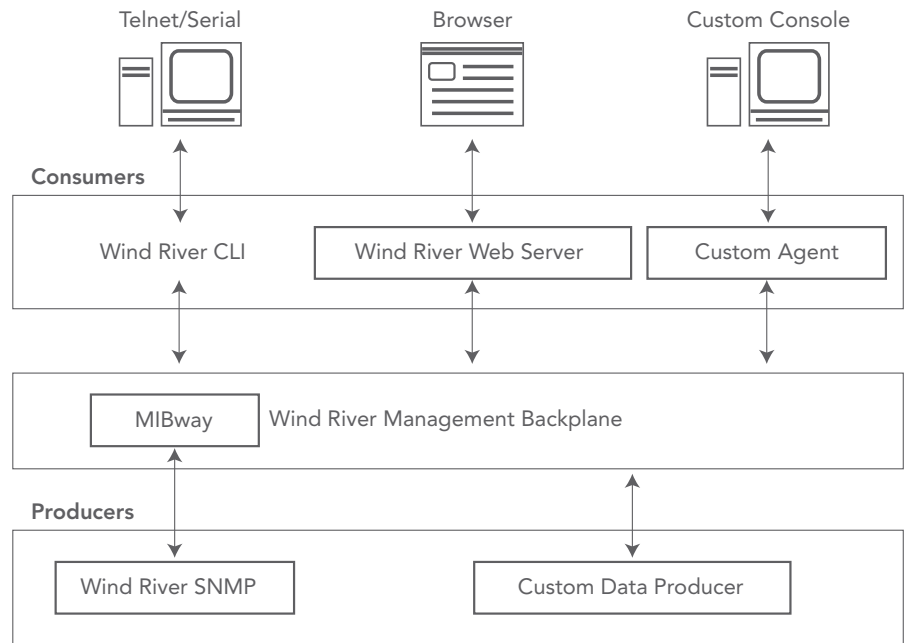


Figure 9: Wind River network management architecture

version 4 (MIPv4), and remote network access applications. Diameter runs on one or more network access points, sending authentication requests to a shared Diameter server.

The Diameter protocol has several advantages over previous AAA protocols in that it offers improvements in the areas of reliability, security, scalability, and flexibility. Wind River Diameter Client 6.9 supports Diameter Proxy Agent.

Wind River RADIUS and Diameter 6.9 add the following:

- Support for 64-bit
- Diameter secure key storage
- Support for RFC 4675: RADIUS Attributes for virtual LAN and priority support
- RADIUS support for RFC 5247: Extensible Authentication Protocol (EAP) Key Management Framework, section 5.9

Management

Wind River provides a scalable, unified, small-footprint management framework that enables creation of Web-based, CLI-based, or custom management interfaces to manage networked elements. As shown in Figure 9, it consists of a management backplane, which acts as a conduit for data-handling between management interfaces (consumers) and

manageable elements (producers). The scalable framework can have any type of consumers and any type of producers.

Wind River Management Backplane interfaces with a CLI agent, Wind River CLI; an embedded web server, Wind River Web Server; and an SNMP implementation, Wind River SNMP (Simple Network Management Protocol). In addition, the framework comes with a full-featured, Windows-based developer tool (GUI), Wind River Management Integration Tool (WMIT). This tool eases the development of management interfaces by bringing all the framework components together.

Management Configuration Editor (MCE) is a simplified Eclipse plug-in to help with development of CLI- and Web-based management interfaces. MCE is integrated with Wind River Workbench and may be run on any host that Workbench supports. Developers may choose MCE, WMIT, or both tools to configure a project. MCE is intended as a replacement for WMIT.

WMIT supports only 32-bit target code and cannot be used for 64-bit projects. The MCE can produce 64-bit target code, even if it is run on a 32-bit host. You cannot convert between WMIT and MCE if you are generating 64-bit code with MCE.

Wind River SNMP

SNMP is designed to facilitate management and configuration of networked devices. Wind River SNMP is a highly portable, memory-efficient, standards-compliant implementation of SNMP specifically designed for original equipment manufacturers (OEMs) and system integrators who require full compliance with SNMP standards in a fast, small SNMP agent. This complete solution for integrated SNMP design and implementation includes a full management information base (MIB) development platform. It is composed of SNMP v1/v2c/v3 and AgentX.

Features of Wind River SNMP 10.5 include the following:

- Customer selection of compilation of any combination of SNMPv1 and SNMPv2, with the SNMPv3 option
- Support for the Advanced Encryption Standard (AES) cipher algorithm, as specified in RFC 3826
- Asynchronous support
- SNMP notifications
- “Target” and “Notify” MIBs
- SNMP proxy
- SNMP v1/v2/v3 coexistence
- AgentX module
- MIB compiler
- Compact, interoperable, standards-based configuration
- Integration with Wind River Network Stack
- Portable design and implementation
- A new API to support SNMPv3 INFORM PDU operations
- Operation in VxWorks 6.9 for both 64-bit and 32-bit VxWorks
- Ability to explicitly set a sysName other than the host name and a value for sysServices using the m2SysGroupInfo-Set() routine

Wind River Web Server

Wind River Web Server is a scalable, secure, small-footprint commercial embedded web server. In addition to the functionality of a standard web server, it provides all the functionality needed to quickly create a browser-based management interface. Specifically designed for embedded systems, Wind River Web Server is HTTP 1.0 and 1.1 compliant and supplies SSL hooks to provide a secure transaction mechanism. The Wind River

Management Integration Tool is a GUI tool that accelerates the process of creating and configuring a custom web-based management interface or a standalone web server by generating more than 70 percent of the required embedded code for such an application. The web-based management interfaces with a scalable backplane that interacts with SNMP through Wind River MIBway or with any custom manageable data.

Features of Wind River Web Server 4.9 include the following:

- HTTP 1.0/1.1-compliant web server
- Bidirectional CGI layer
- LiveControl
- Visual integration tool
- GZIP/PKZIP compression
- Support for HTML, DHTML, CSS, JavaScript, and XML
- Drop-in support for SNMP objects
- Bundled SMTP email alerts
- User time-out sessions
- HTML/query string processing
- Bidirectional gateway for tying management objects to HTML pages, email alerts, and JavaScript libraries
- File-based uploads (RFC 1867)
- Server side includes (SSI)
- Secure authentication (basic base64 encoding and digest authentication)
- SSL hooks verified with OpenSSL
- Wind River SNMP inheritance through MIBway
- In-depth tutorial and sample code that steps through API usage, development tools, and best practices
- Ability to use a GET request to set WindMark values
- Operation in VxWorks 6.9 for 64-bit and 32-bit VxWorks

Wind River CLI

Wind River CLI includes a full-featured command shell and development tools that enable users to build either the standard “craft” style interface or a custom interface to manage a networked device. CLI commands can be executed on a device through either an RS-232 or a Telnet connection. The Wind River Management Integration Tool is a GUI tool that accelerates the process of creating and configuring a custom web-based management interface or a standalone web server by generating more than 70 percent of the final

embedded CLI code for such an application. CLI interfaces with a scalable backplane, which interacts with SNMP through MIBway or directly with any custom manageable data.

Features of Wind River CLI 4.9 include the following:

- Complete CLI management solution
- High-speed generation of command tree, handler functions, and individual commands
- Drop-in, prebuilt commands
- Telnet server
- Secure communication over SSH
- With MIBway, instant reflection of SNMP MIBs in the command line
- Same architecture as Wind River Web Server
- Command completion
- Context-sensitive help
- Command history
- Intermediate mode handling
- Parameter handling, verification, and grouping
- Negate commands (e.g., to restore defaults)
- Support for simultaneous Telnet sessions and serial ports
- Common command libraries
- Security parameters defined by object, command, or session
- Fully re-entrant ANSI C code
- In-depth tutorial and sample code that steps through API usage, developed tools, and best practices
- Ability to use a GET request to set WindMark values
- Operation in VxWorks 6.9 for 64-bit and 32-bit VxWorks

Wind River MIBway

Wind River MIBway enables developers to automatically leverage all SNMP objects for reuse in command-line and web-based management interfaces, with zero additional engineering effort required. Wind River MIBway provides an SNMP inheritance library to access data objects already instrumented for the Wind River SNMP agent. This makes it possible to leverage the thousands of developer hours already invested in writing MIB variables and code in a schema that is both flexible and scalable for future device management requirements.

Benefits of Wind River MIBWay 4.9 include the following:

- Instant leverage of all existing SNMP code
- Reduction in development cost by cutting down months of coding and testing to days
- Creation of powerful, feature-rich web and command-line interfaces
- Separation of application logic from interface design
- Embedded code that handles SNMP-specific queries from Wind River Management Backplane
- Single-click integration with Wind River SNMP
- In-depth tutorial and sample code that steps through API usage, development tools, and best practices
- Ability to use a GET request to set WindMark values
- Operation in VxWorks 6.9 for 64-bit and 32-bit VxWorks

Wind River Management Integration Tool

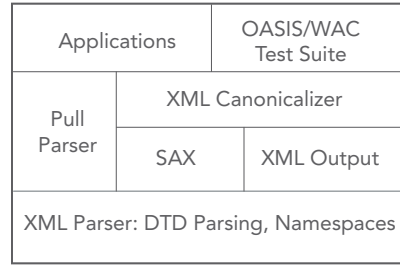
The Wind River Management Integration Tool is a Windows-based GUI that enables users to build web-based or CLI-based management applications by incorporating features to set project options, configuration options, build options, and resource constraints settings, and automate code generation. It provides an MIB compiler to facilitate Wind River SNMP users as well as a simple HTML editor as a miscellaneous tool.

Management Configuration Editor

Management Configuration Editor (MCE) is an Eclipse plug-in integrated with Wind River Workbench to help develop management interfaces. This tool is provided in addition to Wind River Management Integration Tool so developers may use MCE on any host that supports Wind River Workbench (whereas Wind River Management Integration Tool is supported only on Windows). MCE functionality is limited when compared to that of Wind River Management Integration Tool. Wind River Management Integration Tool and MCE will coexist until all necessary functionality is available in MCE and customers have completed migration to it.

Wind River CLI, Web, and MIBWay add functionality to the MCE. The MCE is intended as a replacement for the WMIT

Embedded XML Parser



Embedded SOAP

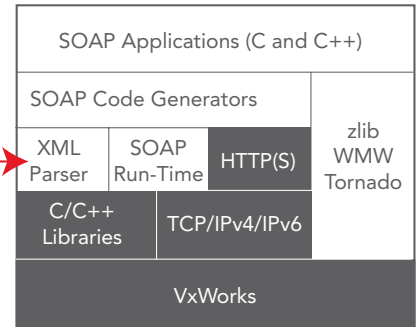


Figure 10: Wind River web services

and is being developed in phases. During the development and transition period, the WMIT will also be provided. Currently, the MCE does not have the full functionality of the WMIT. Most options are available from the MCE; however, there are additional options that can only be configured using the WMIT. SSH options are only available from the MCE.

Wind River HTTP Client

Wind River HTTP Client is a library of client-side functions required to interact with an HTTP server. Using the functions provided, developers can write simple applications for transferring files (using GET and POST methods) with URL syntax.

Features of Wind River HTTP Client include support for the following:

- HTTP 1.1 specification
- GET and POST methods
- Cookies
- Direct and proxy server requests
- Secure HTTP communication with HTTPS

Distributed Messaging and Services

Wind River Web Services

Wind River Web Services enables distributed applications running on a variety of platforms to communicate and interoperate seamlessly in a manner conforming to Web Services standards. It allows developers to create interoperable Web Services applications (clients and servers) by providing the fundamental building blocks: XML, SOAP, WSDL, and GUI-based compiler tools for Web Services intermediate code generation and compilation. Wind River Web Services is standards-compliant and specifically tuned for embedded systems applications.

For instance, Wind River Web Services can be used to share data between real-time embedded controllers and a desktop in an industrial operation center; configure a print job and bill for the task from the same consumer devices application; or manage and configure a network device such as a router or an access point.

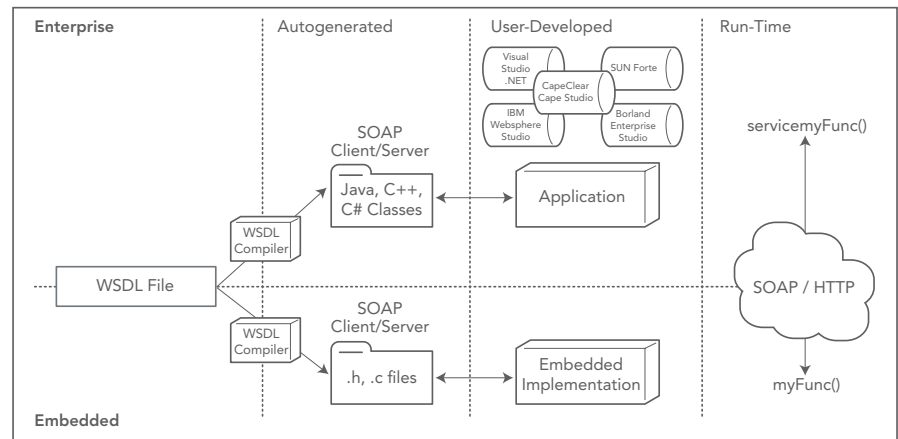


Figure 11: Web Services software development flow

Features of Wind River Web Services 1.7 include the following:

- Upgrades to the XML component in the Expat 2.0.1 version
- Upgrades to the SOAP component in the gSOAP 2.7.13 distribution
- WS-Security
- WS-I Basic Profile 1.0 conformance
- Clear and structured code and documentation for ease of configuration and maintenance
- Standards-conformant: XML 1.0, SOAP 1.2
- Communication through use of SOAP messages with any system supporting Web Services, including Microsoft .NET or Apache Axis
- Graphical WSDL compiler tool integrated into Wind River Workbench

Wind River DCOM

Wind River DCOM is the technology that implements Component Object Model (COM) and distributed COM (DCOM) on VxWorks. The name Wind River DCOM refers both to this technology and to the product. Wind River DCOM, an implementation of Microsoft's DCOM, scaled for device software development, provides the foundation for management protocols such as OLE for Process Control (OPC). Wind River DCOM enables application distribution between VxWorks-based devices and non-real-time devices, such as desktop computers. It allows developers to seamlessly integrate device software applications with Windows applications. Wind River DCOM provides a compact, performance-focused solution targeted specifically for the strict requirements of devices.

Features of Wind River DCOM 2.3.8 include the following:

- Small footprint
- Source-compatible with Win32 SDK COM and DCOM API
- Object template library that provides convenience methods for DCOM application developers
- IDL compiler (compiling IDL files into Wind River DCOM application classes)
- GUI wizard for creating DCOM interfaces

Bridging and Routing

Wind River Learning Bridge

Wind River Learning Bridge is a transparent layer 2 Ethernet learning bridge that learns the network topology by analyzing the source address of incoming frames from all attached networks. The learning bridge attaches above the MUX layer as a SNARF network service type, and it includes two mirror END drivers used to bridge traffic destined for a stack located on the same machine as the bridge.

Wind River Learning Bridge includes a station cache: a basic database that stores the relationship between MAC addresses and the ports from which it sees frames associated with those MAC addresses. Forwarding decisions are based on this cache. Both source and destination MAC addresses are used to build the cache database, and a cache-aging algorithm removes inactive entries. Learning Bridge is used by the Wind River Wireless Security Authenticator.

Wind River Learning Bridge 1.5 adds 64-bit functionality and provides relay agent information option (option 82) functionality.

Graphics and Local Interface

Wind River Media Library

The Wind River Media Library component is used for developing hardware-independent media applications for a variety of platforms. It includes a comprehensive API for 2D graphics, window management,

region management, text display, color management, video overlay support, alpha blending, and JPEG image support. The 2D API allows hardware-accelerated features to be used in a hardware-independent manner. The integrated window manager and input event routing facilities enable multiple applications to share one screen. For example, native C/C++ applications and Java-based applications can execute simultaneously while sharing the input and output device. The event service handles input events and routes them to specific applications, and it controls cursors for pointer devices, such as touch screens, mice, and remote controls.

The device development component is used for implementing drivers. It interfaces directly with the application's target hardware devices, including graphics chips, video controllers, LCD displays, audio chips, keyboards, and touch screens, and it provides a rich set of reference drivers for common hardware configurations. This component includes generic frame buffer drivers for 1-, 4-, 8-, 16-, and 32-bit color modes, which allow developers to bootstrap new drivers quickly and support any graphics device easily. The graphics driver framework provides both a native Media Library interface and an X.org driver interface, enabling development on the most current graphics hardware in the market. Media Library also includes an integrated FreeType font engine, which supports TrueType fonts and enables faster GUI application development. The driver development component is also extensible, so it can accommodate the specific hardware functionalities of a device.

Features of Wind River Media Library 5.3 include the following:

- Support for the 2D EXA acceleration capabilities supplied by X.org drivers
- Support for version 7.4 X.org drivers
- An X.org Vesa driver, which can be used on most PCI graphics cards
- DIU graphics and audio drivers for the Freescale ads5121e

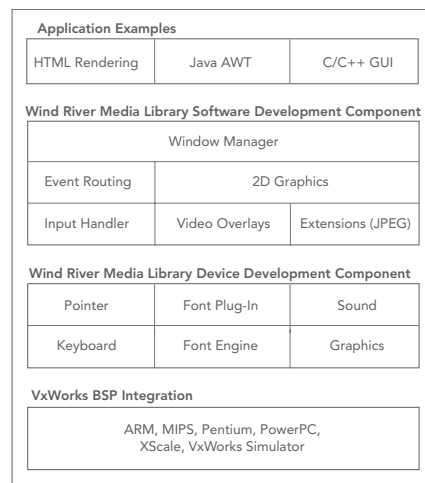


Figure 12: Wind River Media Library

- Support for USB2 keyboards and mice
- Support for polling for an input device
- New window menu-handling APIs
- FreeType font engine v2.3.2
- Screen rotation support
- VxBus support
- Additional XFree86 resolutions
- Virtual input support
- Shared data library (optional) for kernel applications
- Multiple display functionality
- Menu and button widgets
- Touch screen calibration support
- RTP support for local bus graphics devices

Connectivity

Wind River CAN

Wind River CAN 1.5.5, an implementation of the Controller Area Network (CAN) protocol for VxWorks embedded targets, provides developers with a standardized interface to one or more CAN devices. The product supports many of the popular CAN boards in use today, such as ESD PC104 200, ESD PCI 200, MCF5282 FlexCAN, PPC5xx TouCAN, and MSMCAN PC104. In addition, the Wind River CAN API is independent of the target architecture and the I/O mechanism used to access the CAN controller. This standardized interface greatly simplifies programming CAN hardware and allows applications to be ported quickly to new target architectures with minimal or no changes to user application source code. Additional protocols, such as CANopen (available from Wind River partner IXXAT) and DeviceNet, are integrated on top of this standard interface.

Wind River OPC

Wind River OPC is an implementation of the OLE for Process Control (OPC) specification for the VxWorks RTOS. The OPC standard protocol enables interoperability between automation/control applications, field devices, and business/office applications by allowing clients and servers from different vendors to speak the same standard language. OPC streamlines development of device interfaces, increased connectivity, and interoperability between custom

applications and allows applications to access subsystem data easily. The Wind River OPC implementation is designed specifically to support devices with high-performance and small footprint requirements.

Wind River OPC 3.2 support includes the following:

- Sample Data Access client for VxWorks
- OPC Data Access Custom Interface Standard 2.05a specification
- OPC Alarms and Events 1.1 specification
- OPC Data eXchange 1.0 specification
- Interactive sample OPC client
- Optimization for real-time devices
- Integration with development tools

Wireless

Wind River Wireless Ethernet Driver

Wind River Wireless Ethernet Driver provides access point and station-side support for the industry-standard 802.11a, b, g, and draft-n specifications. Included are drivers for Atheros AR500x and Broadcom BCM43xx chipsets. 802.11 draft-n and Wi-Fi Multimedia Enhancement (WME) are supported in the Broadcom driver. A fully abstracted hardware interface layer provides ease of portability to other wireless chips. The driver supports multiple hardware interfaces on the same target, allowing for more advanced applications. The driver can be used in a wide variety of target hardware platforms. A standard IOCTL application interface is provided for user configuration and control. Wireless security is provided through preintegration with the Wind River Wireless Security protocol, supporting the 802.1X, WPA, WPA2, 802.11i, and WPS protocol standards. Wind River Wireless Ethernet Driver facilitates management of spectrum regulation differences between different countries through 802.11d support.

The security implementation includes preshared keys and TKIP (Temporal Key Integrity Protocol). A range of encryption and hashing algorithms is available to give developers flexibility in trading off security level versus performance.

Features of Wind River Wireless Ethernet Driver 3.3 include the following:

- Supports multiple modes: 802.11a, b, g, and draft-n
- Supports country-specific spectrum regulations through 802.11d
- Supports WME; enables packet routing prioritization based on the type of service (TOS) of each packet
- Supports Wi-Fi Protection Access (WPA/WPA2), WPS, and 802.11i for security
- Supports Broadcom BCM4328 PCIE card
- Supports VxBus drivers only
- Uses Wind River Cryptography Libraries instead of the obsolete Wind River Security Libraries
- Contains configuration enhancements for syslog level consistency and debug mode operation
- Offers new WLAN VSB options: Enable Atheros Wireless Driver Support (IPWLAN_ATHEROS), Enable Broadcom Wireless Driver Support (IPWLAN_BROADCOM), and Choose the Build-Time WLAN Syslog level
- Offers shell command that allows view of the encryption type used for multicasts
- Supports SMP for the SMP-supported BSPs
- Supports multiple service set identifiers
- Directly supports Atheros AR500x chipsets
- Directly supports Broadcom BCM43xx chipsets
- Ports easily to other chipsets
- Supports both access point and station side
- Supports multiple hardware instances on the same target
- Features user configuration and control through use of IOCTL controls
- Features industry-standard application interface format: ioctl (descriptor, function, value)
- Extends easily to support new features and customer requirements
- Maps directly into the 802.11MIB
- Features extensive debugging/logging support and show routines
- Configures through command line or Wind River Workbench
- Integrates with Wind River Wireless Security protocol: 802.1X

Wind River MACsec

Wind River MACsec 6.9 introduces Wind River's implementation of IEEE 802.1AE, the specification governing connectionless data confidentiality, frame data integrity, and data origin authenticity, at the MAC layer for wired Ethernet LANs.

IEEE 802.1AE offers integrity and confidentiality for stations connected to a LAN. Ethernet frames are authenticated and optionally encrypted and decrypted on a hop-by-hop basis by layer 2-aware devices that support MACsec. By securing a LAN in this fashion, IEEE 802.1AE provides the following:

- **Connectionless data integrity:** A cryptographic hash of the frame using a shared-secret key is generated and validated hop by hop.
- **Data origin authenticity:** Only stations that have been configured with the shared-secret keys can communicate with each other. Conversely, stations that have not been configured with the shared-secret keys but have been mistakenly or otherwise connected to the LAN can be readily identified and removed.
- **Confidentiality:** As an option, the data can be encrypted and decrypted using a shared-secret key.
- **Replay protection:** Frames are numbered to allow stations to identify stale frames, frames that arrive outside of the replay window.
- **Bounded receive delay:** Frames are not delivered after a bounded time.

Wind River MACsec can be turned on or off per physical Ethernet interface and works seamlessly with Wind River Network Stack, including VLANs. MACsec can be enabled on IEEE 802.3 Ethernet interfaces and is not intended for Wind River's IEEE 802.11 wireless Ethernet interfaces, which are protected through Wind River Wireless Security solutions.

Compilers

Wind River Diab Compiler and Wind River GNU Compiler

Wind River Diab Compiler is the default C/C++ compiler for most processor architectures configured for building the VxWorks 6.x kernel, libraries, BSPs, and applications. This compiler's optimization capabilities are based on a very stable and successful compiler technology and it produces compact, high-performance code for PowerPC, ARM, ColdFire, and MIPS architectures.

Wind River Diab Compiler includes the following:

- Tight integration with the VxWorks RTOS, providing proven performance
- Reliable, stable, and mature code-generation technology
- Superior optimization technology to generate fast, compact, high-quality code
- Conformance with C/C++ compiler standards such as ANSI, ISO/IEC, and EABI for maximum tool interoperability
- Complete control of code and data memory allocation
- Position independent code (PIC) and position independent data (PID) support
- Whole program optimization

Wind River GNU Compiler is the default compiler for Intel architectures and is based on the Free Software Foundation (FSF) distribution of the GNU compiler. Wind River has modified a general distribution version of the compiler specifically for use with VxWorks 6.x. The primary areas of modification deal with support for RTPs and shared libraries.

Wind River GNU Compiler is primarily used as an application compiler. It takes advantage of the latest GCC enhancements and ensures easy migration of code, built with GCC, into a VxWorks environment.

Wind River GNU Compiler includes the following:

- `cpp`, the C preprocessor
- `gcc`, the C and C++ compiler
- `ld`, the programmable static linker
- `as`, the portable assembler
- Binary utilities
- Source code for the compiler and related open source tools

Both compilers are included and supported as part of the VxWorks 6.9 platforms.

Intel C++ Compiler and Intel Integrated Performance Primitives

This release includes the Intel C++ Compiler 12.0 for VxWorks and Intel Integrated Performance Primitives 7.0 for VxWorks. The Intel C++ Compiler processes C and C++ source language to generate code for IA-32 or Intel 64 architecture applications.

The Intel Integrated Performance Primitives library includes general signal and image processing, computer vision, data compression, cryptography, string manipulation, audio processing, video coding, realistic rendering, and 3D data processing. It also includes more sophisticated primitives for construction of audio, video, and speech codecs such as MP3 (MPEG-1 Audio, Layer 3), MPEG-4, H.264, H.263, JPEG, JPEG2000, JPEG XR, GSM-AMR, and G.723.

By supporting a variety of data types and layouts for each function, the Intel IPP library delivers a rich set of options for developers to choose from when designing and optimizing an application. To speed up performance, Intel IPP functions are optimized to use all benefits of Intel Architecture processors. In addition most of the Intel IPP functions do not use complicated data structures, which helps reduce overall execution overhead.

Wind River Workbench Development Suite

Wind River Workbench 3.3 is an Eclipse-based development suite that enables creating and building projects, establishing and managing host to target communications, and configuring, debugging, and monitoring the VxWorks operating system as well as VxWorks applications running on a simulator or real hardware. Through its powerful combination of capabilities, integration, and availability, Workbench enables organizations to standardize on a common environment for device software development, helping developers, project teams, and companies improve their effectiveness.

Workbench offers the following:

- Best-in-class capability, for both platform developers and application developers throughout the entire device software development life cycle
- Broad availability to support increased standardization across projects
 - Multiple-target OS support, including support for VxWorks 5.5, VxWorks 6.x, and Linux
 - Target processor support for PowerPC, Intel, ARM, MIPS, and ColdFire architectures
 - Plug-in architecture enabling additional target OS, target processor, and target connection support to be added
- Extensible framework, based on Eclipse, to seamlessly integrate third-party and in-house plug-ins for customization and scalability

Workbench 3.3 includes significant new capabilities in support of increased development team productivity:

- General Workbench enhancements
 - Integration of Eclipse 3.6 and CDT 7.0 development frameworks
 - Code coverage configuration improvements
 - Tree-based XML configuration editor for multi-core and multi-operating-system architectures
 - Workbench Debug Mode
 - Support for configuration management systems (ClearCase, CVS, Subversion) from the Workbench UI
 - Videos to help guide users on workflows
 - Memory Analyzer performance improvements

- Team sharing of source path mappings
- Improved startup and launch time
- Updated host OS support
- VxWorks platform enhancements
 - VxWorks core dump analysis
 - Dynamic Printf capability
 - VxWorks Source Build configuration tool enhancements
 - Multi-target launch capability for DKMs and RTPs
 - VxWorks Simulator integrated in Workbench's target console view
 - Debugger that provides the ability to monitor expressions in multiple contexts
- Enterprise deployment capabilities
 - Sharing of developer's workspace content such as connection information, perspectives and views, target configuration, and preferences
 - Documentation and help system that can be served from a centralized host
 - Deferred license checkout to facilitate use of open source Eclipse or third-party components in Workbench without a license

Eclipse

Because of its award-winning openness, capability, and strong community support, Eclipse is used as the framework for the Wind River Workbench development suite. The Eclipse 3.6 framework supplies the necessary infrastructure to graphically and functionally integrate the components of Workbench. Open, extensible, and backed by a strong community of commercial and open source developers, the Eclipse framework provides developers using Workbench with a wide range of additional integrated functionalities. More information on Eclipse and available third-party plug-ins is available from the Community Projects and Plug-ins section of the Eclipse website, www.eclipse.org.

Project System

The Workbench Project System allows developers to organize and manage the primary components in a device software development project, including source files and target systems. VxWorks projects of different types can be created for configuring and building the VxWorks source, kernel images, and board support packages as well as application projects

based on real-time processes or user-developed kernel modules. By design, Workbench enables users to manage multiple projects simultaneously.

Build System

The Workbench Build System specifies the tools, options, and parameters to use when building device software projects, enabling you to set build parameters easily from the project level down to the individual file level. The Build System allows for use of simple global build-settings, fine-grained control at the level of an individual file, and everything in between.

Command-Line Build System

In addition to the Workbench Build System, a full-featured command-line build system is provided for developers who prefer this type of environment. Using GNU make, Tcl libraries, and VxWorks-specific tools, developers can configure VxWorks source and build VxWorks images as well as develop applications and libraries using command-line build facilities. These command-line tools are often integrated into a customized build system.

Workbench Debugger

The Workbench debugger addresses the needs of developers involved with hardware bring-up, firmware/driver/BSP development, kernel development, and application development. It provides more capability than the GNU debugger (GDB) or other basic source-level debuggers, including unique and powerful debugging features such as dynamic printf insertion during debugging sessions. The Workbench debugger includes the ability to debug VxWorks 6.x targets via full kernel, task, and RTP debugging, including visibility and synchronous control of tasks associated to an RTP. These capabilities can be extended further with Wind River's on-chip debugging solutions. In combination, these tools provide the necessary functionality for hardware bring-up, device driver/BSP debugging, kernel debugging, and application software debugging.

The Workbench debugger supports VxWorks debugging for single-core processors as well as multi-core processors running VxWorks in either SMP or AMP mode. Multi-context debugging capabilities allow developers to debug code running in multiple contexts simultaneously. Multiple contexts means any of the following:

- Multiple cores
- Multiple tasks/processes/threads
- Multiple RTPs or DKMs
- Multiple physical processors
- Multiple processor types
- Multiple boards
- Multiple target operating systems

The Workbench debugger provides extensive browsing and inspection capabilities on objects in the target platform. This awareness of VxWorks objects allows developers to quickly solve hard to diagnose problems, ensuring the highest level of productivity throughout the project.

Debugging features in Workbench include support for multi-context launches using a single launch configuration for both DKMs and RTPs and advanced support for configuring and debugging hypervisor-based systems via JTAG debug capabilities added in Wind River Workbench On-Chip Debugging.

VxWorks Simulator

VxWorks Simulator 6.9, formerly known as VxSim, is a complete prototyping and simulation tool for VxWorks 6.x applications. VxWorks Simulator supports simulation of SMP systems, up to a maximum of 32 CPUs on any supported host. It also provides a simulation environment for VxWorks AMP development using MIPC. It supports 64-bit operation on supported 64-bit host platforms. It enables you to develop and test significant portions of your application earlier in the development cycle, before hardware is available. It can also lower your development cost by allowing developers to share fewer hardware targets by enabling host-based development. The simulator is fully integrated into the Wind River Workbench development environment as a target connection, allowing complete configuration and debugging control through standard interfaces.

VxWorks Simulator is a native application that has been ported from the VxWorks 6.x operating system to accurately implement the sophisticated features of VxWorks 6.x, including SMP, RTPs, memory protection, file systems, and UNIX-style networking (TCP/IP, rlogin, etc.). The simulator also provides network simulation capabilities that let you create complete simulations of complex networks consisting of multiple IPv4, IPv6, or other protocols, subnets, and routing systems.

The simulator runs on your chosen host workstation, decreasing the need for evaluation hardware early in the development cycle. It also provides easy access to the host operating system API, so you can use the host facilities and peripherals in your simulation. For instance, a PCI card used in your final system can be installed on the host machine then accessed by the simulator.

Workbench VxWorks Source Build Configuration

Wind River Workbench 3.3 provides a project type that allows you to configure and build custom VxWorks libraries, which you can then use as the basis for VxWorks image projects. This project type supports the creation and management of VxWorks Source Build (VSB) projects. These projects are based on a specific BSP and allow the customer to adjust build options and content to match a specific application. The selected options are used to rebuild the VxWorks run-time sources to fit that configuration. Also, developers have the ability to create VSB RTP project source builds. Though it is not mandatory for customers to purchase VxWorks source code, VSB projects can only be set up if the sources are installed.

VxWorks 6.x Kernel Configurator

VxWorks 6.x Kernel Configurator is a graphical utility that simplifies and accelerates the task of selecting the operating system components that must be included in a bootable VxWorks image. In addition to configuring VxWorks images for single-core processors, the kernel configurator allows the creation of SMP and AMP projects on any supported SMP or AMP target.

When creating a new bootable kernel image, Workbench analyzes available kernel components as well as BSP and compiler selections. The configurator displays a summary of key configuration data, such as the number of selected components or data and text size. A bundle selector allows users to quickly and easily include or exclude dedicated configuration bundles composed of multiple components from a kernel image. Sample configuration bundles provided with the configurator include components needed for POSIX compliance, real-time process development, or error management.

Selecting kernel components individually gives you greater flexibility and control over your VxWorks image. VxWorks 6.x Kernel Configurator analyzes component dependencies and highlights conflicts when components are required but not selected or if components are incompatible with one another. An autoscale feature analyzes the entire VxWorks image and removes unused kernel components that may increase the size of a bootable image unnecessarily.

Host Shell

The Host Shell, formerly known as WindSh, provides a command-line interface that allows you to download application modules and invoke both VxWorks 6.x and application module subroutines. This facility has many uses:

- Interactive exploration of the operating system by calling any VxWorks routine and API
- Debugging and monitoring processes
- Interactive exploration of VxWorks 6.x RTPs
- Interactive development by calling any application (RTP) routines
- VxWorks 6.x application (RTP) and kernel testing
- Error management support through output of error dumping; the ability to turn on/off error management on a per-task or per-RTP basis
- Message channels (IPC) support through text dump of the message traffic
- Debugging through dynamic printf insertion
- Debugging of multiple instances of VxWorks in an AMP multi-core configuration

The Host Shell executes on the development host, not the target, but it enables you to spawn tasks, look at RTPs, read from or write to target devices, and exert full control over the target. The Host Shell receives your commands, executes them locally on the host, and dispatches requests to the target server for any action involving the symbol table or target-resident programs or data.

Because the shell executes on the host system, you can use it with minimal intrusion on target resources. As with other VxWorks 6.x tools, only the target agent is required on the target system. Therefore, the Host Shell can remain available at all times—you can use it to maintain a production system, as well as to experiment and test during development. Since you do not need to rebuild the VxWorks 6.x image, the Host Shell is useful on targets with restricted memory and permits system mode debugging, which helps with debugging drivers.

Kernel Shell

The VxWorks 6.x Kernel Shell, formerly known as the Target Shell, runs within the VxWorks 6.x kernel and provides direct access to VxWorks 6.x through a console or a network connection, such as Telnet. The Kernel Shell provides similar capabilities to those provided by the Host Shell; it is often used when control or visibility into system status is needed outside a development environment. The kernel works with VxWorks SMP. The task information display includes the CPU/core on which tasks run.

A tip utility, similar to the tip utility available with UNIX, is available to enable the use of the Kernel Shell and Host Shell across multiple instances of VxWorks in a multi-core AMP configuration. This capability makes it possible to display output from one or more cores on the same console of a separate host machine and to log on to individual cores remotely and execute shell commands on them. The tip utility uses an MIPC-based serial device for communication between cores.

The Kernel Shell command interpreter can dynamically spawn tasks in RTPs, as well as in the kernel, which is useful for

debugging purposes. The Kernel Shell can also dynamically call routines in RTPs without the overhead of creating and spawning a task each time a routine is dynamically called.

Run-Time Analysis Tools

Workbench contains powerful and dynamic visualization tools for device software applications. They provide developers with visibility into the entire platform: application code, third-party libraries, and the operating system. You can monitor variables, optimize performance, and find memory problems—all while the system is still running.

System Viewer

System Viewer provides detailed analysis and graphical visualization of VxWorks 6.x system events, revealing the complex interactions of tasks, interrupts, and system objects of an application executing on a target. Context switches are clearly shown, as are system events such as semaphores, message queues, signals, tasks, timers, and user events. System Viewer allows device software developers to detect anomalous behavior quickly then understand the cause and effect by reviewing the complete history of events leading up to the problem, including error management events from VxWorks 6.x.

Performance Profiler

Profiling is critical for real-time systems. Once you understand performance bottlenecks, it becomes easier to optimize application code. Performance Profiler is a dynamic execution profiler that provides detailed function-by-function performance analysis, specifying individual routines within the program that are consuming the CPU cycles. Performance Profiler pinpoints inefficiencies and shows how performance changes over time.

Memory Analyzer

Ensuring optimal use of memory is a critical activity in device software design. In many applications, memory usage is not fully understood and a large portion of available memory is wasted. Systems can run for days before failing due to noncharacterized memory leaks. Memory

Analyzer is an instant memory analyzer that provides greater visibility into memory usage. Without any special compilation or instrumentation, you can monitor available memory, detect leaks that occur due to system calls or third-party libraries, and even watch leaks as they happen.

Data Monitor

This real-time graphical monitoring tool is used to examine variables, data structures, or memory locations in your system. You can watch any set of variables, see peak values and out-of-range settings you would otherwise miss, trigger collection on specific events, change variables while your program runs, and save collected data to disk. Data Monitor presents this live analysis of your program without stopping or slowing your code.

Code Coverage Analyzer

Code Coverage Analyzer enables analysis of code to determine which code segments are executed during testing. Visibility into the execution of individual statements, decisions, and conditions enables you to create more thorough test scenarios, ensuring delivery of higher-quality devices. It also becomes easy to identify and remove code that is never executed, thus preventing future problems and reducing your overall memory footprint.

Optional Add-ons for VxWorks Platforms

Wind River Workbench On-Chip Debugging

Wind River Workbench On-Chip Debugging provides superior visibility and control of target resources including CPU and peripheral registers, memory, and cache for efficient debug during all phases of the development life cycle. Workbench On-Chip Debugging increases productivity during board bring-up, device driver development, kernel stabilization, and system integration by improving the time it takes to identify and resolve system-level issues such as race conditions, memory corruption, and other complex interactions among kernel, devices, and applications. Workbench

On-Chip Debugging also provides a viable alternative to agent-based debugging where debug ports are not available or where agent-based instrumentation of the OS is not desired.

Built on the same project-oriented development environment, Wind River Workbench On-Chip Debugging is designed to seamlessly integrate with the latest versions of VxWorks and supports visibility and debug of VxWorks kernel objects, tasks, and threads. VxWorks 6.9 can easily be extended with the full capabilities of Wind River Workbench On-Chip Debugging through the purchase of an add-on software module and either the multi-core-capable Wind River ICE 2 JTAG debug unit or the entry-level Wind River Probe JTAG debug unit. The following are key benefits:

- Tightened project hand-off among hardware and software developers
- Superior control of target system including CPU, peripheral registers, memory, and cache
- Awareness of VxWorks kernel objects, tasks, and threads
- Streamlined development through advanced hardware diagnostics and flash programming
- Real-time program trace execution (for supported processors)
- Advanced support for AMP, SMP, and virtualized system environments

For more information on Wind River Workbench On-Chip Debugging, visit www.windriver.com/products/OCD or contact your Wind River sales representative.

IPL CANTATA++

IPL Cantata++, available for VxWorks 5.5 and VxWorks 6.x-based platforms, is an optional set of tools that allows developers greater efficiency in completing unit testing, integration testing, and code coverage analysis on the tests. The integration of Cantata++ with Workbench places these capabilities within easy reach. Cantata++ increases software quality, decreases time-to-market, and reduces support costs through better, faster, more automated testing in the development life cycle.

Technical Specifications

- Backward-compatible with VxWorks 5.5, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, and 6.8
- Kernel scalability and performance tuning using VxWorks Source Build
- State-of-the-art memory protection
- Memory management and error management
- Message channels IPC, including support for multiprocessor and multi-OS messaging using TIPC
- Improved POSIX compliancy, including full support for JTRS SCA AEP 2.2.2 and to POSIX IEEE Std. 1003.13-2003 PSE52
- Dual-mode IPv4/IPv6 network stack
- Power management framework, with CPU power management
- TrueFFS flash file system, dosFs (FAT-compatible file system), and highly reliable file system (HRFS)
- High-speed interconnect framework with PCI and local bus support
- VxMP 2.3.5
- Wind River Diab Compiler 5.9 (formerly Wind River Compiler)
- Wind River GNU Compiler 4.3.3
- Intel C++ Compiler 12.0 for VxWorks and Intel Integrated Performance Primitives 7.0 for VxWorks
- Wind River VxWorks Simulator 6.9
- Wind River TIPC 1.7.7
- Wind River Workbench 3.3
 - Wind River System Viewer
 - Wind River Run-Time Analysis Tools
 - Wind River Workbench Memory Analyzer
 - Wind River Workbench Performance Profiler
 - Wind River Workbench Data Monitor
 - Wind River Workbench Code Coverage Analyzer
- Wind River CAN 1.5.5
- Wind River CLI, Web, MIBway 4.9
- Wind River Cryptography Libraries 6.9
- Wind River DCOM 2.3.8
- Wind River EAP 6.9
- Wind River Firewall 6.9
- Wind River IKE 6.9
- Wind River IPsec 6.9
- Wind River L2TP 6.9
- Wind River Learning Bridge 1.5
- Wind River MACsec 6.9
- Wind River Media Library 5.3
- Wind River MIPC 2.1
- Wind River Mobile IP 6.9
- Wind River NAT 6.9
- Wind River Network Stack 6.9

- Wind River OPC 3.2
- Wind River PPP 6.9
- Wind River RADIUS and Diameter 6.9
- Wind River SNMP 10.5
- Wind River SSH 6.9
- Wind River SSL 6.9
- Wind River USB 2.6
- Wind River Web Services 1.7
- Wind River Wireless Ethernet Driver 3.3
- Wind River Wireless Security 6.9
- Evaluation copy of Datalight FlashFX Pro 4.1.3

Architectures, Hosts, and Board Support Packages

Supported Target Architectures and Processor Families

- ARM
 - ARM9
 - ARM11
 - ARM11 MPCore
 - ARM Cortex A8
 - ARM Cortex A9 MPCore
- Intel
 - Pentium family
 - Xeon
 - Xeon LV
 - Core
 - Core 2 Duo
 - Atom
- MIPS
 - MIPS 4Kx
 - MIPS 5Kx
 - MIPS 24Kx
 - MIPS 34Kx
 - MIPS 74Kx
 - Cavium OCTEON CN3XXX
 - Cavium OCTEON Plus CN5XXX
 - Cavium OCTEON Plus CN63XX
 - Netlogic (formerly RMI) XLR, XLS
 - Altera MP32
- PowerPC
 - PowerPC 40x
 - PowerPC 44x
 - PowerPC 60x
 - PowerPC 7xx
 - PowerPC 74xx
 - PowerPC 83xx
 - PowerPC 85xx, 8572
 - PowerPC 86xx, 8641d
 - QorIQ P20xx
 - QorIQ P4080

Supported Hosts

- Windows XP Professional, Service Pack 2 or 3
- Windows Vista (Business and Enterprise), Service Pack 2
- Windows 7
- Red Hat Enterprise Linux Workstation 4, Update 6 or 8, x86 (32-bit)
- Red Hat Enterprise Linux Workstation 5, Update 2 or 3, x86 (32-bit/64-bit)
- Red Hat Fedora 9, x86-64
- Red Hat Fedora 11, x86 (32-bit/64-bit)
- Novell SUSE Linux openSUSE 11.0, x86 (32-bit/64-bit)
- Novell SUSE Linux openSUSE 11.1, x86 (32-bit/64-bit)
- Novell SUSE Linux Enterprise Desktop 10.2, x86 (32-bit/64-bit)
- Novell SUSE Linux Enterprise Desktop 11.0, x86 (64-bit)
- Ubuntu Desktop 8.04, Update 4, x86 (64-bit)
- Ubuntu Desktop 9.04, Update 4, x86 (32-bit/64-bit)
- Solaris 10 (with GTK), Update 11/06, SPARC 32-bit

Our software partners include the following:

Technology	Partner
Ada development	AdaCore
Bluetooth	Parrot, Stonestreet One
CORBA	Objective Interface Systems (OIS)
Databases	Gracernote
ATM	Metaswitch Networks (previously Data Communication Ltd.)
Bluetooth	iAnywhere Solutions
CIFS/Samba	Visuality Systems
Modeling tools	IBM Rational
Test tools	IPL, Klocwork, LDRA
DLNA	DigiOn Inc.
DTV technology	Zentek
Fieldbus solutions	HMS, IXXAT, Softing, Woodhead (Applied, SST)
File system failsafe	Datalight
File system: NAND Flash	Datalight
File system: CIFS	Visuality Systems
GPS	Trimble
HTML-based UI and technology (browsers)	Access, Espial, Opera Software, ProSyst, PsiNaptic
IEEE 1394	VividLogic
Industrial Ethernet, CANopen stack	IXXAT
Input methods	Agfa, Bitstream, Zi
IP routing, MPLS	Access (IP Infusion)
Java VM	aicas, Aonix, Aplix, Skelmir
Layer 2/3 switching	Access (IP Infusion)
Layer 2/3/4 with Ethernet	Broadcom (LVL7)
MOST	SMSC
Navigation	Destinator, 3DVU, 3SOFT
NDDS stack	RTI
OPC	Softing AG
OS co-residency	KUKA Controls
OSGi	Makewave AB
QoS	Data Connection Ltd., IP Infusion
Security (consumer)	Nagravision
Speech recognition	Asahi Kasei, Conversay, Fonix, Nuance
TR-069 and others (Broadband Forum's Technical Reports)	Works Systems Inc.
Voice Signaling	DCL, Flextronics
Web Server	Allegro (RomPager)

Supported Board Packages

The VxWorks platforms support a wide variety of board support packages on the target architectures listed previously. For a complete list of available BSPs, visit the Board Support Packages section of the Wind River website at www.windriver.com/products/bsp_web/index.html.

Partner Ecosystem

Wind River's world-class partner ecosystem assures tight integration between our core technologies and those of the premier hardware and software companies we've chosen to complement our solutions. Our partners help extend the capabilities of Wind River's development and run-time platforms by offering out-of-the-box integration and support for key technologies in the fast-moving industrial market. Our customer support team is trained to troubleshoot partner technologies in use with Wind River products, making ours the most comprehensive and best supported partner ecosystem in the embedded and mobile industries.

Our hardware partners include the following:

- Advantech
- ADLink Technology Inc.
- Applied Micro
- Altera
- ARM
- Broadcom
- Cavium
- Continuous Computing
- Curtiss-Wright Controls
- Emerson Network Power
- Eurotech
- Freescale
- GE Intelligent Platforms
- IBM
- Intel Corporation
- Kontron
- LSI Corporation
- Marvell Semiconductor Inc.
- Mindspeed Technologies
- MIPS Technologies
- RadiSys
- JI NetLogic Microsystems
- Texas Instruments
- Xilinx Inc.

For a full list of hardware partners refer to www.windriver.com.

Professional Services

Wind River Professional Services enables companies to reduce risk and improve competitiveness. Our team delivers device software expertise within structured engagements that directly address key development challenges and contribute to the success of our clients. Wind River's track record for successful device software engagements stretches across a spectrum of technologies, from set-top boxes to spacecraft, cell phones, and industrial robots. Our proven engagement methodology, a track record of timely delivery, and in-depth understanding of market and technology dynamics make Wind River a valuable implementation partner to clients worldwide.

Wind River solutions are augmented by market-focused services practices that build on the collective expertise of our engineers to provide timely and cost-effective design, integration, migration, and optimization services. Our services practices are built on four key pillars:

1. **Tailored services:** Our services are tailored to the unique requirements of the vertical markets in which we focus.
2. **Specialized expertise:** We deliver our services using specialized skills, knowledge, and experience that help us meet the specific needs of a vertical market or technology. This includes in-depth knowledge not only of Wind River products and technology but the technology of our partners in a given vertical industry, open source technologies, the nuances of the industry, and how all these requirements combine to drive the needs of the customer.
3. **Portfolio of intellectual property:** We offer a portfolio of solutions, some developed in conjunction with our customers, that can help reduce the cost and time frame of solution delivery.
4. **Project management:** We employ a global project management approach based on best practices and refined by more than 20 years of advanced systems development experience.

Installation and Orientation Service

Proper installation and orientation of the VxWorks platforms means you won't waste time solving easily avoidable problems before you can begin your next development project. Wind River offers an Installation and Orientation Service to ensure your project starts on time and without hassle by delivering the following:

- **Onsite installation:** Guided install on your hardware and host platform, along with a sample build process, demonstrations, and examples of customizations
- **Hands-on orientation:** Architecture, development file system, adding open source packages, porting drivers, addressing design issues
- **Advice:** Introduction to Wind River support channels and processes, additional services, project review, and consultation

The Wind River Installation and Orientation Service will expedite your path to productivity, allow you to rest assured that we have eliminated a common source of user error, and help you realize all of the platform's potential.

Education Services

New products and new development approaches can create extraordinary value, if individuals and teams learn to use them effectively. Lack of product knowledge can cause longer development schedules, poor quality, and higher costs. To help your team achieve optimal results from your technology investment, Wind River offers flexible education and coaching services to fit your schedule and project requirements.

Public Classes

Public classes provide detailed information on product, technology, and design-related topics. Hands-on exercises allow students to experiment with the products. Attending a public class may be the most cost-effective option for individuals or a small development team.

Private Classes

Private training classes include participants exclusively from your company. If you have a large project team or a number of new users, private classes may provide you the best value:

- You can tailor the agenda. Our instructors consult with you to determine which topics should be included and emphasized. Your participants do not waste precious class time on topics that are unimportant to them.
- Class discussions can cover your specific project needs, technical requirements, and challenges.
- You provide a location convenient for your employees, or choose Live Remote delivery. Either way, your employees save travel expenses and time away from the office.

Mentoring Services

Wind River provides expert assistance, best practices, and coaching to help you integrate Wind River solutions into your environment. Wind River Mentoring combined with formal training classes speeds you through the steepest part of the learning curve. Your team can avoid lengthy trial-and-error cycles and quickly become productive with your Wind River solutions.

The following are examples of Wind River Mentoring services:

- **Product installation:** A Wind River expert will install the products you've purchased and handle special requirements, such as multisite installation, installation on shared workstations, license server deployment, and plug-ins.
- **Tools integration:** A subject-matter expert will provide guidance on your specific data, system, and process integration, to optimize workflow and productivity. Depending on the complexity of your environment, the consultant can also help integrate licensing, edit-compile-debug workflow, advanced debugging visualization tools, kernel and application build configurations, and code repository systems.

- **Technology adoption:** A subject-matter expert will analyze and assist in formulating a technology adoption plan that includes such items as the design framework, application integration, and deployment—while taking into consideration best practices and maintenance issues. We can provide workflow reference material for new developers or infrequent users.
- **Technology assistance:** Wind River experts will provide guidance on various technology-related topics such as configuration, device drivers, debugging techniques, and performance optimization, specific to your unique needs.

Mentoring is also available remotely. You can arrange for a regular schedule of check-ins with an engineering specialist, ensuring that you remove productivity obstacles early and catch problems before they impact other parts of a project.

Live Remote Delivery

Live Remote delivery is a flexible alternative to classroom training or in-person mentoring.

Live Remote classes provide a remote-access, instructor-led environment that allows you to participate in live training events from the convenience of your home or office, or anywhere you have an Internet connection. You can watch live demonstrations, listen to lectures, practice hands-on lab exercises, ask questions, and receive feedback just as you would in a conventional class.

Most Wind River training courses and Wind River Mentoring are available for Live Remote delivery:

- Save the trouble, expense, and time to travel to a training site.
- Receive efficient, multisite training; your team members who are spread across geographic regions can collaborate within the same training or mentoring session.

Support Services

Wind River Customer Support, a Service Capability and Performance (SCP)–certified organization, provides support for all Wind River VxWorks platforms. Your subscription to VxWorks platforms includes full maintenance and support, delivered through Wind River's global customer support organization and our Online Support (OLS) website. Customers with a current subscription receive both maintenance updates and major upgrades.

Visit our Online Support website at www.windriver.com/support for fast access to product manuals, downloadable software, and other problem-solving resources. OLS offers a comprehensive knowledge base with a robust search feature for locating product information and manuals by keyword, author, published date, document type, language, and solution category.

Additional support features, including proactive email alerts covering particular technologies, platforms, or product patches and technical tips for common problems, are available for all customers on subscription.

Support on modified or unsupported configurations is best-effort-based. Wind River Customer Support will try to reproduce the problem on a supported configuration. If the problem can be validated, Wind River will provide a fix that will be tested on a supported configuration. Wind River Professional Services can provide support for boards or host operating system versions that are not supported by the standard product, as well as for customized versions of the source code or additional nonstandard packages.

If you cannot find the information you need through Online Support, contact our global support team for access to the industry's most knowledgeable and experienced support staff. Visit www.windriver.com/support/contact.html for contact details.

For more details on our support processes including escalations and defect resolution, consult Wind River's Customer Support User's Guide (CSUG), available at www.windriver.com/support/resources/csug.pdf.

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