Introduction of SpaceChain OS

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Key Word	SpaceChain OS RealEvo
Abstract	SpaceChain OS real-time operating system

Revision History

Version	Date	Reason
V1.00	2018/05/04	Create file

Contents

1. SPACECHAIN OS

1.1 Review

The development of SPACECHAIN OS was started from 2017. All SPACECHAIN OS and related code are open source, and you can access GitHub for the source code and related development files.

SPACECHAIN OS is an embedded hard real-time operating system that is suitable for the embedded devices. Unlike desktop operating systems such as macOS or Windows, embedded operating systems are more oriented toward industrial control and other fields. These devices may not even have human-machine interface or buttons, but are widely seen around us. For example, power grid control equipment, charging piles, subways, Mars landing vehicles, drones and so on. In these successful cases, users have strict requirements on the reliability, stability, real-time performance, and resource consumption of the operating system.

SPACECHAIN OS focuses on the development of application and middleware layers to meet the needs of aerospace, blockchain and other industries. Therefore, SPACECHAIN OS is suitable for the development of common technologies. One example is the migration of QTUM to SPACECHAIN OS, which greatly expands the application of QTUM. Without changing the hardware, the blockchain can run on most embedded devices through SPACECHAIN OS support. Another example is the development of communication middleware and its satellite-borne test for verifying reliability. The research results are published for all aerospace enthusiasts and related companies, avoiding users to repeatedly develop basic functions.

1.2 Features

SPACECHAIN OS has the following features.

- SPACECHAIN OS is an open source embedded real-time operating system whose reliability and security are easier to verify.
- Hard real-time kernel, as well as advanced and efficient scheduling algorithm can provide optimized drivers for different processors to improve overall system performance.
- Ensures the consistency and reusability of software code across different products by supporting processors across platforms (including ARM, MIPS, PowerPC, x86, Sparc, RISC-V and DSP architecture processors). For example, even if different parts of the spacecraft are equipped with different processors, the software code can be fully reused. For most companies and research institutions, SPACECHAIN OS can meet all the needs of the software operating system.
- SPACECHAIN OS supports symmetric multi-processing (SMP) platforms and also has real-time processes and dynamic loading mechanisms. For large-scale

projects, these features can fully meet the requirements for multisectoral distributed development and support the unified integration of application software developed by different sectors on the operating system.

- SPACECHAIN OS is mature, easy to program, simple in system architecture, and has a complete set of easy-to-use supporting development tools and software. Currently, SPACECHAIN OS can be used together with integrated development environment RealEvo-IDE and hardware simulator RealEvo-Simulator to facilitate system development and debugging, speed up software development and shorten product development cycle.
- DAPPs for developing blockchain functionality do not require the use of dedicated development tools.
- SPACECHAIN OS upper scripting applications can be directly developed using scripting languages such as Python and Lua.
- To develop SPACECHAIN OS applications or to modify and compile SPACECHAIN OS underlying files and BSPs, dedicated development tools are required.
- The foundation of SPACECHAIN OS is SylixOS. In the process of development, SPACECHAIN OS maintains full compatibility with SylixOS and there is no separate branch of the kernel. The protocol used by SylixOS is GPL V3.

1.3 Real-time

SPACECHAIN OS and SylixOS use the same kernel. In June 2015, Tsinghua University conducted real-time comparative tests on SylixOS, Linux, and Linux+RT. They used the real-time testing tool rt-tests to evaluate the real-time performance of SylixOS, Linux, and Linux+RT operating systems on the Freescale i.MX6 quad-core and TI AM335X single-core hardware platforms. The test results show that the real-time performance of SylixOS is not only significantly ahead of Linux, but also superior to Linux+RT. Because VxWorks cannot run rt-tests real-time testing tools, comparison tests under the same conditions cannot be performed. The results show that SPACECHAIN OS has excellent real-time performance with the same kernel.

The following are some of the test results:

I. Real-time testing on TI AM335X single-core hardware platform without pressure

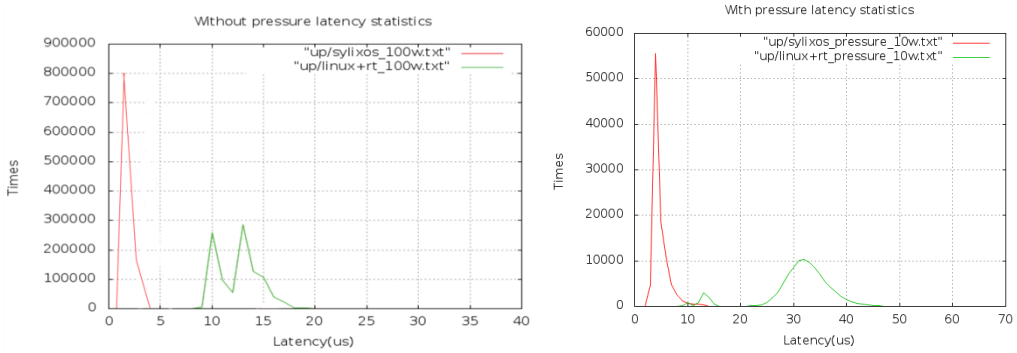
	SPACE CHAIN OS	**Linux + RT**	**Linux**	**Comparing result**
Maximum latency(us)	12	35	717	SPACECHAIN OS < Linux + RT< Linux

Minimum latency (us)	1	8	7	SPACECHAIN OS < Linux + RT< Linux
Average latency (us)	2	12	13	SPACECHAIN OS < Linux + RT< Linux

II. Real-time testing on TI AM335X single-core hardware platform with pressure

	SPACE CHAIN OS	**Linux + RT**	**Linux**	**Comparing result**
Maximum latency (us)	26	67	894	SPACECHAIN OS < Linux + RT< Linux
Minimum latency (us)	1	8	17	SPACECHAIN OS < Linux + RT< Linux
Average latency (us)	3	31	35	SPACECHAIN OS < Linux + RT< Linux

The response latency is shown in the figures below. The left figure shows the without pressure results, and the right figure shows the with pressure results:



From the above figures, it can be clearly seen that the with pressure average latency of SPACECHAIN OS is the shortest of the three systems, and its maximum latency is also shorter than Linux + RT. This shows that the real-time performance with pressure of SPACECHAIN OS is superior to that of Linux + RT.

It can be seen from this report that the real-time performance of SPACECHAIN OS is excellent.

1.4 Open Source

SPACECHAIN OS is an open source real-time operating system that has the following

advantages when applied to embedded systems:

- Suitable for embedded development

The development of embedded systems is mainly carried out on non-standard hardware platforms. The open source system makes it easier for users to tailor the system based on the hardware platform and their own needs to achieve customized development.

- Improve the system reliability

The primary requirement for embedded systems is security and reliability, while the security and reliability of the open source system is more easily verified. Its code allows public review, and its bugs are also easy to find and fix, so the code quality is more secure.

- Reduce the risk of use

Users can obtain system source code and nurture their own team for system maintenance without worrying about no one maintaining the old version of operating system after the upgrade.

- Easy to locate faults

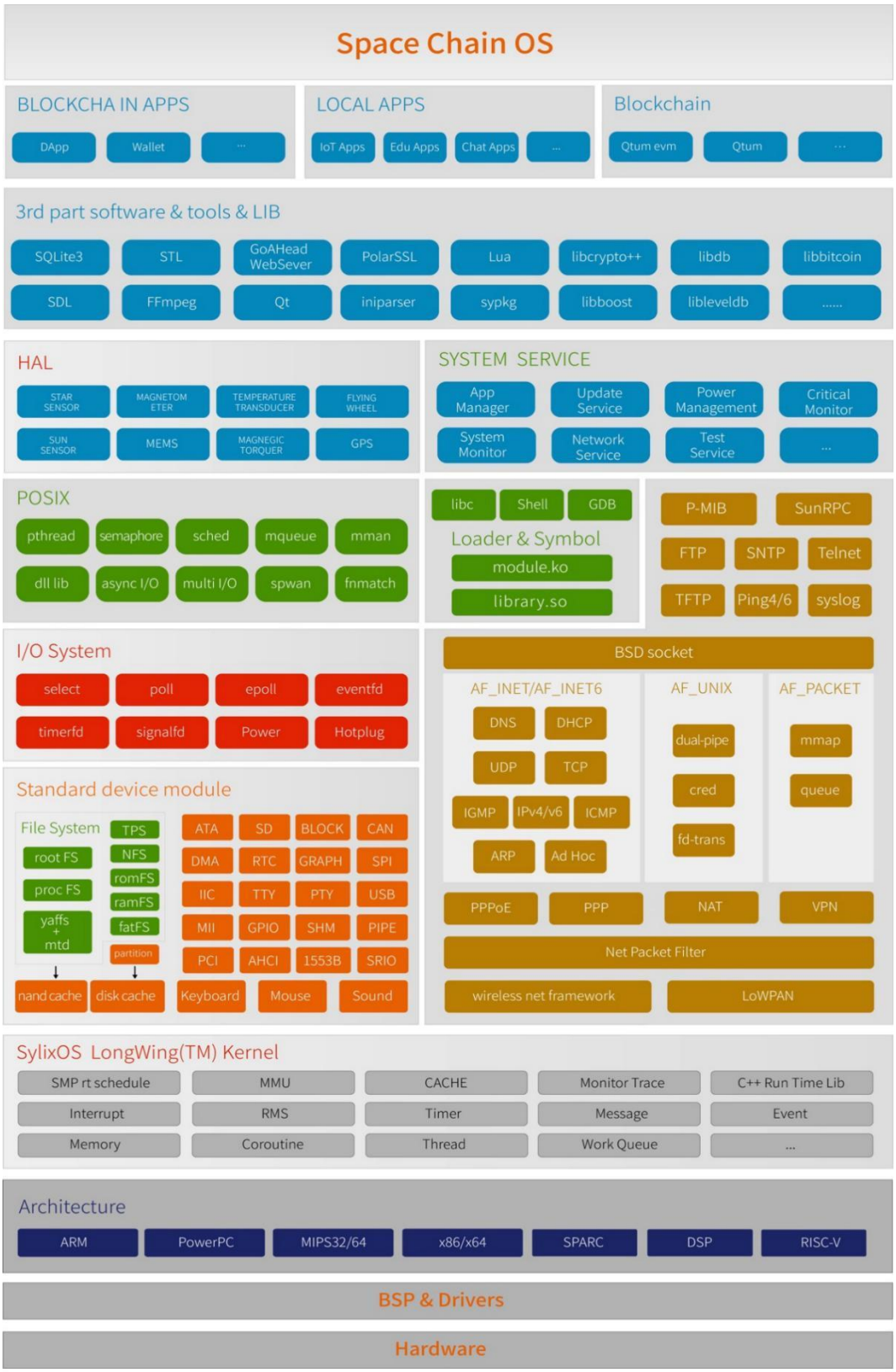
Embedded systems can easily fail in graphical displays, network communications, and peripherals during development. The open source system can avoid problems caused by closed source systems such as difficult fault location, long troubleshooting period, and slow development progress, so as to improve the efficiency of fault location.

- High technical transparency

The development of open source systems is driven by the community. Enthusiasts can get the latest information at any time and participate in the evolution of the system. The development of the system is no longer limited by the ideas of one company, and enthusiasts can understand the future development planning and direction of the system.

1.5 Functional features

The SPACECHAIN OS architecture is shown below. Note: the function in the dashed box is in development.



- Compatible with IEEE 1003 (ISO/IEC 9945) operating system interface specification
- Compatible with POSIX 1003.1b (ISO/IEC 9945-1) real-time programming

standards

- Excellent real-time performance (the time complexity of task scheduling and switching algorithm is O(1)).
- Support unlimited multitasking
- Preemptive scheduling supports 256 priorities
- Support virtual processes
- As a preemptive multitask hard real time operating system, SPACECHAIN OS supports priority inheritance and prevents priority reversal.
- Many products developed based on SPACECHAIN OS require 7x24 hours of uninterrupted running, so SPACECHAIN OS has an extremely stable kernel.
- Support tightly coupled symmetrical multi-processors, such as ARM Cortex-A9 SMPCore, Intel Duo Core(TM), and Loongson 3
- Support standard I/O, multiplexed I/O, and asynchronous I/O interfaces
- Support a variety of emerging asynchronous event synchronization interfaces, such as signalfd, timerfd, eventfd, etc
- Support a variety of standard file systems: TPSFS (power-fail safe), FAT, YAFFS, ROOTFS, PROCFS, NFS, ROMFS, etc.
- Support file record locks and databases
- Support memory management unit (MMU)
- Support third-party GUI graphics libraries, such as Qt, Microwindows, μC/GUI, etc.
- Support dynamic loading of applications, dynamic link libraries, and kernel modules
- Support standard TCP/IPv4/IPv6 dual network protocol stack and provide standard socket operation interface
- Support AF_UNIX, AF_PACKET, AF_INET, AF_INET6 protocols
- Internally integrate a variety of network tools, such as FTP, TFTP, NAT, PING, TELNET, NFS, etc.
- Internally integrate Shell interfaces and support environment variables (compatible with common Linux Shell operations)
- Support a variety of standard device abstract ions, such as TTY, BLOCK, DMA, ATA, SATA, GRAPH, RTC, PIPE, etc.
- Support a variety of industrial equipment and bus models, such as CAN, I2C, SPI, SDIO, PCI/PCIE, 1553B, USB, etc.

- Provide high-speed timer device interfaces and timing services with frequency higher than the main clock
- Support hot-plug devices
- Support power consumption management
- Kernel behavior tracker is provided to facilitate application performance and fault analysis.

The following table shows a functional comparison between SPACECHAIN OS and two other commonly used operating systems.

Function	SPACECHAIN OS	VxWorks	RTEMS	Function	SPACECHAIN OS	VxWorks	RTEMS
Kernel preemption	■	■	■	POSIX	Outstanding	Good	Good
Priority	256	256	256	CAN	■	■	□
Priority inheritance	■	■	■	Compatible with UNIX	Outstanding	Good	Moderate
Number of tasks	Unlimited	Unlimited	Unlimited	Real-time database	■	■	■
Process support	POSIX process	RTP process	□	ODBC	■	□	□
Coroutines (fibers)	■	□	□	MMU management	■	■	□
RMS scheduling	■	□	■	SMP multicore	Real-time scheduling	Real-time scheduling	Collabo-rative scheduling
Dynamic loading	■	■	□	Descriptor transfer	■	□	□
Asynchronous IO	■	■	□	ProcFs	■	■	□
Ad-hoc network protocol	MAODV	□	□	Multiplexed IO	■	■	■
Unix domain protocol	■	Uncertain	□	Support C++	■	■	■
Built-in hot-plug	■	□	□	Record lock	■	Incomplete	□
High speed timer	■	□	□	Script (Lua, Python)	■	Incomplete	Incomplete

1.6 Middleware

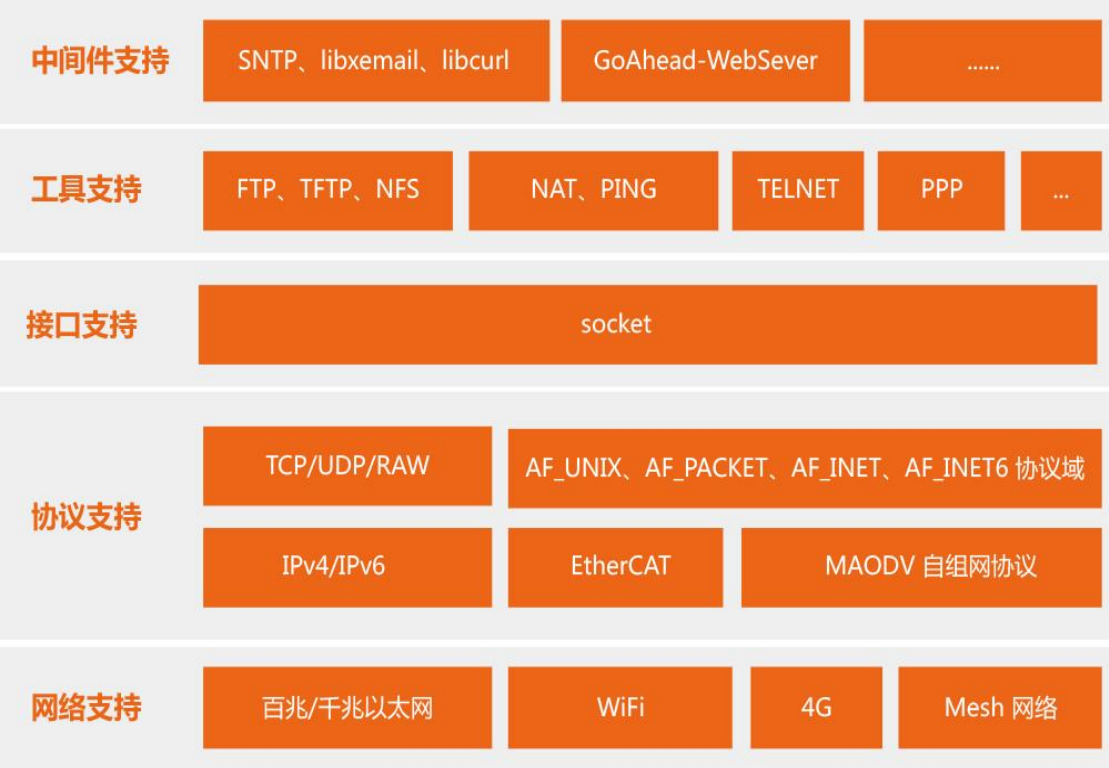
Thanks to perfect support for standards such as POSIX, SPACECHAIN OS has and supports a variety of middleware.

category	Middleware function	Function
Standard device	TTY, BLOCK, DMA, RTC, PIPE	Device abstraction
Industrial bus	USB、I2C、SPI、SDIO	Bus driver
	PCI、PCI-E	Bus driver
	CAN、MIL-STD-1553B	Bus driver
Graphical display	Qt/Qwt	GUI library
	μC/GUI、MiniGUI、Microwindows	GUI library
File system	exFATj, FAT, YAFFS, ROMFS, ROOTFS, PROCFS, NFS, RAMFS	File system
	TpsFs (power-fail safe file system)	File system
Network communication	IPv4, IPv6, AF_UNIX, AF_PACKET	Protocol suite
	socket	Programming interface
	FTP, TELNET, TFTP, NAT, SNTP, PING	network tool
Standard middleware	SQLite3, ODBC	Databse
	Mini-XML, libexpat	Format conversion
	Python, Lua, MuJS, Espruino, Duktape	Scripting language
	GoAhead-WebServer, libcurl, libxemail	Network
	OpenSSL, PolarSSL	Security
	zlib	Compression
	Zmodem, Xmodem	Transfer tool
	ReadLine, Libtool	Others
Application middleware	OpenCV, EtherCAT, CANopen, IEC61850, QGIS	
	Application protocols, Industry middleware	

1.7 Network communication

SPACECHAIN OS supports complete network functions and a variety of network tools:

- Support Fast/Gigabit ethernet;
- Support wireless net framework;
- Support Mesh network and MAODV ad-hoc network protocols;
- Support mainstream WiFi and 4G modules;
- Support IPv4/IPv6 dual network protocol stack and standard socket interface;
- Support AF_UNIX, AF_PACKET, AF_INET, AF_INET6 protocols;
- Support a variety of network tools, such as FTP, TFTP, NAT, PING, TELNET, NFS and PPP;
- Support mainstream industrial real-time Ethernet, such as EtherCAT;
- Support a variety of network middleware, such as SNTP, libxemail, libcurl, GoAhead-WebServer, etc.



1.8 Graphical display

- Support Graphics User Interfaces (GUI) such as Qt, Microwindows, μC/GUI and MiniGUI, as well as third-party Qt control libraries such as Qwt;
- RealEvo-QtSylixOS software is supported to facilitate users to develop and debug application interface on Qt Creater;
- Support multi - screen display and VNC remote display
- Support touch screen, keyboard and mouse, and allow the input devices to be hot-plugged.

1.9 File storage

- Support a variety of standard file systems: FAT, YAFFS, ROOTFS, PROCFS, NFS, ROMFS, etc.
- Support the patent file system TpsFs (power-fail safe file system) developed by Acoinfo, and completely solve the power-fail safety problem of embedded industry file storage;
- Support record locks and databases;
- The file system supports POSIX standard I/O operations;
- The file storage medium supports NOR FLASH, NAND FLASH, eMMC, SD, CF, IDE hard disk and SATA hard disk.

2. Power-fail safe file system TpsFs

TpsFs is a power-fail safe file management system developed for high-capacity storage devices, which can guarantee the integrity of files when power is failed. It has the following features:

B+tree storage structure is adopted to make space management more efficient and file access faster;

Transaction commit is used for the operation of file system metadata to ensure power-fail safety;

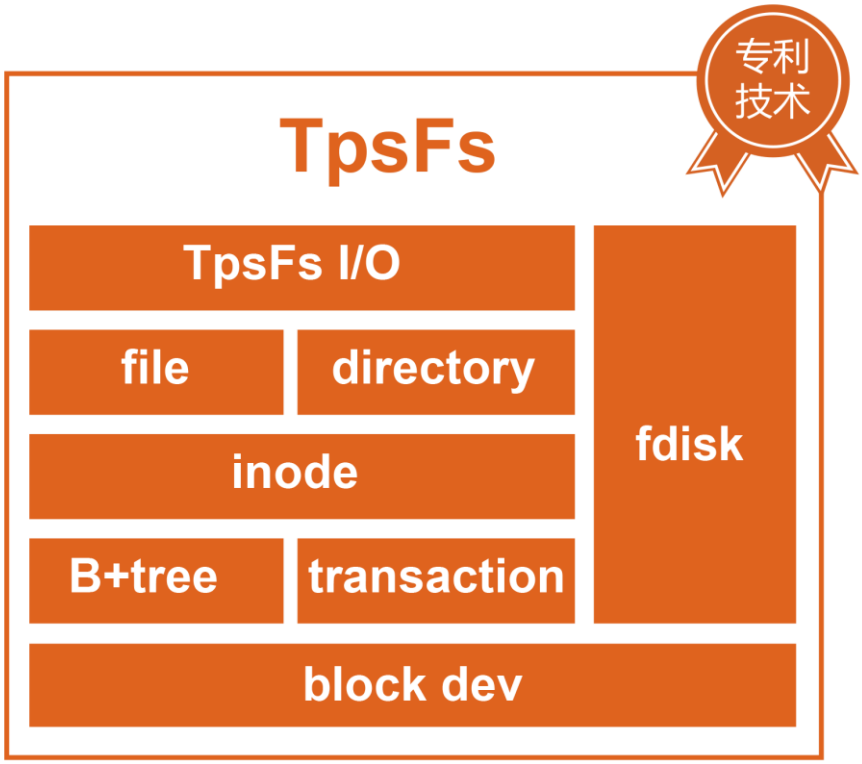
64-bit file system with support for EB-level file length;

Simple interface for easy porting;

Support operations such as hard links, soft links and file locks;

Has convenient graphical access tools;

Multiple techniques are used to ensure the fault recovery capability of the file system.



3. Compilation tool chain RealEvo-Compiler

At present, the SPACECHAIN OS can be compiled and developed using the RealEvo series tools provided by Acoinfo. RealEvo-Compiler is a compiler developed by Acoinfo based on the latest version of GCC and now supports seven major architecture platforms. Including:

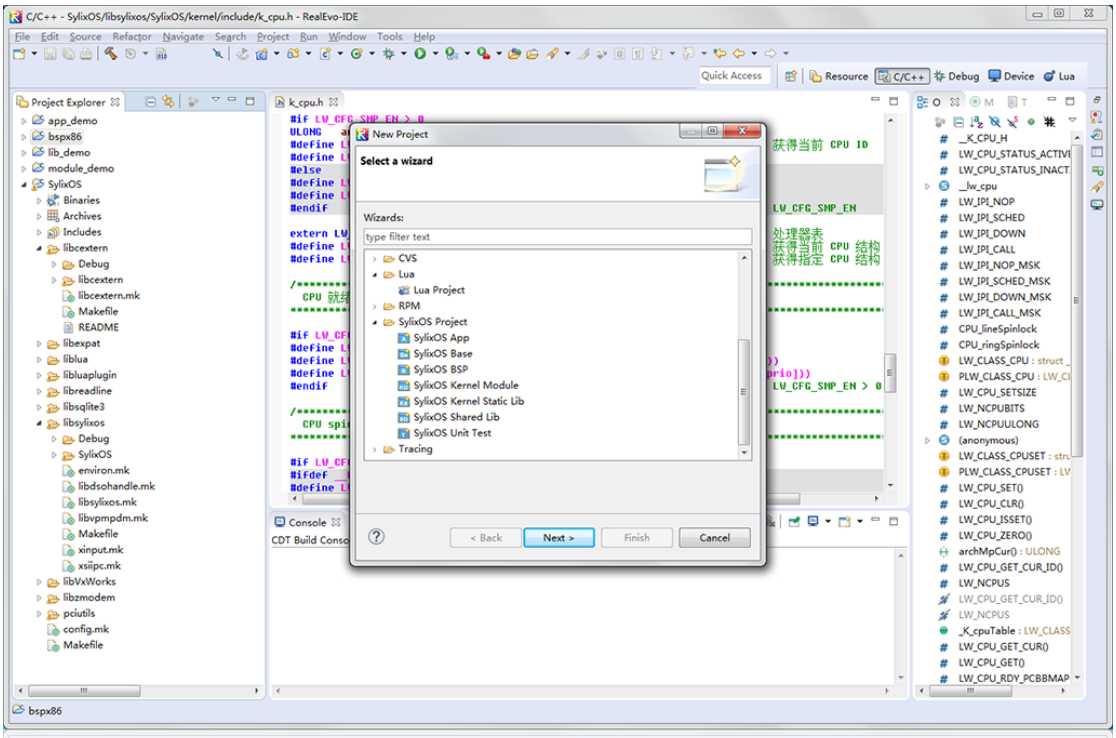
- RealEvo-Compiler ARM compiler is optimized for the Cortex-A series processors and supports the most advanced ARMv8 AArch64 processor of ARM at present;
- RealEvo-Compiler MIPS compiler supports MIPS32, MIPS64, Loongson and Ingenic processors;
- RealEvo-Compiler PowerPC compiler supports NXP and the PowerPC series processors developed by State Microelectronics;
- RealEvo-Compiler x86 compiler supports x86 architecture processors of Intel and AMD.

4. Integrated development environment RealEvo-IDE

RealEvo series integrated development environment integrates design, development, debugging, simulation, deployment, and testing functions, providing a complete embedded development solution. RealEvo adopts full-graphical operations and completely automated processes to avoid duplication of effort and minimize development costs.

4.1 Project management scheme

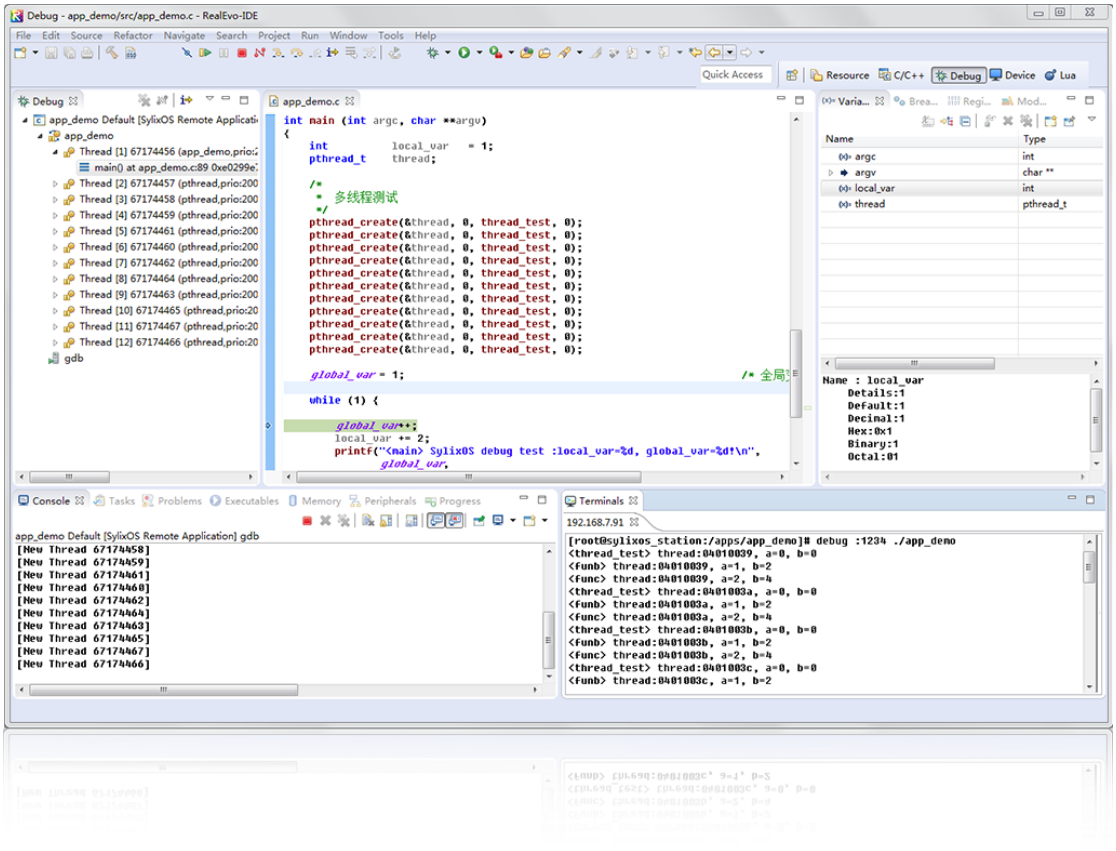
- Workspace-based management mechanism
- Wizard assisted project construction
- Graphical configuration
- Automatic code generation
- One-click project deployment



4.2 Powerful debugging

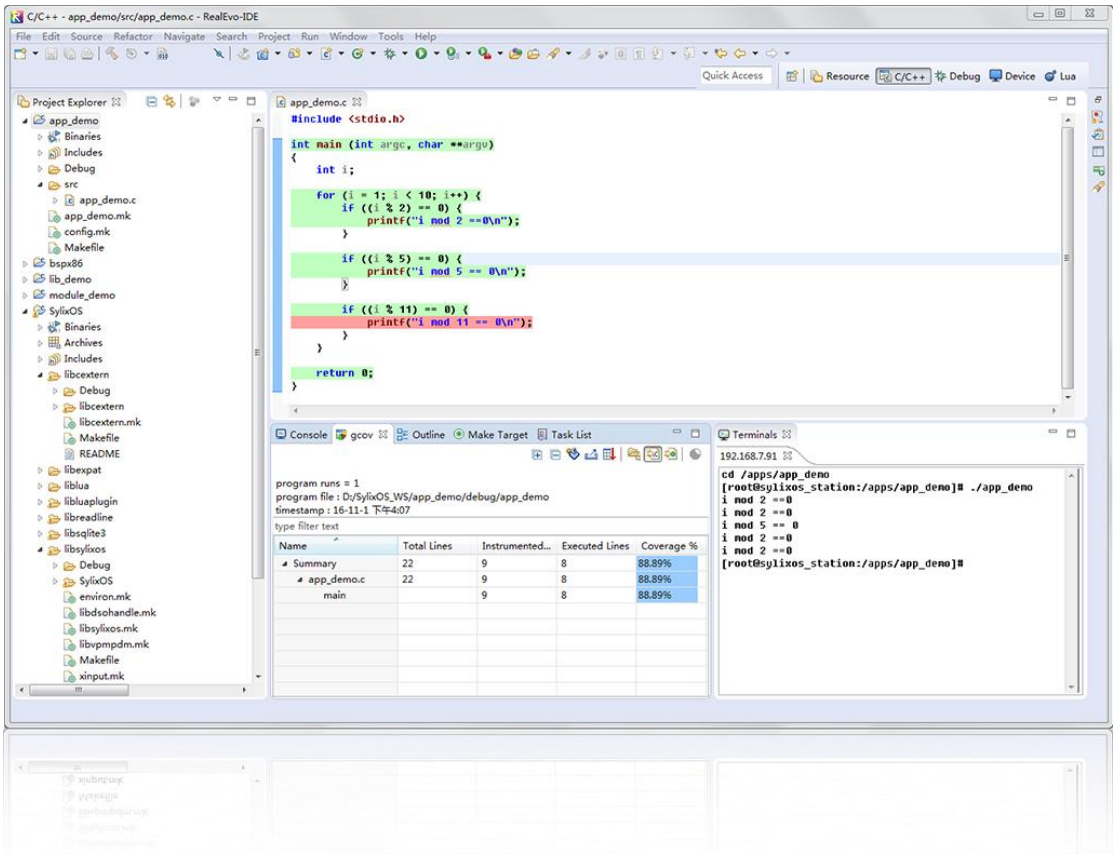
- Support basic functions such as breakpoints, single-steps, etc.
- Support network and serial port debugging
- Support running process debugging

- Support multi-core or multi-thread parallel debugging
- Support dynamic library debugging
- Support multi-thread non-stop debugging
- Support one-click push debugging



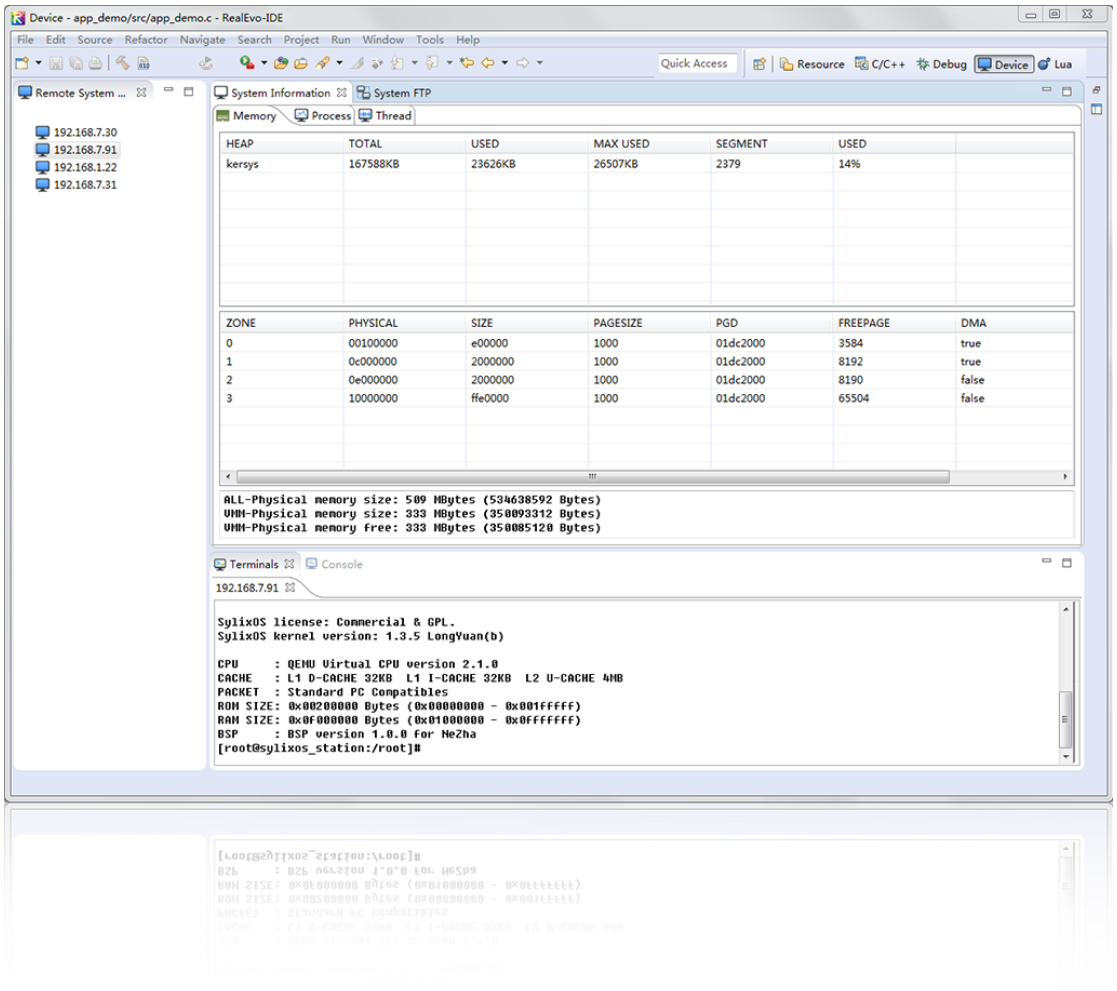
4.3 Integrated excellent development tools

- Platform-optimized compilation tool chain
- Powerful multi-platform simulator
- Excellent design and testing tools
- Performance analysis tool
- Code coverage analysis tool
- User-friendly code editor



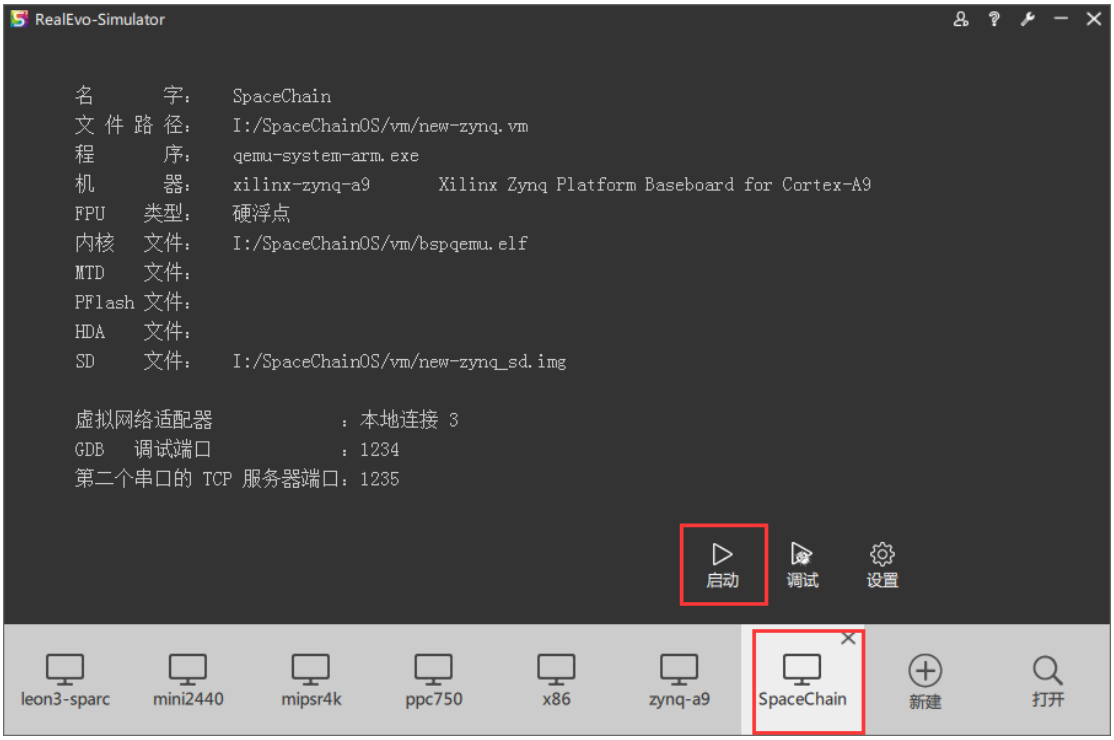
4.4 Convenient device management function

- Support real-time monitoring of device status
- Provide a remote shell
- Integrated FTP client
- Integrated TFTP file server


Device - app_demo/src/app_demo.c - RealEvo-IDE
File Edit Source Refactor Navigate Search Project Run Window Tools Help
Quick Access
Resource C/C++ Debug Device Lua
Remote System ...
192.168.7.30
192.168.7.91
192.168.1.22
192.168.7.31
System Information
System FTP
Memory Process Thread
HEAP TOTAL USED MAX USED SEGMENT USED
kersys 167588KB 23626KB 26507KB 2379 14%
ZONE PHYSICAL SIZE PAGESIZE PGD FREEPAGE DMA
0 00100000 e00000 1000 01dc2000 3584 true
1 0c000000 2000000 1000 01dc2000 8192 true
2 0e000000 2000000 1000 01dc2000 8190 false
3 10000000 ffe0000 1000 01dc2000 65504 false
ALL-Physical memory size: 509 MBytes (534638592 Bytes)
VMM-Physical memory size: 333 MBytes (350093312 Bytes)
VMM-Physical memory free: 333 MBytes (350085120 Bytes)
Terminals
Console
192.168.7.91
SylixOS license: Commercial & GPL.
SylixOS kernel version: 1.3.5 LongYuan(b)
CPU : QEMU Virtual CPU version 2.1.0
CACHE : L1 D-CACHE 32KB L1 I-CACHE 32KB L2 U-CACHE 4MB
PACKET : Standard PC Compatibles
ROM SIZE: 0x00200000 Bytes (0x00000000 - 0x001fffff)
RAM SIZE: 0x0F000000 Bytes (0x01000000 - 0x0fffffff)
BSP : BSP version 1.0.0 for NeZha
[root@sylixos_station:/root]#

5. Hardware simulator RealEvo-Simulator

- RealEvo-Simulator is a computer hardware system simulation software developed by Acoinfo based on the latest QEMU.
- Currently supports the simulation of ARM, MIPS, PowerPC, and x86 architecture processors, as well as the simulation of commonly used peripherals such as SD cards, network cards, USB, hard disks, FLASH, LCD, and touch screens.
- The translation execution mechanism adopted by RealEvo-Simulator greatly improves the performance of processor simulation.
- The virtual machine files provided by SPACECHAIN OS allow the user to use the simulator to successfully simulate the running of the blockchain function and facilitate development. For the blockchain running on embedded devices, simulators can be used to verify the running without hardware.



6. Blockchain

Now, SPACECHAIN OS already supports QTUM, which runs a complete blockchain node on SPACECHAIN OS with full functionality. The following figure shows the command to get this node information. For details, please refer to SPACECHAIN OS GitHub and QTUM.