



The bridge to possible

Working with and building for non-x86 Compute Architectures

Background – Challenge – Solutions

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Cisco Webex App

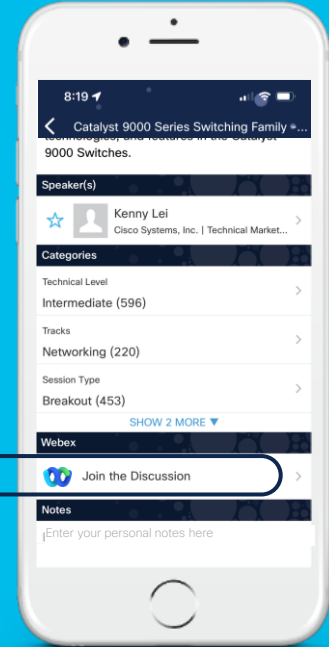
Questions?

Use Cisco Webex App to chat with the speaker after the session

How

- 1 Find this session in the Cisco Live Mobile App
- 2 Click “Join the Discussion”
- 3 Install the Webex App or go directly to the Webex space
- 4 Enter messages/questions in the Webex space

Webex spaces will be moderated until February 24, 2023.





Agenda

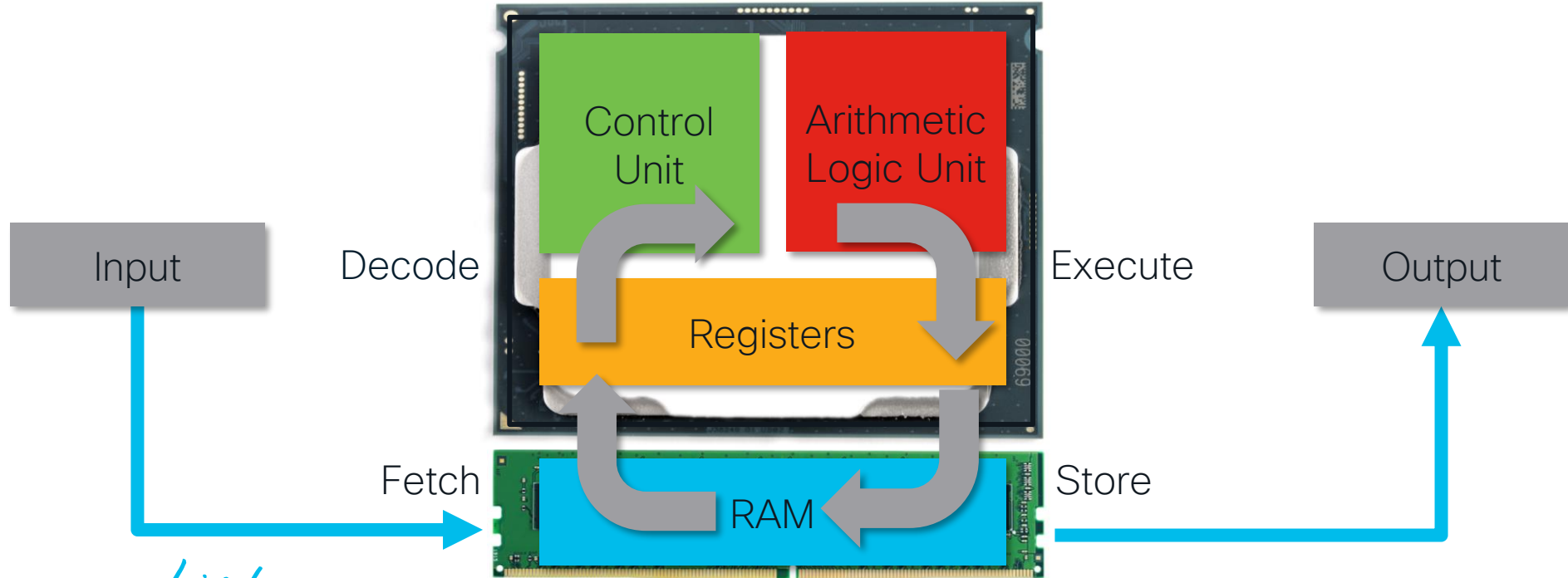
- Background: Compute Architectures
- Challenge: Mix of Architectures
- Solutions + Demos
- Summary

Compute Architectures



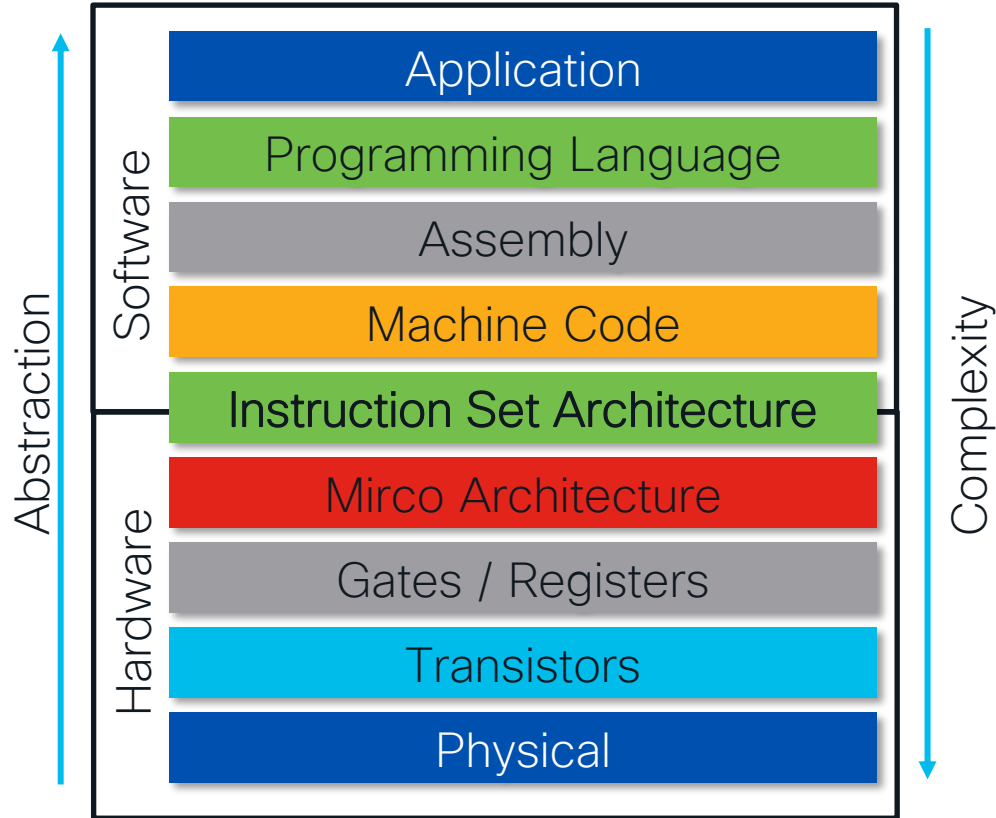
CPU – Central Processing Unit

- In essence: **Fetch** – **Decode** – **Execute** – (**Store**)



ISA - Instruction Set Architecture

- High-level programming language **abstracts** complexity
- **Compiler translates** code to lower-level instructions
- **Instruction Set** defines how:
 - Instructions are processed
 - Memory is accessed
 - IO is managed



Different ISAs/Compute Architectures – Historical

The table below compares basic information about instruction sets to be implemented in the CPU architectures:																				
Architecture	Bits	Ver	CDC Upper 3000 series	48	1963	Register--	CISC	48-bit A reg., 48-bit Q reg., 6 15-bit R registers	Variable (24- or 48-bit)	Multiple types of	Big									
6502	8		CDC 6000 Central Processor (CP)	60	1964	Nios II	32	200x	3	Register-Register	RISC	32	Fixed (32-bit)	Condition register	Little	Soft processor that can be instantiated on an Altera FPGA device	No	On Altera/Intel FPGA only		
6809	8					NS320xx	32	1982	5	Memory-Memory	CISC	8	Variable Huffman coded, up to 23 bytes long	Condition code	Little	BitBit instructions				
680x0	32		CDC 6000 Peripheral Processor (PP)	12	1964	OpenRISC	32, 64	1.3 ^[21]	2010	3	Register-Register	RISC	16 or 32	Fixed	?	?	?	Yes	Yes	
8080	8					PA-RISC (HP/PA)	64 (32→64)	2.0	1986	3	Register-Register	RISC	32	Fixed (32-bit)	Compare and branch	Big → Bi	MAX	No		
8051	32 (8→32)		Crusoe (native VLIW)	32 ^[13]	2000	PDP-8 ^[22]	12	1966		Register-Memory	CISC	1 accumulator 1 multiplier quotient register	Fixed (12-bit)	Condition register Test and branch		EAE (Extended Arithmetic Element)				
						PDP-11	16	1970	2	Memory-Memory	CISC	8 (includes stack pointer, though any register can act as stack pointer)	Variable (16-, 32-, or 48-bit)	Condition code	Little	Floating Point, Commercial Instruction Set	No	No		
x86	16, 32, 64 (16→32→64)		Elbrus (native VLIW)	64	Elbrus-4S	2014	POWER, PowerPC, Power ISA	32/64 (32→64)	3.1 ^[23]	1990	3	Register-Register	RISC	32	Fixed (32-bit), Variable (32- or 64-bit with the 32-bit prefix ^[23])	Condition code	Big/Bi	AltVec, APU, VSX, Cell	Yes	Yes
Alpha	64		DLX	32	1990		RISC-V	32, 64, 128	20191213 ^[24]	2010	3	Register-Register	RISC	32 (including "zero")	Variable	Compare and branch	Little	?	Yes	Yes
ARC	16/32/64 (32→64)	ARC				RX	64/32/16		2000	3	Memory-Memory	CISC	4 integer + 4 address	Variable	Compare and branch	Little			No	
ARM/A32	32	ARM	eSi-RISC	16/32	2009	S-core	16/32		2005			RISC			Little					
Thumb/T32	32	ARM				SPARC	64 (32→64)	OSA2017 ^[25]	1985	3	Register-Register	RISC	32 (including "zero")	Fixed (32-bit)	Condition code	Big → Bi	VIS	Yes	Yes ^[26]	
Arm64/A64	64	ARM	Itanium (IA-64)	64	2001		SuperH (SH)	32		1994	2	Register-Register-Register-Memory	RISC	16	Fixed (16- or 32-bit), Variable	Condition code (single bit)	Bi		Yes	Yes
AVR	8		Mico32	32	?	2006						Register-Memory-Memory-Register	CISC	16 general 16 control (S/370 and later) 16 access (ESA/370 and later)	Variable (16-, 32-, or 48-bit)	Condition code, compare and branch	Big		No	No
			MIPS	64 (32→64)	6 ^[17] ^[18]	1981	System/360 System/370 z/Architecture	64 (32→64)		1964										
AVR32	32	Rev	MMIX	64	?	1999						Register-Register								
			Nios II	32		200x	Transputer	32 (4→64)		1987	1	Stack machine	MISC	3 (as stack)	Variable (8 – 120 bytes)	Compare and branch	Little			
			NS320xx	32		1982	VAX	32		1977	6	Memory-Memory	CISC	16	Variable	Compare and branch	Little		No	
Blackfin	32		OpenRISC	32, 64	1.3 ^[21]	2010	Z80	8		1976	2	Register-Memory	CISC	17	Variable (8 to 32 bits)	Condition register	Little			
Architecture	Bits	Version	Introduced	Max # operands	Type	Design	Registers (excluding FP/vector)	Instruction encoding	Branch evaluation	Endian-ness	Extensions	Open	Royalty free							

Different ISAs/Compute Architectures - Today

	x86	ARM	Power
Since	1978	1985	1992
# Bit	16/32/64	32/64	32/64
Instruction set	CISC	RISC	RISC
Endianness	Little	Bi (little by default)	Bi (big by default)
Power usage	High	Low	Medium
Linux architecture	i386/amd64/x86_64	arm/arm64/aarch64	powerpc/ppc/ppc64
Licensing	Strict	Flexible	Semi-strict
Examples	Intel 8086 Intel Pentium/Core/Xeon AMD (Ryzen) VIA	Cortex (A/X) Ampere Altra Qualcomm Snapdragon Apple M1/ M2	IBM Power (Power10) Freescale (T-series) Xenon (Xbox 360) Espresso (Wii U)

x86



Current situation: ARM vs x86



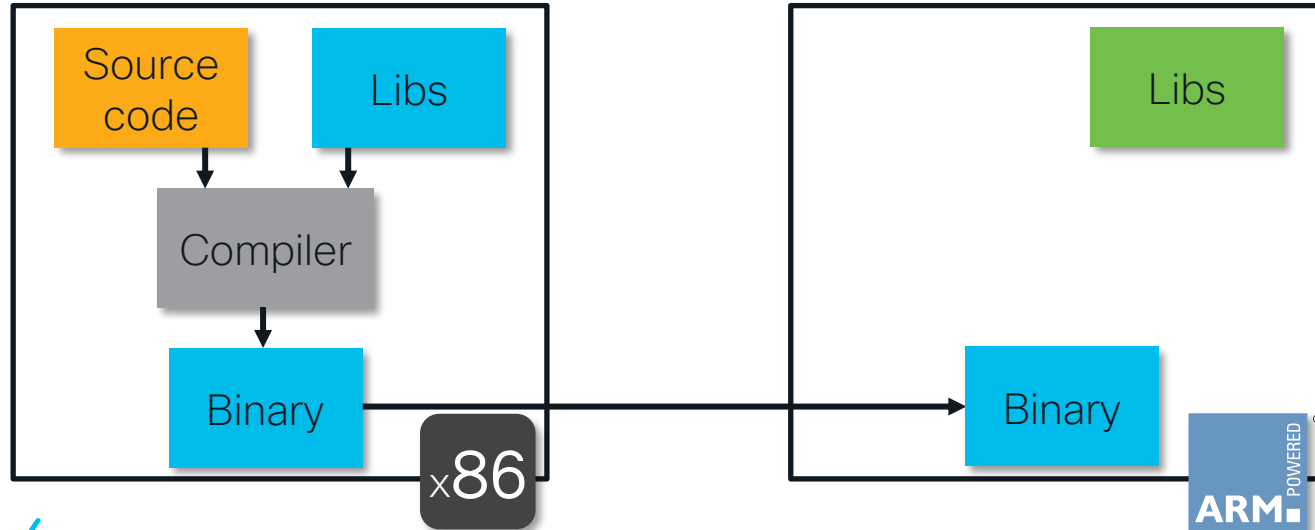
- In essence: **RISC vs. CISC**
- x86 traditionally targets peak performance, ARM energy efficiency
- For **workstations** & **servers**: choice of ISA is not technical
 - With the right hardware, everything can run performant
 - Code compatibility is most important
 - Today, **x86** is dominant here
- For **embedded**, **RISC** makes sense
 - Smaller, cheaper, less power
 - Today, **ARM** is dominant here

CISC	RISC
Complex instructions	Simple instructions
More registers	Less Registers
Microprogramming	Complex compilers
Hardware-focused	Software-focused

The problem

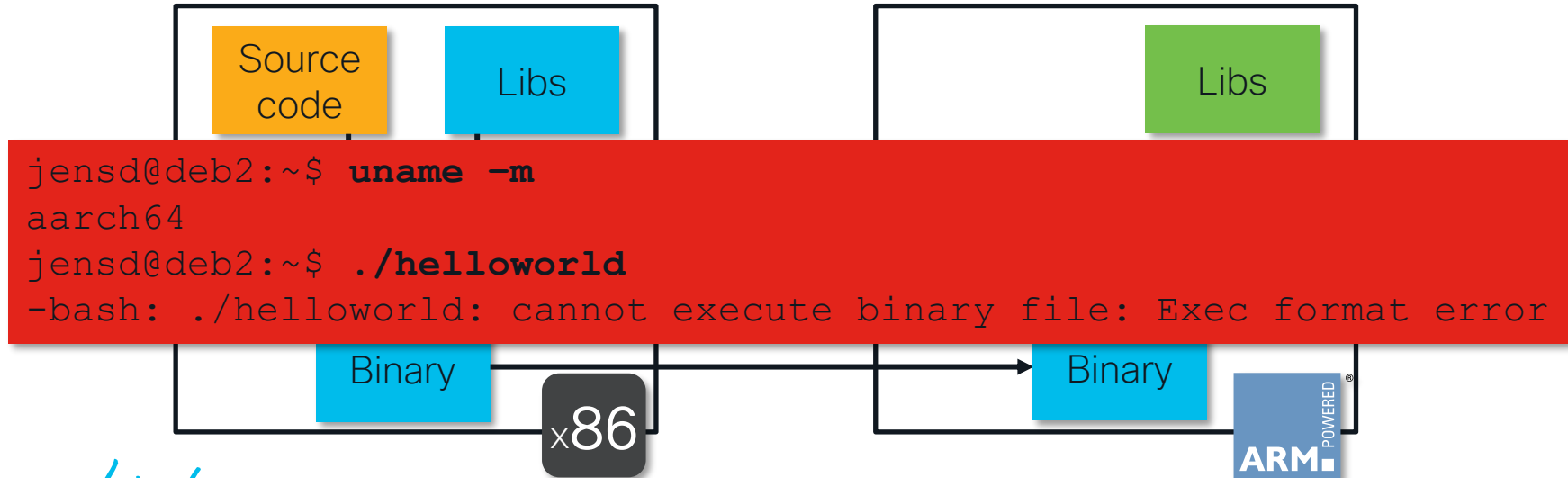
The problem: Current situation

- **Mix of architectures** is real today
- Developer workstation and destination **on different architecture**
- Compiled binary or container image: doesn't run



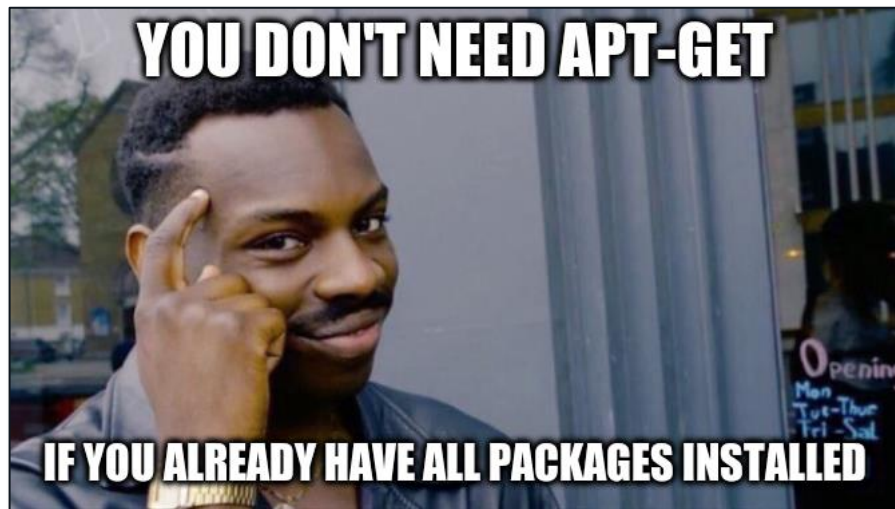
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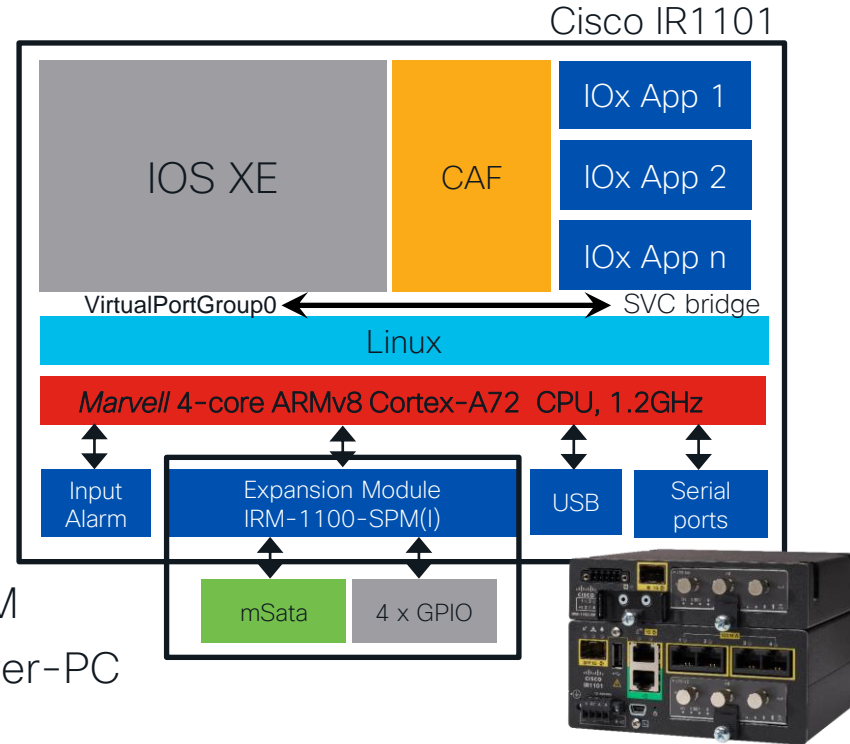
The problem – In practice

- **Self-written code**/tools/automation/containers:
 - Does not run on other architecture
 - Hard to test
- **Common tools**:
 - In **theory**: use package manager
 - In **practice**:
 - Missing packages
 - Missing dependencies
 - No package manager
 - Old/EOL version
 - Uncommon/custom distro
 - Dark site
 - ...



The problem – Relevant for Cisco?

- Where is this relevant?
 - IOx and App-hosting
 - Guest-shell
 - Guest-OS (GOS)
 - Open Agent Container (OAC)
 - Low level troubleshooting tools
- Platforms:
 - Data Center: NX-OS: x86
 - Service Provider: IOS-XR: x86, 32/64 bit ARM
 - Enterprise: IOS-XE: x86, 32/64 bit ARM, Power-PC

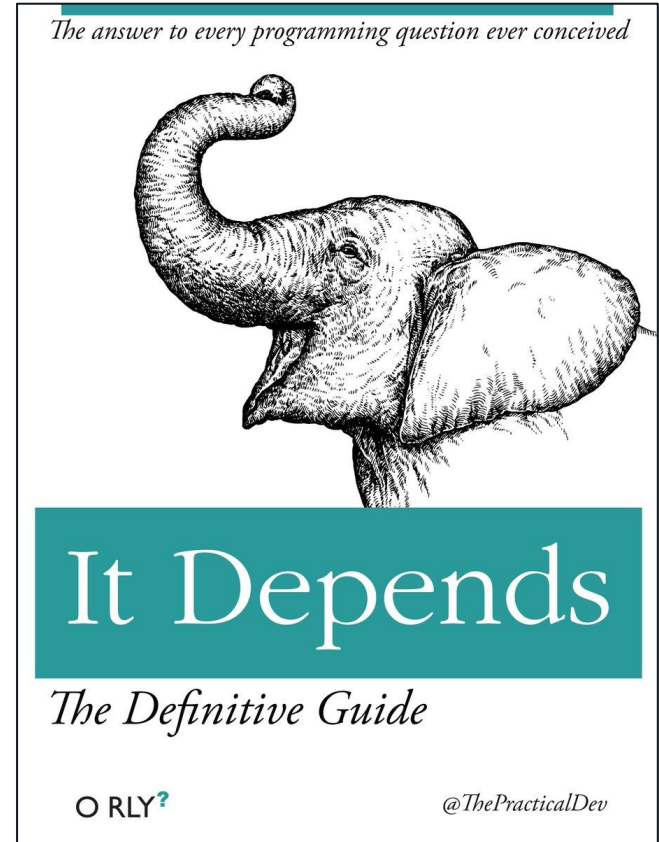


Solution

Solution

It depends...

- Use destination architecture
 - Platform independent languages
 - Cross compilation
 - Emulation
-
- Automation is your friend
 - CI/CD
 - Docker BuildX



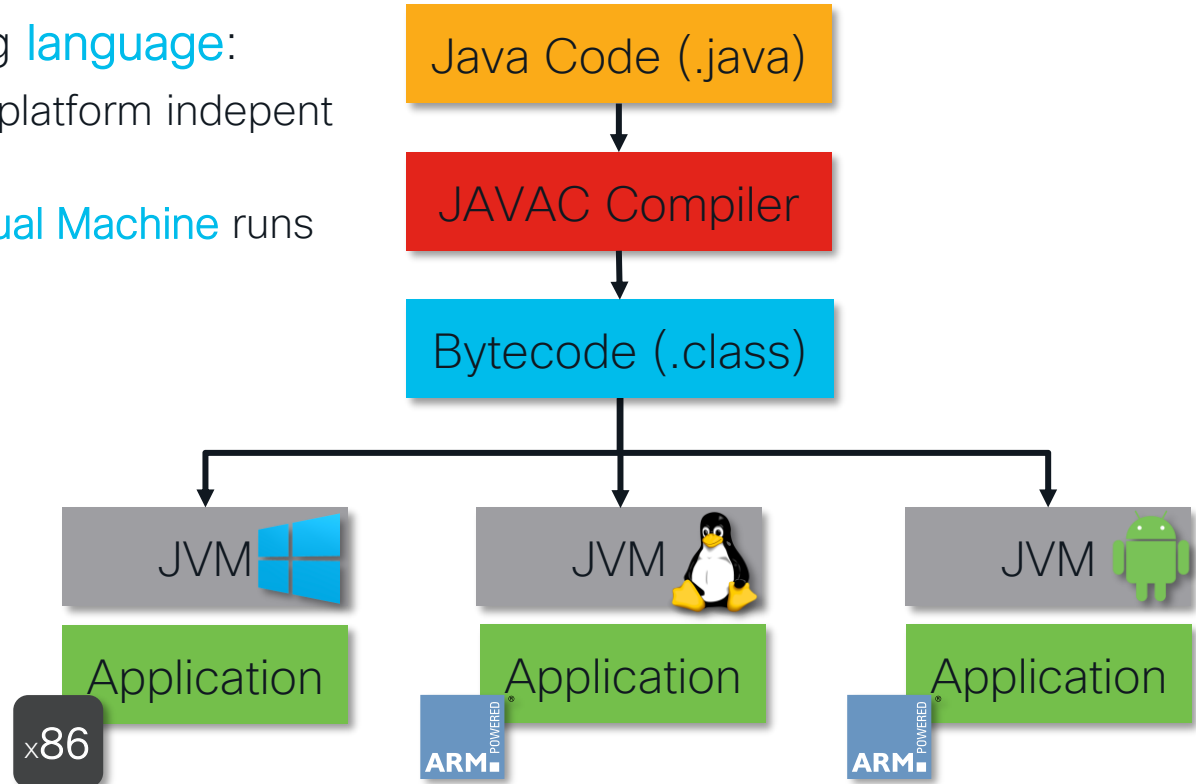
Solution 1: Use destination architecture

- **Develop, build and test on native** CPU architecture:
 - **Physical** hardware on destination architecture
 - **Cloud-based** solution:
 - AWS Graviton
 - Custom Silicon with Neoverse
 - MS Azure
 - Ampere Altra
 - Google GCP Tau T2A
 - Ampere Altra
 - OCI Ampere A1
 - Ampere Altra



Solution 2: Platform Independent Languages

- **Interpreted** programming **language**:
 - Compile (at runtime) into platform independent **bytecode**
 - Architecture-specific **Virtual Machine** runs bytecode
- Popular examples:
 - Java
 - Python
 - PHP
 - Bash
 - TCL ☺



DEMO: Platform Independent Languages

Source code:

```
jensd@Macbook ~ % cat test.py
#!/usr/bin/python3

import os
arch = os.uname().machine
print("Hello Devnet!")
print("This code is running on:", arch)
```

Run on x86:

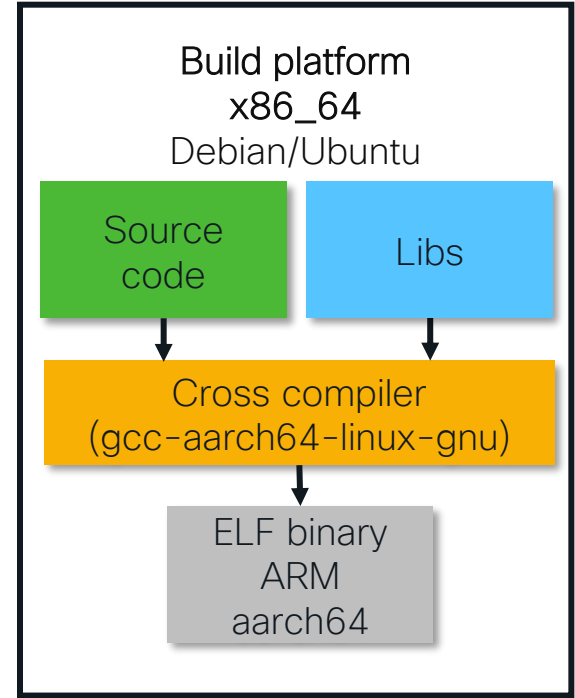
```
jensd@deb1:~$ uname -m
x86_64
jensd@deb1:~$ ./test.py
Hello Devnet!
This code is running on: x86_64
```

Run on ARM:

```
jensd@deb2:~$ uname -m
aarch64
jensd@deb2:~$ ./test.py
Hello Devnet!
This code is running on: aarch64
```

Solution 3: Cross Compiling

- **Compiled language**: C/C++/Go/Rust/...
- **Build for platform X on platform Y**
- Terminology:
 - **Build platform**: Architecture of build machine
 - **Host platform**: Architecture you are building for
 - Target platform: When building compiler tools 🇨🇦
- Build platform can't run resulting binary!



DEMO: Cross Compiling – Prepare machine



For 64 bit ARM (aarch64):

```
jensd@deb1:~$ sudo apt install gcc make gcc-aarch64-linux-gnu  
binutils-aarch64-linux-gnu  
Reading package lists... Done  
Building dependency tree... Done  
...  
Processing triggers for man-db (2.8.5-2) ...  
Processing triggers for libc-bin (2.28-10) ...
```

cross-compiler

For 32 bit
ARM (arm):

```
jensd@deb1:~$ sudo apt install gcc make gcc-arm-linux-gnueabi  
binutils-arm-linux-gnueabi  
Reading package lists... Done  
Building dependency tree... Done  
...
```

assembler (as) , linker (ld) and binary tools

DEMO: Cross Compiling - Build

Source code:

```
jensd@deb1:~$ cat helloworld.c
#include<stdio.h>
int main()
{
    printf("Hello Devnet!\n");
    return 0;
}
```

Build on x86:

cross-compiler

```
jensd@deb1:~$ uname -m
x86_64
jensd@deb1:~$ aarch64-linux-gnu-gcc helloworld.c -o helloworld-aarch64 --static
jensd@deb1:~$ file helloworld-aarch64
helloworld-aarch64: ELF 64-bit LSB executable, ARM aarch64, version 1
(GNU/Linux), statically linked,
BuildID[sha1]=eeb6cee92dd8cce1832cee6a3fb236cf659996b8, for GNU/Linux 3.7.0,
not stripped
```

output (binary)

DEMO: Cross Compiling - Run

- Run on x86:

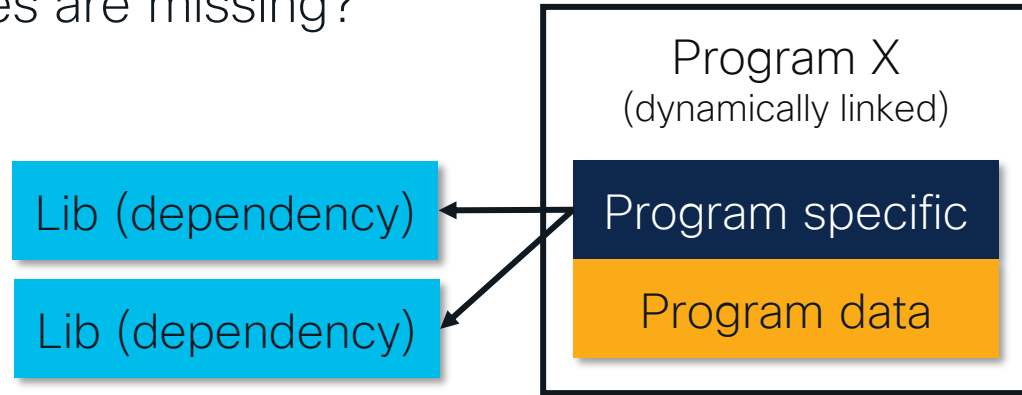
```
jensd@deb1:~$ uname -m  
x86_64  
jensd@deb1:~$ ./helloworld-aarch64  
-bash: ./helloworld-aarch64: cannot execute binary file: Exec format error
```

- Run on ARM:

```
jensd@deb2:~$ uname -m  
aarch64  
jensd@deb2:~$ ./helloworld-aarch64  
Hello Devnet!
```

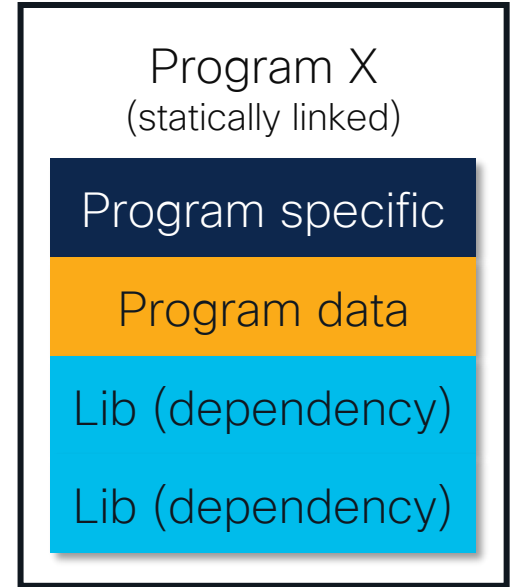
Cross Compiling – Dependencies

- What about **dependencies**?
- By default and recommended: **Dynamic Linking**
- **Dependencies are** external libs and **architecture specific**
- What if dependencies are missing?



Cross Compiling – Static Linking

- Static linking: **include dependencies in binary**
- Not recommended*
 - **Unsecure**: no patches/updates in included libs
 - **Incompatibility**: conflicting libraries that do lower level system calls
 - **Larger** resulting binary
 - Can be **difficult**, especially with libc/glibc

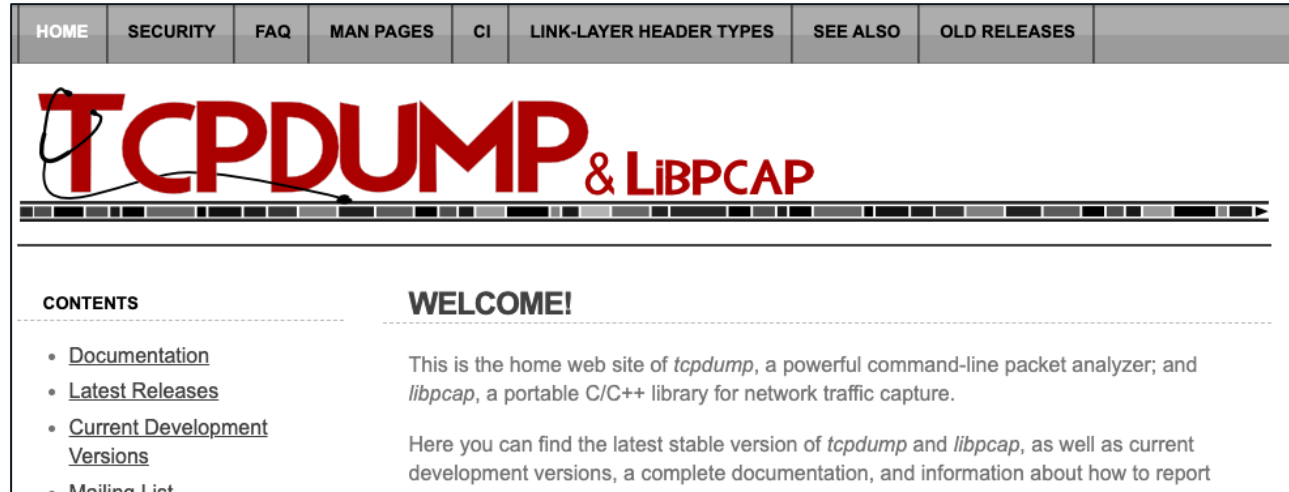


*It works for me 😊

DEMO: Cross Compiling – Static Linking – Source

Build open
source tool:
tcpdump on
x86_64 to use
on aarch64

Get source code:



```
jensd@deb1:~$ wget https://www.tcpdump.org/release/libpcap-1.10.1.tar.gz
jensd@deb1:~$ tar -xvzf libpcap-1.10.1.tar.gz
jensd@deb1:~$ wget https://www.tcpdump.org/release/tcpdump-4.99.1.tar.gz
jensd@deb1:~$ tar -xvzf tcpdump-4.99.1.tar.gz
jensd@deb1:~$ cd libpcap-1.10.1/
jensd@deb1:~/libpcap-1.10.1$
```

DEMO: Cross Compiling – Static Linking – Build

- Build libpcap and tcpdump for aarch64 on x86_64 using musl

```
jensd@deb1:~/libpcap-1.10.1$ CC=aarch64-linux-musl-gcc
jensd@deb1:~/libpcap-1.10.1$ ./configure --build x86_64-pc-linux-gnu --host
aarch64-linux-gnu LDFLAGS="-static"
checking build system type... x86_64-pc-linux-gnu
checking host system type... aarch64-unknown-linux-gnu
```

host-architecture

static linking

build-architecture

```
jensd@deb1:~/libpcap-1.10.0$ cd ../tcpdump-4.99.1
jensd@deb1:~/tcpdump-4.99.0$ ./configure --build x86_64-pc-linux-gnu --host
aarch64-linux-gnu LDFLAGS="-static"
jensd@deb1:~/tcpdump-4.99.0$ make
jensd@deb1:~/tcpdump-4.99.1$ file tcpdump
tcpdump: ELF 64-bit LSB pie executable, ARM aarch64, version 1 (SYSV), statically
linked, with debug_info, not stripped
```

DEMO: Cross Compiling – Static Linking – Run

- Run on x86:

```
jensd@deb1:~/tcpdump-4.99.1$ ldd tcpdump
        not a dynamic executable
jensd@deb1:~/tcpdump-4.99.1$ ./tcpdump
-bash: ./tcpdump: cannot execute binary file: Exec format error
```

- Run on ARM:

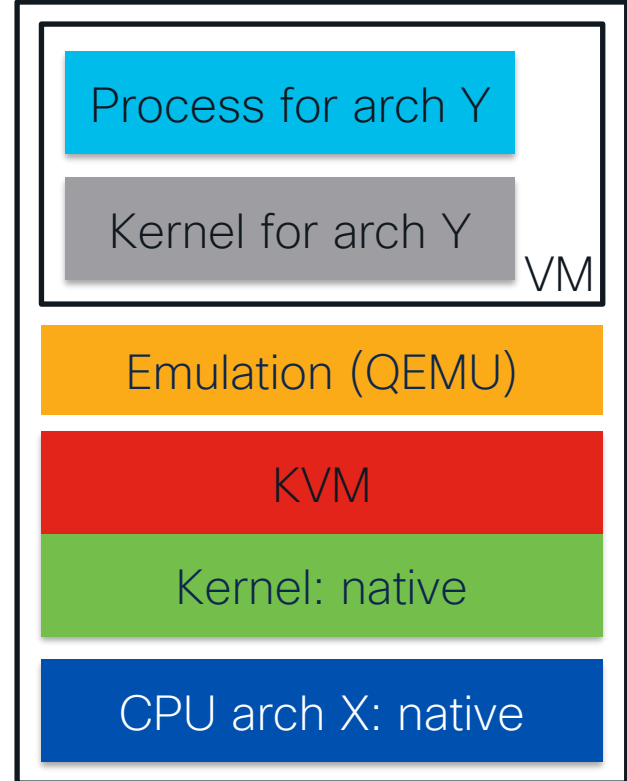
```
jensd@deb2:~$ uname -m
aarch64
jensd@deb2:~$ sudo ./tcpdump -i enp0s9
tcpdump: verbose output suppressed, use -v[v]... for full protocol decode
listening on enp0s9, link-type EN10MB (Ethernet), snapshot length 262144
bytes
...
```

Solution 4: Emulation – QEMU Virtualization

- **Emulate** destination architecture on VM
 - Run virtual machine
 - **Build/Test on VM** as on native platform
- **QEMU**: Generic and open source machine emulator and virtualizer
- Supports many CPU **architectures**
 - For example: **ARM**, alpha, MIPS, **PowerPC**, SPARC, s390x, ...



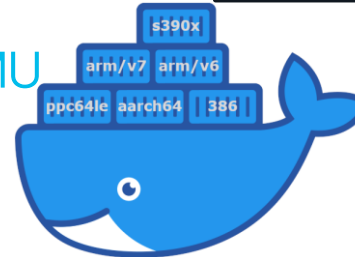
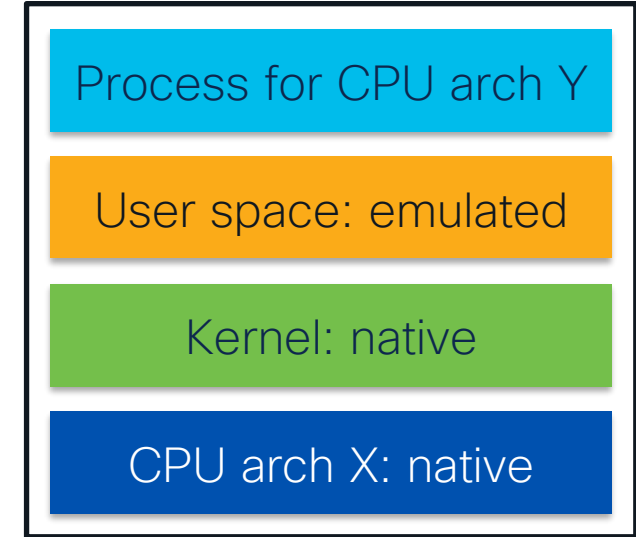
Virtualization



Solution 5: Emulation – QEMU User mode emulation

- **Emulate** with **User mode emulation**:
 - Run processes for another architecture
 - Build/Run Docker image/container for different arch
 - Test binaries as on native
- **Binfmt**: Kernel Support for miscellaneous Binary Formats
 - Instructs kernel to **run binaries with QEMU**

User mode emulation:



DEMO: Emulation – Preparation



- Install OS/Docker
- Install **QEMU emulation binaries** and **binfmt**

```
jensd@deb1:~$ sudo apt-get install qemu-user qemu-user-static binfmt-support
```

- User mode emulation binaries:

```
jensd@deb1:~$ ls /usr/bin/qemu-*static
/usr/bin/qemu-aarch64-static    /usr/bin/qemu-mips64-static    /usr/bin/qemu-s390x-static
/usr/bin/qemu-alpha-static      /usr/bin/qemu-mipsel-static    /usr/bin/qemu-sh4eb-static
/usr/bin/qemu-armeb-static      /usr/bin/qemu-mipsn32el-static /usr/bin/qemu-sh4-static
/usr/bin/qemu-arm-static        /usr/bin/qemu-mipsn32-static   /usr/bin/qemu-sparc32-static
/usr/bin/qemu-cris-static        /usr/bin/qemu-mips-static      /usr/bin/qemu-sparc64-static
/usr/bin/qemu-i386-static        /usr/bin/qemu-or32-static      /usr/bin/qemu-sparc-static
/usr/bin/qemu-m68k-static        /usr/bin/qemu-ppc64abi32-static /usr/bin/qemu-tilegx-static
/usr/bin/qemu-microblazeel-static /usr/bin/qemu-ppc64le-static   /usr/bin/qemu-x86_64-static
/usr/bin/qemu-microblaze-static /usr/bin/qemu-ppc64-static
/usr/bin/qemu-mips64el-static    /usr/bin/qemu-ppc-static
```

DEMO: Emulation – Test User mode emulation

- On x86:

```
jensd@deb1:~$ uname -m
x86_64
jensd@deb1:~$ docker run -v /usr/bin/qemu-aarch64-static:/usr/bin/qemu-
aarch64-static -i -t arm64v8/alpine
/ # uname -m
aarch64
```

Container needs emulation binary

- In the background:

```
jensd@deb1-x86-64:~$ ps aux | grep qemu
jensd      508680  0.6  0.8 1201160 47844 pts/1    Sl+   16:45   0:00
docker run -v /usr/bin/qemu-aarch64-static:/usr/bin/qemu-aarch64-
static -it --rm arm64v8/alpine
root       508741  0.6  0.1 226092  7700 pts/0     Ssl+  16:45   0:00
/usr/libexec/qemu-binfmt/aarch64-binfmt-P /bin/sh /bin/sh
```


DEMO: Emulation – non-x86 Docker image 1/2

1) Dockerfile & Node.js source:

```
FROM arm64v8/alpine
COPY qemu-aarch64-static /usr/bin
RUN apk add --no-cache nodejs npm
COPY server.js .
EXPOSE 1337
CMD ["node","server.js"]
```

```
jensd@debl-x86-64:~$ cat server.js
var http = require('http');
var os = require('os');

var kernel=os.release();
var arch=process.arch;

var server = http.createServer(function (request, response) {
  response.writeHead(200, {"Content-Type": "text/html"});
  response.end("<h1>Node & Docker Running <br /> Kernel: " +
    kernel+"<br />Arch:"+arch+"<h1>");
});

server.listen(1337);
console.log("Node HTTP Server started at port 1337");
```

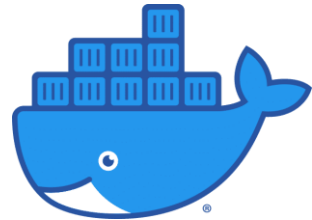


2) Build on x86

```
jensd@debl:~$ docker build -t devnetjs .
```

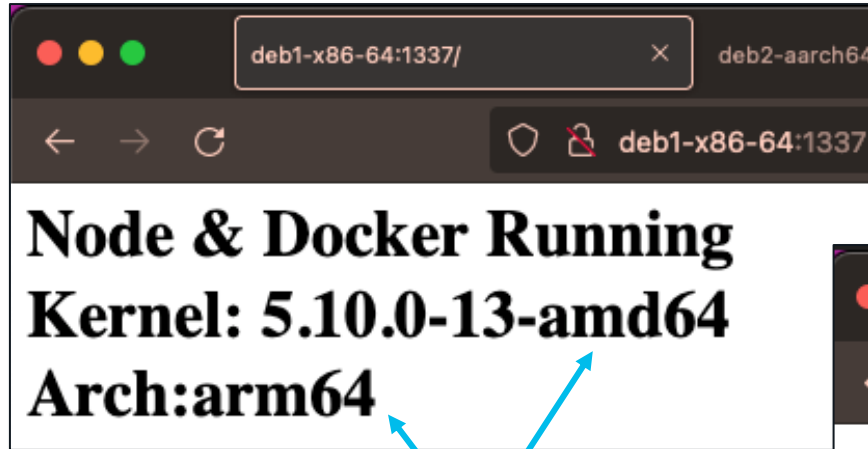
2) Run

```
jensd@debl:~$ docker run -ti --rm -p 1337:1337 devnetjs
Node HTTP Server started at port 1337
```



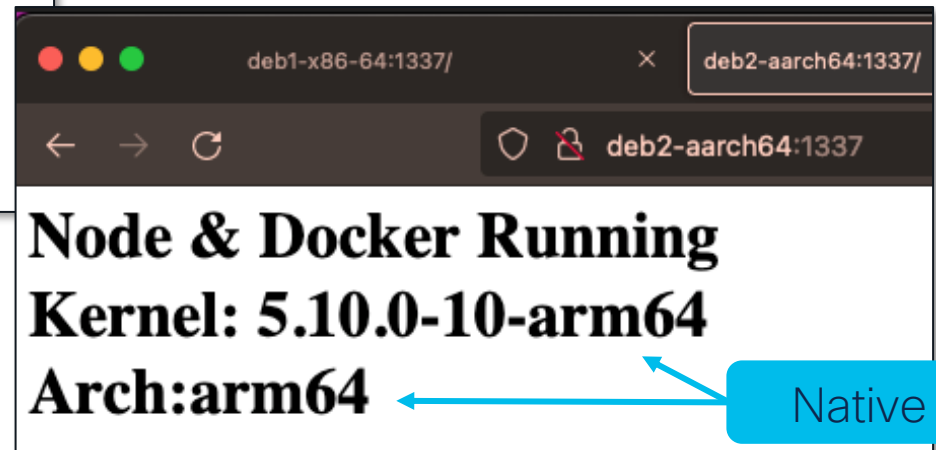
DEMO: Emulation – non-x86 Docker image 2/2

Run on x86:



Emulated

Run on ARM:



Native

Emulation – Testing

- Remember the cross-compiled tools we could not run?
- After installing QEMU and binfmt:

```
jensd@deb1:~$ uname -m
x86_64
jensd@deb1:~$ file helloworld-aarch64
helloworld-aarch64: ELF 64-bit LSB executable, ARM aarch64, version 1
(GNU/Linux), statically linked,
BuildID[sha1]=eeb6cee92dd8cce1832cee6a3fb236cf659996b8, for GNU/Linux
3.7.0, not stripped
jensd@deb1:~$ ./helloworld-aarch64
Hello Devnet!
```

Automation

- Integrate in **CI/CD** pipeline
 - Cross Compile, Emulation, Testing, ...
 - Gitlab runners for each arch
- **Docker BuildX:**
 - Using QEMU emulation support in the kernel
 - Building on multiple native nodes using same builder instance
 - Using stage in Dockerfile to cross-compile to different architectures



Summary

Situation today: mix of x86 and ARM

Code platform independent

Use Cross Compilation for compiled languages

Use Emulation to build containers and testing

Combine everything with automation

Complete your Session Survey

- Please complete your session survey after each session. Your feedback is important.
- All surveys can be taken in the Cisco Events Mobile App or by logging in to the Session Catalog and clicking the "Attendee Dashboard" at <https://www.ciscolive.com/emea/learn/sessions/session-catalog.html>



Continue Your Education



Visit the Cisco Showcase for related demos.



Book your one-on-one Meet the Engineer meeting.



Attend any of the related sessions at the DevNet, Capture the Flag, and Walk-in Labs zones.



Visit the On-Demand Library for more sessions at ciscolive.com/on-demand.



The bridge to possible

Thank you

CISCO *Live!*

CISCO *Live!*


ALL IN

Additional Examples

Cross Compiling – Demo with make 1/3 – Source

Build open
source tool:
strace on
x86_64 to use
on aarch64

Get source code:



strace
linux syscall tracer

Official repositories are at [GitHub](#) and [GitLab](#).

You can get latest binary packages from [Fedora](#) or [Ubuntu](#) or [Debian](#).

strace is a diagnostic, debugging and instructional userspace utility for Linux. It is used to monitor and tamper with interactions between processes and the Linux kernel, which include system calls, signal deliveries, and changes of process state.

System administrators, diagnosticians and trouble-shooters will find it invaluable for solving problems with programs for which the source is not readily available since they do not need to be recompiled in order to trace them.

The operation of strace is made possible by the kernel feature known as [ptrace](#).

Some of the features

Attach to an already running process.

```
$ strace -p 26380
strace: Process 26380 attached
...
```

Print paths and more info associated with file descriptors.

```
$ strace -yy cat /dev/null
...
openat(AT_FDCWD, "/dev/null", O_RDONLY) = 3</dev/null<char 1:3>>
fstat(3</dev/null<char 1:3>>, {st_mode=S_IFCHR|0666, st_rdev=makedev(0x1, 0x3),
..}) = 0
fadvise64(3</dev/null<char 1:3>>, 0, 0, POSIX_FADV_SEQUENTIAL) = 0
read(3</dev/null<char 1:3>>, "", 131072) = 0
...
```

```
jensd@deb1:~$ wget https://github.com/strace/.../v5.17/strace-5.17.tar.xz
...
strace-5.17.tar.xz 100%[=====>] 2.17M 11.6MB/s in 0.2s
2022-04-22 17:22:46 (11.6 MB/s) - 'strace-5.17.tar.xz' saved [2281220/2281220]
jensd@deb1:~$ tar -xf strace-5.17.tar.xz
jensd@deb1:~$ cd strace-5.17/
jensd@deb1:~/strace-5.17$
```

Cross Compiling – Demo with make 2/3 – Build

Building on x86:

build-architecture

host-architecture

```
jensd@deb1:~$ uname -m
x86_64
jensd@deb1:~$ ./configure --build x86_64-pc-linux-gnu --host aarch64-linux-
gnu LDFLAGS="-static -pthread" --enable-mpers=check
checking for a BSD-compatible install... /usr/bin/install -c
checking for aarch64-linux-gnu-strip... aarch64-linux-gnu-strip
...
jensd@deb1:~/strace-5.17$ make
aarch64-linux-gnu-gcc -E -P -DHAVE_CONFIG_H \
...
make[1]: Leaving directory '/home/jensd/strace-5.17'
jensd@deb1:~/strace-5.17$ file ./src/strace
./src/strace: ELF 64-bit LSB executable, ARM aarch64, version 1 (GNU/Linux),
statically linked, BuildID[sha1]=c198971f9db07df7b05eb195a8ef9cc9f16657fe,
for GNU/Linux 3.7.0, with debug_info, not stripped
```

Cross Compiling – Demo with make 3/3 – Run

- Run on x86:

```
jensd@deb1:~$ uname -m  
x86_64  
jensd@deb1:~$ ./strace -V  
-bash: ./strace: cannot execute binary file: Exec format error
```

- Run on ARM:

```
jensd@deb2:~$ uname -m  
aarch64  
jensd@deb2:~$ ./strace -V  
strace -- version 5.17  
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This is free software; see the source for copying conditions. There is NO  
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
```