# Red Hat Developer Tools 1

## Using LLVM 10.0.1 Toolset

Installing and using the LLVM 10.0.1 toolset

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# Red Hat Developer Tools 1 Using LLVM 10.0.1 Toolset

Installing and using the LLVM 10.0.1 toolset

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## Abstract

LLVM is a Red Hat offering for developers on the Red Hat Enterprise Linux platform. The Using LLVM provides an overview of this product, explains how to invoke and use the LLVM versions of the tools, and links to resources with more in-depth information.

# Table of Contents

CHAPTER 1. LLVM ..... 4
1.1. ABOUT LLVM TOOLSET 4
1.2. COMPATIBILITY 4
1.3. GETTING ACCESS TO LLVM TOOLSET ON RED HAT ENTERPRISE LINUX 7 5
Prerequisites 5
Procedure 5
Additional Resources 6
1.4. INSTALLING LLVM TOOLSET 6
1.4.1. Installing CMake on Red Hat Enterprise Linux 7
1.4.1.1. CMake installable documentation 7
1.4.2. Installable documentation 7
1.5. ADDITIONAL RESOURCES 7
Online documentation 7

CHAPTER 2. CLANG ..... 9
2.1. USING CLANG 9
2.1.1. Compiling a C source file to a binary file 9
2.1.2. Compiling a C source file to an object file 10
2.1.3. Linking C object files to a binary File 10
2.1.4. Using the clang Integrated Assembler 10
2.2. RUNNING A C PROGRAM 11
2.3. USING CLANG++ 11
2.3.1. Compiling a C++ Source File to a Binary File 11
2.3.2. Compiling a C++ source file to an object file 12
2.3.3. Linking C++ object files to a binary file 12
2.4. RUNNING A C++ PROGRAM 13
2.5. ADDITIONAL RESOURCES 13
Installed documentation 13
Online documentation 14
See Also 14

CHAPTER 3. LLDB ..... 15
3.1. PREPARING A PROGRAM FOR DEBUGGING 15
3.2. RUNNING LLDB 15
3.3. LISTING THE SOURCE CODE 16
3.4. USING BREAKPOINTS 17
Setting a New Breakpoint 17
Listing Breakpoints 17
Deleting Existing Breakpoints 18
3.5. STARTING EXECUTION 18
3.6. DISPLAYING CURRENT PROGRAM DATA 19
3.7. CONTINUING EXECUTION AFTER A BREAKPOINT 19
3.8. ADDITIONAL RESOURCES 21
Online documentation 21
See also 21

CHAPTER 4. CONTAINER IMAGES WITH LLVM TOOLSET ..... 22
4.1. IMAGE CONTENTS 22
4.2. ACCESSING THE IMAGES 22
4.3. USING AS BUILDER IMAGES WITH SOURCE-TO-IMAGE 22
4.4. ADDITIONAL RESOURCES 23

CHAPTER 5. CHANGES IN LLVM 10.0.1 TOOLSET ..... 24

# CHAPTER 1. LLVM

## 1.1. ABOUT LLVM TOOLSET

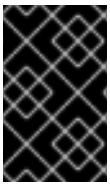
LLVM Toolset is a Red Hat offering for developers on the Red Hat Enterprise Linux platform. It provides the **LLVM** compiler infrastructure framework, the **Clang** compiler for the C and C++ languages, the **LLDB** debugger, and related tools for code analysis.

LLVM Toolset is distributed as a part of Red Hat Developer Tools for Red Hat Enterprise Linux 7. LLVM Toolset is available as a module for Red Hat Enterprise Linux 8.

The following components are available as a part of LLVM Toolset:

**Table 1.1. LLVM Components**

| Name | Version | Description |
|---|---|---|
| **clang** | 10.0.1 | An LLVM compiler front end for C and C++. |
| **lldb** | 10.0.1 | A C and C++ debugger using portions of LLVM. |
| **compiler-rt** | 10.0.1 | Runtime libraries for LLVM. |
| **llvm** | 10.0.1 | A collection of modular and reusable compiler and toolchain technologies. |
| **libomp** | 10.0.1 | A library for utilization of Open MP API specification for parallel programming. |
| **lld** | 10.0.1 | An LLVM linker. |
| **python-lit** | 0.10.0 | A software testing tool for LLVM- and Clang-based test suites. |



**IMPORTANT**

LLVM Toolset for Red Hat Enterprise Linux 7 also provides CMake as a separate package. On Red Hat Enterprise Linux 8, CMake is available in the system repository. For more information on how to install CMake, see Section 1.4, “Installing LLVM Toolset”.

## 1.2. COMPATIBILITY

LLVM Toolset is available for Red Hat Enterprise Linux 7 and Red Hat Enterprise Linux 8 on the following architectures:

- The 64-bit Intel and AMD architectures

- The IBM Power Systems architecture [1]
- The 64-bit ARM architecture [2]
- The little-endian variant of IBM Power Systems architecture
- The IBM Z Systems architecture

## 1.3. GETTING ACCESS TO LLVM TOOLSET ON RED HAT ENTERPRISE LINUX 7

This chapter lists the steps to perform before installing LLVM Toolset on a Red Hat Enterprise Linux 7 system. Complete the following steps to attach a subscription that provides access to the repository for Red Hat Developer Tools, and then enable the Red Hat Developer Tools and Red Hat Software Collections repositories.

### Prerequisites

- Verify that **wget** is installed on your system. The tool is available from the default Red Hat Enterprise Linux repositories. To install it, run the following command as root:

```
# yum install wget
```

### Procedure

1. Get the latest subscription data from the server:

```
# subscription-manager refresh
```

2. Use the following command to register the system:

```
# subscription-manager register
```

   You can also register the system by following the appropriate steps in Registering and Unregistering a System in the Red Hat Subscription Management document.

3. Display a list of all subscriptions that are available for your system and identify the pool ID for the subscription:

```
# subscription-manager list --available
```

   This command displays the subscription name, unique identifier, expiration date, and other details related to it. The pool ID is listed on a line beginning with **Pool ID**.

4. Attach the subscription that provides access to the **Red Hat Developer Tools** repository. Use the pool ID you identified in the previous step.

```
# subscription-manager attach --pool=<appropriate pool ID from the subscription>
```

5. Verify the list of subscriptions attached to your system:

```
# sudo subscription-manager list --consumed
```

6. Enable the **rhel-7-*variant*-devtools-rpms** repository:

```
# subscription-manager repos --enable rhel-7-variant-devtools-rpms
```

Replace ***variant*** with the Red Hat Enterprise Linux system variant ( **server** or **workstation**).

Consider using Red Hat Enterprise Linux Server to access the widest range of the development tools.

7. Enable the **rhel-*variant*-rhscl-7-rpms** repository:

```
# subscription-manager repos --enable rhel-variant-rhscl-7-rpms
```

Replace ***variant*** with the Red Hat Enterprise Linux system variant ( **server** or **workstation**).

8. Add the Red Hat Developer Tools GPG key to your system:

```
# cd /etc/pki/rpm-gpg
# wget -O RPM-GPG-KEY-redhat-devel https://www.redhat.com/security/data/a5787476.txt
# rpm --import RPM-GPG-KEY-redhat-devel
```

Once the subscription is attached to the system and the repositories are enabled, install LLVM Toolset as described in Section 1.4, "Installing LLVM Toolset".

### Additional Resources

- For more information on how to register your system using Red Hat Subscription Management and associate it with subscriptions, see the Red Hat Subscription Management collection of guides.

## 1.4. INSTALLING LLVM TOOLSET

LLVM Toolset is distributed as a collection of RPM packages that can be installed, updated, uninstalled, and inspected by using the standard package management tools that are included in Red Hat Enterprise Linux.

Note that a valid subscription that provides access to the Red Hat Developer Tools content set is required in order to install LLVM Toolset on your Red Hat Enterprise Linux 7 system. For detailed instructions on how to associate your Red Hat Enterprise Linux 7 system with an appropriate subscription and get access to LLVM Toolset, see Section 1.3, "Getting access to LLVM Toolset on Red Hat Enterprise Linux 7".

**IMPORTANT**

Before installing LLVM Toolset, install all available Red Hat Enterprise Linux updates.

1. Install all of the components included in LLVM Toolset for your operating system:
   - On Red Hat Enterprise Linux 7, install the **llvm-toolset 10.0** collection:

```
# yum install llvm-toolset-10.0
```

   - On Red Hat Enterprise Linux 8, install the **llvm-toolset** module:

```
# yum module install llvm-toolset
```

This installs all development and debugging tools, and other dependent packages to the system.

### 1.4.1. Installing CMake on Red Hat Enterprise Linux

CMake is available as a separate package. To install CMake:

On Red Hat Enterprise Linux 7, install the **llvm-toolset-10.0-cmake** package:

```
# yum install llvm-toolset-10.0-cmake llvm-toolset-10.0-cmake-doc
```

On Red Hat Enterprise Linux 8, install the **cmake** package:

```
# yum install cmake cmake-doc
```

#### 1.4.1.1. CMake installable documentation

The **cmake** package contains installed documentation. On Red Hat Enterprise Linux 7, find the documentation in **opt/rh/llvm-toolset-10.0/root/usr/share/doc/llvm-toolset-10.0-cmake-3.6.2/html/index.html**. On Red Hat Enterprise Linux 8, find the documentation in **/usr/share/doc/llvm/html/index.html**.

### 1.4.2. Installable documentation

The following section describes how to install the LLVM Toolset installable documentation.

- On Red Hat Enterprise Linux 7, install the **llvm-doc-10.0** package:

```
# yum install llvm-toolset-10.0-llvm-doc
```

The documentation is available in **/opt/rh/llvm-toolset-10.0/root/usr/share/doc/llvm-toolset-10.0-llvm-10.0/html/index.html**.

- On Red Hat Enterprise Linux 8, install the **llvm-doc** package:

```
# yum install llvm llvm-doc
```

The documentation is available in **/usr/share/doc/llvm/html/index.html**.

The documenation for CMake is not included in the LLVM documentation package. To install the documentation for CMake, see Section 1.4.1.1, “CMake installable documentation”.

## 1.5. ADDITIONAL RESOURCES

A detailed description of LLVM Toolset and all its features is beyond the scope of this document. For more information, see the resources listed below.

### Online documentation

- LLVM documentation overview – The official **LLVM** documentation.

[1] Only available on RHEL 7.

[2] Only available on RHEL 8.

# CHAPTER 2. CLANG

**clang** is a **LLVM** compiler front end for C-based languages: C, C++, Objective C/C++, OpenCL, and Cuda.

LLVM Toolset is distributed with **clang 10.0.1**.

## 2.1. USING CLANG

NOTE

You can execute any command using the **scl** utility on Red Hat Enterprise Linux 7, causing it to be run with the LLVM binaries available. To use LLVM Toolset on Red Hat Enterprise Linux 7 without a need to use **scl enable** with every command, run a shell session with:

```
$ scl enable llvm-toolset-10.0 'bash'
```

### 2.1.1. Compiling a C source file to a binary file

To compile a C program to a binary file:

- For Red Hat Enterprise Linux 7:

  ```
  $ scl enable llvm-toolset-10.0 'clang -o output_file source_file'
  ```

- For Red Hat Enterprise Linux 8:

  ```
  $ clang -o output_file source_file
  ```

This creates a binary file named ***output_file*** in the current working directory. If the **-o** option is omitted, the compiler creates a binary file named **a.out** by default.

**Example 2.1. Compiling a C Program with clang**

Consider a source file named **hello.c** with the following contents:

```
#include <stdio.h>

int main(int argc, char *argv[]) {
  printf("Hello, World!\n");
  return 0;
}
```

Compile this source code on the command line by using the **clang** compiler from LLVM Toolset:

- For Red Hat Enterprise Linux 7:

  ```
  $ scl enable llvm-toolset-10.0 'clang -o hello hello.c'
  ```

- For Red Hat Enterprise Linux 8:

```
$ clang -o hello hello.c
```

This creates a new binary file called **hello** in the current working directory.

### 2.1.2. Compiling a C source file to an object file

When you are working on a project that consists of several source files, it is common to compile an object file for each of the source files first and then link these object files together. This way, when you change a single source file, you can recompile only this file without having to compile the entire project.

To compile a C source file to an object file:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'clang -o object_file -c source_file'
```

- For Red Hat Enterprise Linux 8:

```
$ clang -o object_file -c source_file
```

This creates an object file named ***object_file***. If the **-o** option is omitted, the compiler creates a file named after the source file with the **.o** file extension.

### 2.1.3. Linking C object files to a binary File

To link object files together and create a binary file:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'clang -o output_file object_file ...'
```

- For Red Hat Enterprise Linux 8:

```
$ clang -o output_file object_file ...
```

IMPORTANT

Certain more recent library features are statically linked into applications built with LLVM Toolset to support execution on multiple versions of Red Hat Enterprise Linux. This creates an additional minor security risk as standard Red Hat Enterprise Linux errata do not change this code. If the need arises for developers to rebuild their applications due to this risk, Red Hat will communicate this using a security erratum.

Because of this additional security risk, developers are strongly advised not to statically link their entire application for the same reasons.

### 2.1.4. Using the clang Integrated Assembler

To produce an object file from an assembly language program, run the **clang** tool as follows:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'clang -o object_file source_file'
```

- For Red Hat Enterprise Linux 8:

```
$ clang -o object_file source_file
```

This creates an object file named ***object_file*** in the current working directory.

## 2.2. RUNNING A C PROGRAM

When **clang** compiles a program, it creates an executable binary file. To run this program on the command line, change to the directory with the executable file and run the program:

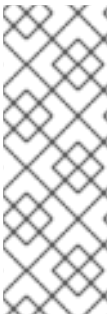
```
$ ./file_name
```

**Example 2.2. Running a C program on the command line**

Assuming that you have successfully compiled the **hello** binary file as shown in Example 2.1, "Compiling a C Program with clang", you can run it by typing the following command:

```
$ ./hello
Hello, World!
```

## 2.3. USING CLANG++



NOTE

You can execute any command using the **scl** utility on Red Hat Enterprise Linux 7, causing it to be run with the LLVM binaries available. To use LLVM Toolset on Red Hat Enterprise Linux 7 without a need to use **scl enable** with every command, run a shell session with:

```
$ scl enable llvm-toolset-10.0 'bash'
```

### 2.3.1. Compiling a C++ Source File to a Binary File

To compile a C++ program on the command line, run the **clang++** compiler as follows:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'clang++ -o output_file source_file ...'
```

- For Red Hat Enterprise Linux 8:

```
$ clang++ -o output_file source_file ...
```

This creates a binary file named ***output_file*** in the current working directory. If the **-o** option is omitted, the **clang++** compiler creates a file named **a.out** by default.

### 2.3.2. Compiling a C++ source file to an object file

When you are working on a project that consists of several source files, it is common to compile an object file for each of the source files first and then link these object files together. This way, when you change a single source file, you can recompile only this file without having to compile the entire project.

To compile an object file on the command line:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'clang++ -o object_file -c source_file'
```

- For Red Hat Enterprise Linux 8:

```
$ clang++ -o object_file -c source_file
```

This creates an object file named ***object_file***. If the **-o** option is omitted, the **clang++** compiler creates a file named after the source file with the **.o** file extension.

### 2.3.3. Linking C++ object files to a binary file

To link object files together and create a binary file:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'clang++ -o output_file object_file ...'
```

- For Red Hat Enterprise Linux 8:

```
$ clang++ -o output_file object_file ...
```

**IMPORTANT**

Certain more recent library features are statically linked into applications built with LLVM Toolset to support execution on multiple versions of Red Hat Enterprise Linux. This creates an additional minor security risk as standard Red Hat Enterprise Linux errata do not change this code. If the need arises for developers to rebuild their applications due to this risk, Red Hat will communicate this using a security erratum.

Because of this accitional security risk, developers are strongly advised not to statically link their entire application for the same reasons.

**Example 2.3. Compiling a C++ Program on the Command Line**

Consider a source file named **hello.cpp** with the following contents:

```
#include <iostream>

using namespace std;

int main(int argc, char *argv[]) {
```

```
    cout << "Hello, World!" << endl;
    return 0;
}
```

Compile this source code on the command line by using the **clang++** compiler from LLVM:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'clang++ -o hello hello.cpp'
```

- For Red Hat Enterprise Linux 8:

```
$ clang++ -o hello hello.cpp
```

This creates a new binary file called **hello** in the current working directory.

## 2.4. RUNNING A C++ PROGRAM

When **clang++** compiles a program, it creates an executable binary file. Change to the directory with the executable file and run this program:

```
./file_name
```

**Example 2.4. Running a C++ program on the command line**

Assuming that you have successfully compiled the **hello** binary file as shown in Example 2.3, "Compiling a C++ Program on the Command Line", you can run it by typing the following at a shell prompt:

```
$ ./hello
Hello, World!
```

## 2.5. ADDITIONAL RESOURCES

A detailed description of the **clang** compiler and its features is beyond the scope of this document. For more information, see the resources listed below.

### Installed documentation

- *clang*(1) — The manual page for the **clang** compiler provides detailed information on its usage; with few exceptions, **clang++** accepts the same command line options as **clang**. To display the manual page for the version included in LLVM Toolset:
  - For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'man clang'
```

  - For Red Hat Enterprise Linux 8:

```
$ man clang
```

### Online documentation

- clang – The clang compiler documentation provides detailed information about use of **clang**.

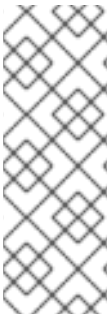
### See Also

- Chapter 1, *LLVM* – An overview of LLVM and more information on how to install it on your system.

# CHAPTER 3. LLDB

**lldb** is a command line tool you can use to debug programs written in C and C++. It allows you to inspect memory within the code being debugged, control the execution state of the code, detect the execution of particular sections of code, and much more.

LLVM Toolset is distributed with **lldb 10.0.1**.



**NOTE**

You can execute any command using the **scl** utility on Red Hat Enterprise Linux 7, causing it to be run with the LLVM binaries available. To use LLVM Toolset on Red Hat Enterprise Linux 7 without a need to use **scl enable** with every command, run a shell session with:

```
$ scl enable llvm-toolset-10.0 'bash'
```

## 3.1. PREPARING A PROGRAM FOR DEBUGGING

To compile a C or C++ program with debugging information that **lldb** can read, make sure the compiler you use is instructed to create debug information.

- For instructions on suitably configuring **clang**, see the section Controlling Debug Information in Clang Compiler User's Manual.
- For instructions on suitably configuring **GCC**, see *Red Hat Developer Toolset User Guide*, Section 7.2. Preparing a Program for Debugging .

## 3.2. RUNNING LLDB

To run **lldb** on a program you want to debug:

- For Red Hat Enterprise Linux 7:

  ```
  $ scl enable llvm-toolset-10.0 'lldb program_file_name'
  ```

- For Red Hat Enterprise Linux 8:

  ```
  $ lldb program_file_name
  ```

This command starts **lldb** in an interactive mode and displays the default prompt, **(lldb)**.

To quit the debugging session and return to the shell prompt, run the following command at any time:

```
(lldb) quit
```

**Example 3.1. Running the lldb Utility on the fibonacci Binary File**

Consider a C source file named **fibonacci.c** with the following content:

```
#include <stdio.h>
#include <limits.h>
```

```
int main (int argc, char *argv[]) {
  unsigned long int a = 0;
  unsigned long int b = 1;
  unsigned long int sum;

  while (b < LONG_MAX) {
    printf("%ld ", b);
    sum = a + b;
    a = b;
    b = sum;
  }
  return 0;
}
```

Enable the debug information and compile the **fibonacci.c** source file with the following command:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'clang -g -o fibonacci fibonacci.c'
```

- For Red Hat Enterprise Linux 8:

```
$ clang -g -o fibonacci fibonacci.c
```

Refer to Section 3.1, “Preparing a program for debugging” for information about controlling debug information using **GCC** or **clang**.

Start debugging the program with **lldb**:

- For Red Hat Enterprise Linux 7:

```
$ scl enable llvm-toolset-10.0 'lldb fibonacci'
(lldb) target create "fibonacci"
Current executable set to 'fibonacci' (x86_64).
(lldb)
```

- For Red Hat Enterprise Linux 8:

```
$ lldb fibonacci
(lldb) target create "fibonacci"
Current executable set to 'fibonacci' (x86_64).
(lldb)
```

The output indicates that the program **fibonacci** is ready for debugging.

## 3.3. LISTING THE SOURCE CODE

To view the source code of the program you are debugging:

```
(lldb) list
```

As a result, the first ten lines of the source code are displayed.

To display the code from a particular line:

```
(lldb) list source_file_name:line_number
```

Additionally, **lldb** displays source code listing automatically in the following situations:

- Before you start the execution of the program you are debugging, **lldb** displays the first ten lines of the source code.
- Each time the execution of the program is stopped, **lldb** displays the lines that surround the line on which the execution stops.

## 3.4. USING BREAKPOINTS

### Setting a New Breakpoint

To set a new breakpoint at a certain line:

```
(lldb) breakpoint source_file_name:line_number
```

To set a breakpoint on a certain function:

```
(lldb) breakpoint source_file_name:function_name
```

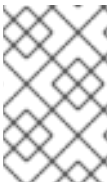
**Example 3.2. Setting a new breakpoint**

This example assumes that you have successfully compiled the **fibonacci.c** file as shown in Example 3.1, “Running the lldb Utility on the fibonacci Binary File” .

Set two breakpoints at line 10 by running the following commands:

```
(lldb) b 10
Breakpoint 1: where = fibonacci`main + 33 at fibonacci.c:10, address = 0x000000000040054e
```

```
(lldb)  breakpoint set -f fibonacci.c --line 10
Breakpoint 2: where = fibonacci`main + 33 at fibonacci.c:10, address = 0x000000000040054e
```



**NOTE**

In **lldb**, the command **b** is not an alias to **breakpoint**. You can use both commands to set breakpoints, but **b** uses a subset of the syntax supported by the **gdb break** command, and **breakpoint** uses **lldb** syntax for setting breakpoints.

### Listing Breakpoints

To display a list of currently set breakpoints:

```
(lldb) breakpoint list
```

**Example 3.3. Listing Breakpoints**

This example assumes that you have successfully followed the instructions in Example 3.2, "Setting a new breakpoint".

Display the list of currently set breakpoints:

```
(lldb) breakpoint list
Current breakpoints:
1: file = 'fibonacci.c', line = 10, exact_match = 0, locations = 1
  1.1: where = fibonacci`main + 33 at fibonacci.c:10, address = fibonacci[0x000000000040054e],
unresolved, hit count = 0

2: file = 'fibonacci.c', line = 10, exact_match = 0, locations = 1
  2.1: where = fibonacci`main + 33 at fibonacci.c:10, address = fibonacci[0x000000000040054e],
unresolved, hit count = 0
```

### Deleting Existing Breakpoints

To delete a breakpoint that is set at a certain line:

```
(lldb) breakpoint clear -f source_file_name -l line_number
```

**Example 3.4. Deleting an Existing Breakpoint**

This example assumes that you have successfully compiled the **fibonacci.c** file.

Set a new breakpoint at line 7:

```
(lldb) b 7
Breakpoint 3: where = fibonacci`main + 31 at fibonacci.c:9, address = 0x000000000040054c
```

Remove this breakpoint:

```
(lldb) breakpoint clear -l 7 -f fibonacci.c
1 breakpoints cleared:
3: file = 'fibonacci.c', line = 7, exact_match = 0, locations = 1
```

## 3.5. STARTING EXECUTION

To start an execution of the program you are debugging:

```
(lldb) run
```

If the program accepts command-line arguments, you can provide them as arguments to the **run** command:

```
(lldb) run argument …
```

The execution stops when the first breakpoint is reached, when an error occurs, or when the program terminates.

**Example 3.5. Executing the fibonacci Binary File in lldb**

This example assumes that you have successfully followed the instructions in Example 3.2, "Setting a new breakpoint".

Execute the **fibonacci** binary file in **lldb**:

```
(lldb) run
Process 21054 launched: 'fibonacci' (x86_64)
Process 21054 stopped
* thread #1, name = 'fibonacci', stop reason = breakpoint 1.1
    frame #0: fibonacci`main(argc=1, argv=0x00007fffffffdeb8) at fibonacci.c:10
   7       unsigned long int sum;
   8
   9       while (b < LONG_MAX) {
-> 10          printf("%ld ", b);
   11          sum = a + b;
   12          a = b;
   13          b = sum;
```

Execution of the program stops at the breakpoint set in Example 3.2, "Setting a new breakpoint".

## 3.6. DISPLAYING CURRENT PROGRAM DATA

The **lldb** tool enables you to display data relevant to the program state, including:

- Variables of any complexity
- Any valid expressions
- Function call return values

The common usage is to display the value of a variable. To display the current value of a certain variable:

```
(lldb) print variable_name
```

**Example 3.6. Displaying the current values of variables**

This example assumes that you have successfully followed the instructions in Example 3.5, "Executing the fibonacci Binary File in lldb". Execution of the **fibonacci** binary stopped after reaching the breakpoint at line 10.

Display the current values of variables **a** and **b**:

```
(lldb) print a
$0 = 0
(lldb) print b
$1 = 1
```

## 3.7. CONTINUING EXECUTION AFTER A BREAKPOINT

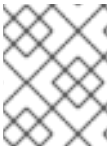
To resume the execution of the program you are debugging after it reached a breakpoint:

```
(lldb) continue
```

The execution stops again when it reaches another breakpoint.

To skip a certain number of breakpoints, typically when you are debugging a loop, run the **continue** command in the following form:

```
(lldb) continue -i number_of_breakpoints_to_skip
```



NOTE

If the breakpoint is set on a loop, in order to skip the whole loop, you will have to set the *number_of_breakpoints_to_skip* to match the loop iteration count.

The **lldb** tool enables you to execute a single line of code from the current line pointer with **step**:

```
(lldb) step
```

To execute a certain number of lines:

```
(lldb) step -c number
```

**Example 3.7. Continuing the execution of the fibonacci binary file after a breakpoint**

This example assumes that you have successfully followed the instructions in Example 3.5, "Executing the fibonacci Binary File in lldb". The execution of the **fibonacci** binary stopped after reaching the breakpoint at line 10.

Resume the execution:

```
(lldb) continue
Process 21580 resuming
Process 21580 stopped
* thread #1, name = 'fibonacci', stop reason = breakpoint 1.1
    frame #0: fibonacci`main(argc=1, argv=0x00007fffffffdeb8) at fibonacci.c:10
   7       unsigned long int sum;
   8
   9       while (b < LONG_MAX) {
-> 10          printf("%ld ", b);
   11          sum = a + b;
   12          a = b;
   13          b = sum;
```

The execution stops the next time it reaches a breakpoint. In this case, it is the same breakpoint. Execute the next three lines of code:

```
(lldb) step -c 3
Process 21580 stopped
* thread #1, name = 'fibonacci', stop reason = step in
    frame #0: fibonacci`main(argc=1, argv=0x00007fffffffdeb8) at fibonacci.c:11
   8
   9       while (b < LONG_MAX) {
   10          printf("%ld ", b);
```

```
-> 11       sum = a + b;
   12       a = b;
   13       b = sum;
   14     }
```

Verify the current value of the **sum** variable:

```
(lldb) print sum
$2 = 2
```

## 3.8. ADDITIONAL RESOURCES

A detailed description of the **lldb** debugger and all its features is beyond the scope of this document. For more information, see the resources listed below.

### Online documentation

- lldb Tutorial – The official **lldb** tutorial.
- gdb to lldb command map – A list of **GDB** commands and their **lldb** equivalents.

### See also

- Chapter 1, *LLVM* – An overview of LLVM and more information on how to install it.

# CHAPTER 4. CONTAINER IMAGES WITH LLVM TOOLSET

LLVM Toolset is available as container images for Red Hat Enterprise Linux 7 and Red Hat Enterprise Linux 8. Container images can be downloaded from the Red Hat Container Registry.

## 4.1. IMAGE CONTENTS

The Red Hat Enterprise Linux 7 and Red Hat Enterprise Linux 8 container images provide content corresponding to the following packages:

| Component | Version | Package |
|---|---|---|
| **llvm** | 10.0.1 | llvm-toolset-10.0.1-llvm |
| **clang** | 10.0.1 | llvm-toolset-10.0.1-clang |
| **lldb** | 10.0.1 | llvm-toolset-10.0.1-lldb |
| **Runtime libraries** | 10.0.1 | llvm-toolset-10.0.1-compiler-rt |
| **OpenMP library** | 10.0.1 | llvm-toolset-10.0.1-libomp |
| **lld** | 10.0.1 | llvm-toolset-10.0.1-lld |
| **python-lit** | 0.10.0 | llvm-toolset-10.0.1-python-lit |

## 4.2. ACCESSING THE IMAGES

To pull the required image, run the following command as **root**:

For the RHEL 7 container image:

```
# podman pull registry.redhat.io/devtools/llvm-toolset-rhel7
```

For the RHEL 8 container image:

```
# podman pull registry.redhat.io/rhel8/llvm-toolset
```

## 4.3. USING AS BUILDER IMAGES WITH SOURCE-TO-IMAGE

The LLVM Toolset container image is prepared for use as a Source-to-Image (S2I) builder image in Red Hat Enterprise Linux 7. Source-to-Image is not supported on Red Hat Enterprise Linux 8.

To be able to build and run your application:

- Add your own assemble script to **/.s2i/bin**.
- Add your own run script to **/.s2i/bin**.

- Run the following command:

```
$ s2i build \file://.app container-image container-image-application name.
```

**Example 4.1. Building an LLVM application image using Source-to-Image**

To build the **hello-world** application:

```
$ git clone https://github.com/sclorg/llvm-container
```

```
s2i build llvm-container/7/test/hello-world/app/ devtools/llvm-toolset-rhel7 llvm-hello-world
```

A locally available application image **hello-world** is built from the repository on GitHub using the **LLVM** Toolset container image.

To fully leverage the LLVM as a S2I builder image, build custom images based on it, with modified S2I assemble scripts and further modifications to accomodate the particular application being built.

A detailed description of the LLVM usage with Source-to-Image is beyond the scope of this document. For more information about Source-to-Image, see:

- *OpenShift Container Platform 4.5 Image Creation Guide* , OpenShift Container Platform-specific guidelines
- *Using Red Hat Software Collections Container Images* , Chapter 2. Using Source-to-Image (S2I).

## 4.4. ADDITIONAL RESOURCES

- LLVM Toolset Container Images – entries in the Red Hat Container Registry
- Using Red Hat Software Collections Container Images

# CHAPTER 5. CHANGES IN LLVM 10.0.1 TOOLSET

**LLVM Toolset** has been updated from version **9.0.1** to **10.0.1**.

With this update, the **clang-libs** packages no longer include individual component libraries. As a result, it is no longer possible to link applications against them. To link applications against the **clang** libraries, use the **libclang-cpp.so** package.

For more information, see the upstream LLVM 10.0.0 Release Notes.