Analyze performance on the Raspberry Pi with Arm Streamline

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Arm Limited. Company 02557590 registered in England.

110 Fulbourn Road, Cambridge, England CB1 9NJ.

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Contents

1 Overview

In this guide, we will explore Linux application and system performance analysis and learn how to find where a system is spending time. Annotating applications and finding performance bottlenecks helps focus software optimization efforts to improve system performance.

The Streamline Performance Analyzer provides system performance metrics, software tracing, and statistical profiling to help engineers get the most performance from hardware and find important bottlenecks in software.

The Raspberry Pi 3 and the Raspberry Pi 4 are low-cost boards with Cortex-A processors. This means that a Raspberry Pi is a useful tool for learning Linux profiling with Streamline. Because Raspberry Pi boards are designed for education, they do not require complex procedures to enable profiling features.

1.1 Before you begin

To work through this guide, you will need access to Streamline, which we will explain in **Starting Streamline**. You will also need a Raspberry Pi 3 or Raspberry Pi 4 board. An HDMI monitor and USB keyboard and mouse is the easiest way to interact with the Raspberry Pi. Finally, an SD card is needed to hold the Raspbian operating system.

A basic understanding of working with terminals in Linux will also be helpful.

2 Starting Streamline

In this section of the guide, we will install and start Streamline on a Windows or Linux computer.

Streamline is included with Arm Development Studio. A **30-day free trial** is available, which you can use to work through this guide. If you already have Arm Development Studio installed, check the **downloads** area to make sure that you have the latest version.

Follow these steps to start Arm Development Studio. You can refer to the Getting Started Guide for more information about the requirements and install process.

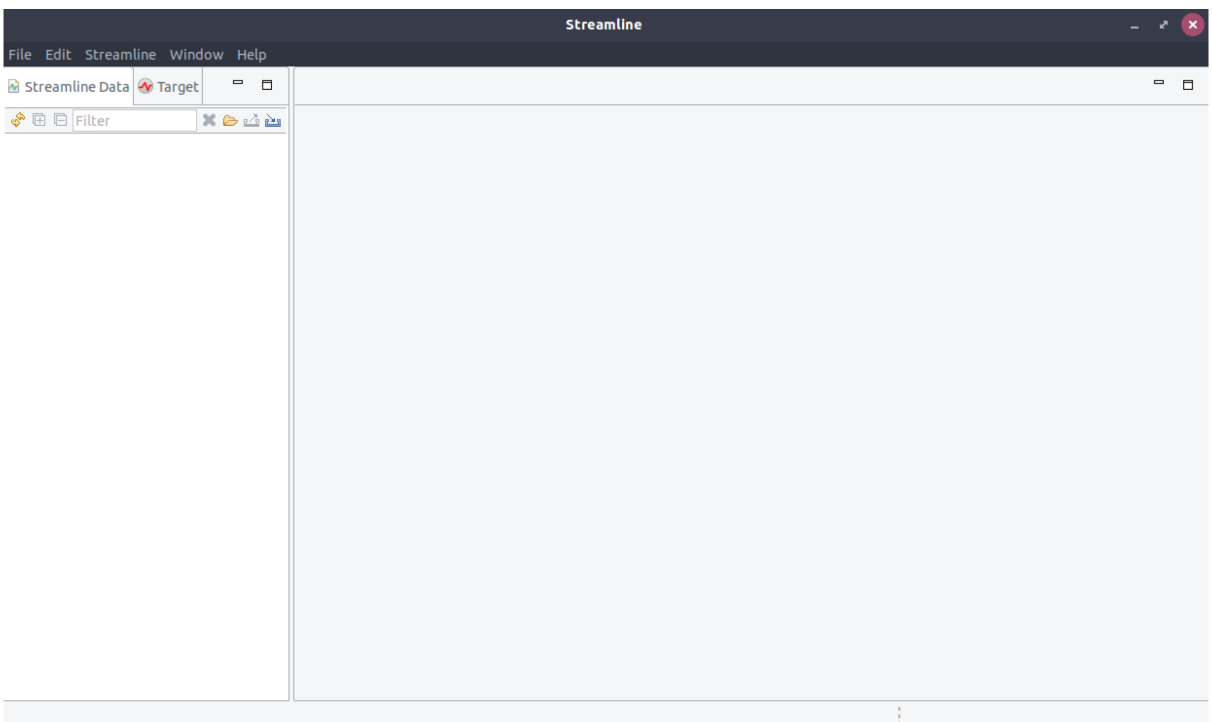
There is only one step required to start Streamline for Linux:

1. Start Streamline for Linux using the Streamline command

```
$ Streamline & .
```

There are two steps required to start Streamline for Windows:

1. Find Streamline for Windows on the start menu. If everything is installed correctly and the license is working, you will see the following screenshot:



2. Install `ssh` and `scp` for Windows if you want to, which enable connection to the Raspberry Pi. Possible options are PuTTY, Windows SSH, and Git Bash SSH.

2.1 Preparing the target

There are two important things to consider when you use Streamline on a new target system:

- Configuring the Linux kernel (if necessary)
- Installing the gator daemon application

The Linux kernel configuration involves ensuring that the profiling features are enabled in the kernel configuration. If the kernel has `perf_event` support, Arm Performance Monitoring Unit (PMU) counters are visible to Streamline. The required kernel support is enabled in the Raspberry Pi kernel, so no special configuration is required.

In the past, a Linux kernel driver facilitated data collection for Streamline, but this has been deprecated. Instead, standard Linux interfaces including `perf` and `trace` are used by Streamline to capture data.

Streamline relies on the Gator daemon application to collect profiling information from a target system. The separation between the data collection and data display makes the daemon approach ideal for embedded systems which have no user interface.

The Gator daemon can be copied from Streamline or compiled from source. Both methods are covered in **Installing the Gator daemon**. For best results, you must run the Gator daemon as `root` on the target system. This is easy to do with a Raspberry Pi.

Related information includes a link to more information about target setup for Streamline.

3 Configuring the Raspberry Pi

In this section of the guide, we will configure the Raspberry Pi to run with Streamline.

Follow these steps:

1. Navigate to the **latest version of Raspbian** from Raspberry Pi. Follow the instructions to create an SD card, using whatever path is easiest.
2. Use the dd command on Linux, or the **Raspberry Pi Imager on Linux, macOS or Ubuntu,** to copy the `.img` file to the SD card. The Raspberry Pi Imager is easy to use. We recommend that you use an SD card that is 16GB or larger.
3. Boot the system for the first time. The easiest way to boot the system is to connect an HDMI monitor and keyboard. The default username is `pi` and the default password is `raspberry`.
4. Connect the wireless or wired network for Internet connectivity. A wired connection is available by plugging an Ethernet cable into your router. Usually no additional steps are needed.

4 Connect to a wireless network

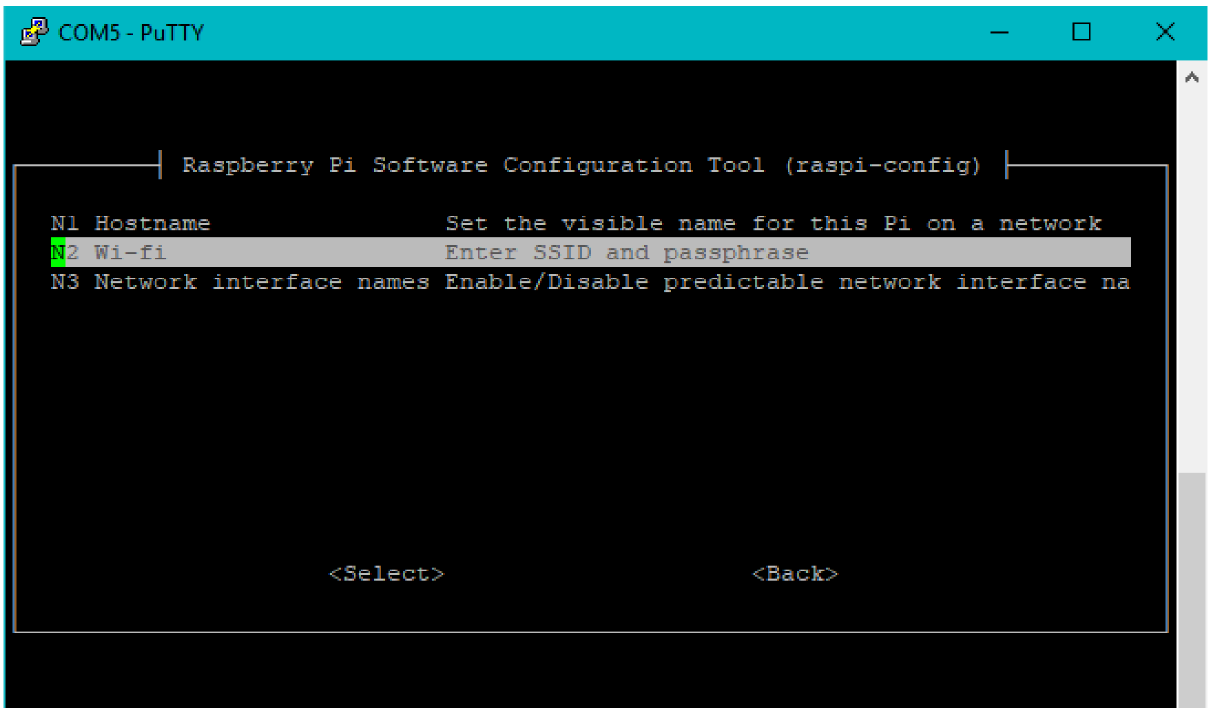
Let's explore how to connect the Raspberry Pi to a wireless network.

Follow these steps to connect to a wireless network:

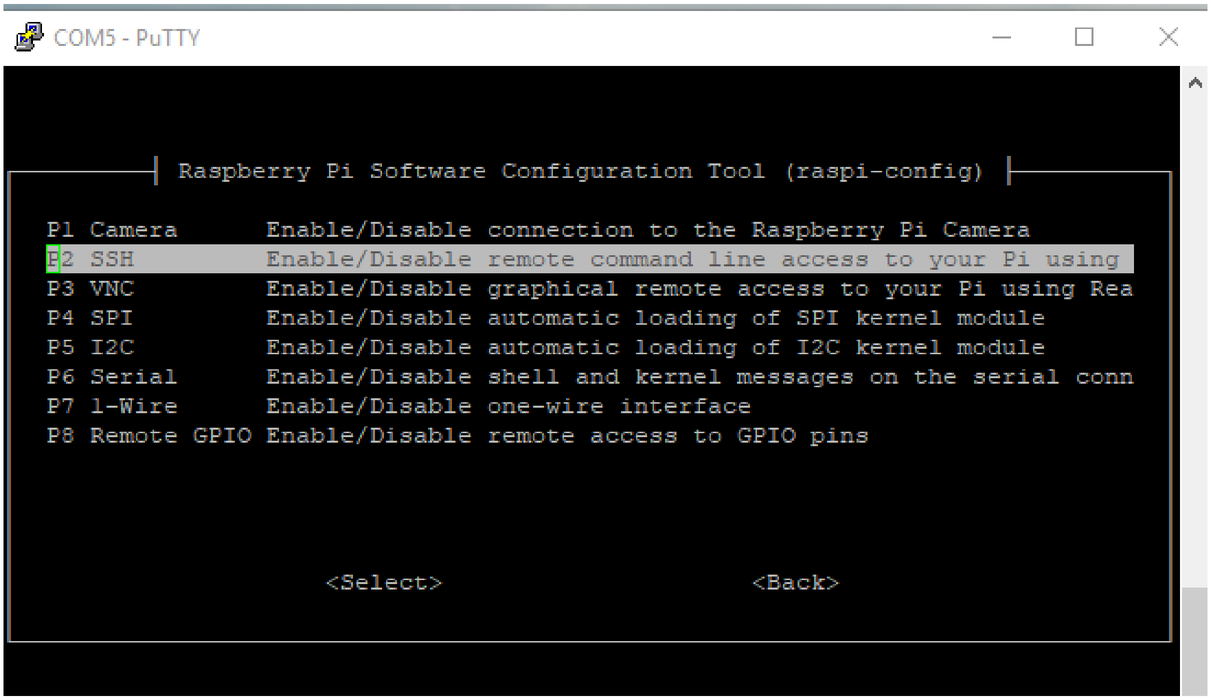
1. Start the console-based Raspberry Pi configuration tool:

```
$ sudo raspi-config.
```

2. Use option 2 to select Network Options, then option 2 again to select Wi-Fi. Enter the SSID and key, if needed, as you can see in this screenshot:



3. Enable `ssh`. Use option 5 **Interfacing Options** from the top menu, then **2 SSH**, as you can see in this screenshot:



If the Raspbian desktop is running, enable the `ssh` server using the configuration **Preferences -> Raspberry Pi**. Click the **Interfaces** tab.

4. Change the password to something other than the default value. The use of `sudo` is automatically enabled for user `pi`. Enter `passwd` on the command line and click **Enter**. You will be prompted to enter the current password and then asked for a new password. The new password will be requested a second time to confirm.

In **Installing the Gator daemon**, we will set up the gator daemon to enable the connection to Streamline.

5 Installing the Gator daemon

In this section of the guide, we will install the Gator daemon. There are two ways to get the Gator daemon software:

- A pre-compiled executable that is provided with Arm Development Studio. This can be copied to the Raspberry Pi and run.
- An **open-source project on github**. The source code can be downloaded, compiled on the Raspberry Pi, and run.

Let's look at each in turn.

5.1 Installing the gatord executable

To copy `gatord` from the Arm DS installation, follow these steps:

1. Use the Linux `scp` command and substitute the IP address of your Raspberry Pi.

For example:

```
$ scp $ARMDS_HOME/sw/streamline/bin/arm/gatord  pi@192.168.68.121:~/
```

5.2 Building gatord from source code

To download the source code from github and compile it, follow these steps:

1. Download the software, using the following commands:

```
$ git clone https://github.com/ARM-software/gator.git
$ cd daemon
$ make
```

2. Start the Gator daemon with root privileges for system profiling. Starting it without root limits the visibility to only those processes that are owned by the user account. The gator command is:

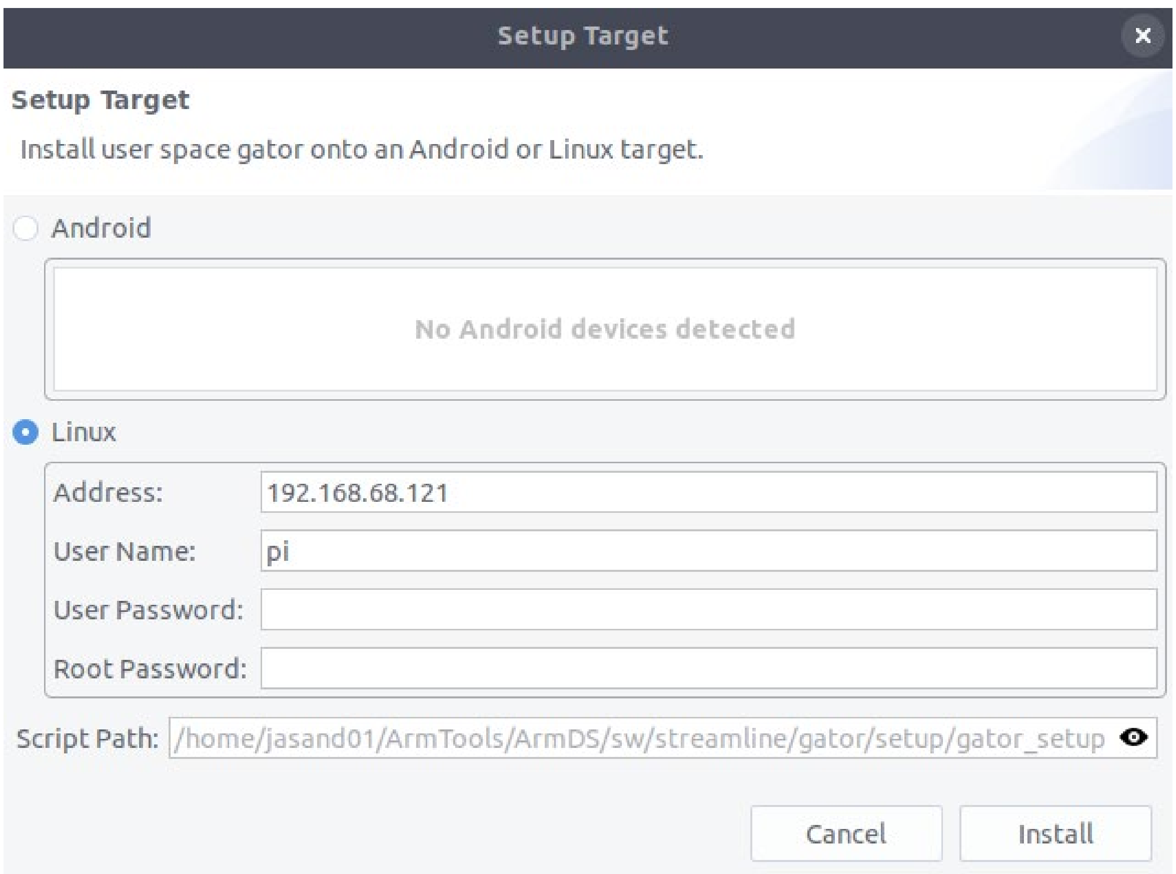
```
$ sudo gatord  &
```

6 Connecting Streamline

To connect Streamline from a Windows or Linux machine, follow these steps:

1. Start the Streamline GUI using the menu or by running Streamline from the command line, as described in Installing Streamline.
2. Click the eyeball on the **Target** tab.
3. Click **Select** if the Raspberry Pi shows up immediately. Click **Setup Target** if the Raspberry Pi does not show up automatically.
4. Enter the IP address of the Raspberry Pi and the username `pi`.

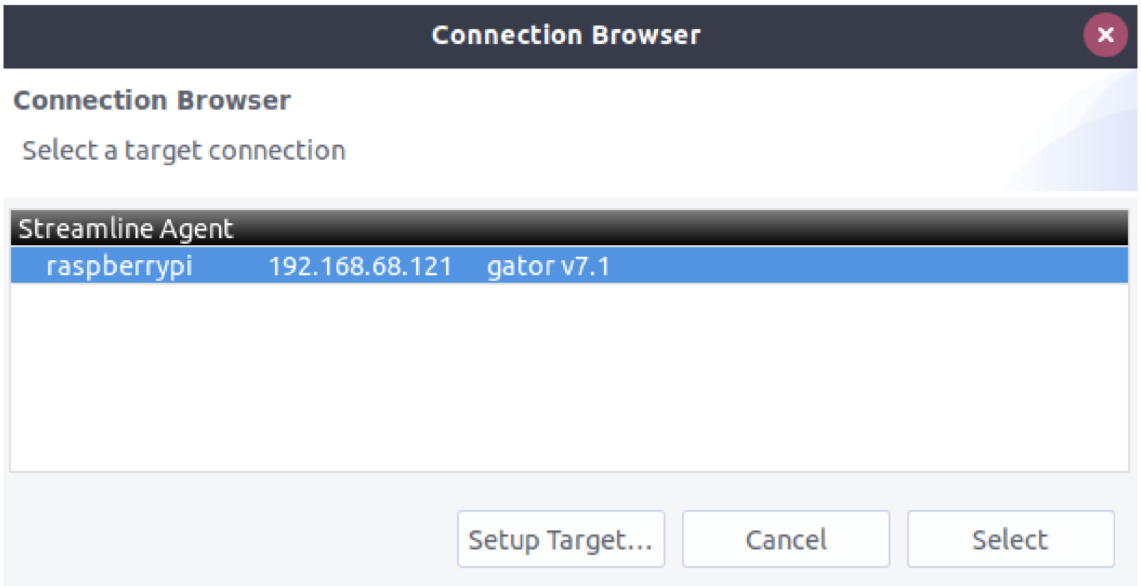
   If you enter the IP address of the Pi but Streamline still cannot find it, ensure that Streamline and the Raspberry Pi are on the same network. Only the last number of the IP addresses of the host and target machine should be different. Below is the target setup dialog:



5. Click **Install**.

6. Click **No** in the dialog box that is displayed after you click **Install**. This dialog box is confusing, because it asks you to install the `gatord` on the target system. You do not need to do this, because the `gatord` is already running.

7. Select the target, as in the screenshot below:

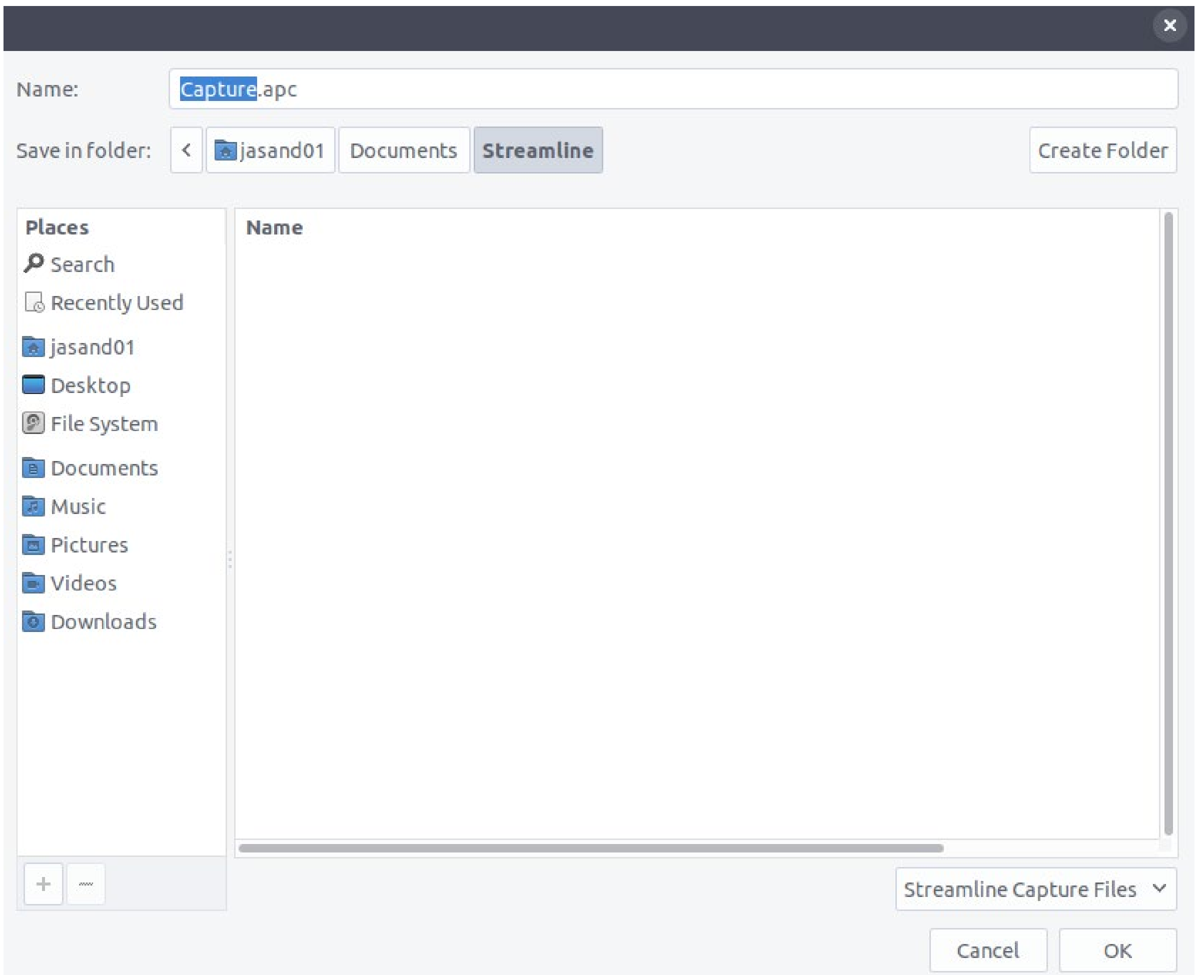


7 Capturing some profiling data

In this section of the guide, we will start a capture session, run a program, and end the capture session. Obtaining a capture confirms that data collection is working.

Follow these steps:

1. Select the name and location of the capture file using the red circle. Click **OK**. You will be promoted for a location and filename to save the capture as shown in this screenshot:



2. Clicking the red stop sign icon ends the capture.

Without any source code or software images, the **Call Paths, Functions,** and **Code** tabs do not provide much information. Instead, these tabs show process names and process ID values with some blank screens and **unknown code** messages. This will improve when Streamline has the software images and source. In **Profiling an example application**, we will download an example application to profile, and learn how to insert markers in the code for Streamline to visualize.

8 Profiling an example application

In this section of the guide, we use the LMbench applications to demonstrate profiling with Streamline. These applications are easy to **download** and build with `-g`. With these applications, Streamline can map the source code of the applications. In **Profiling an example application**, we will download an example application to profile, and learn how to insert markers in the code for Streamline to visualize.

Follow these steps:

1. Download an example Linux application:

```
$ wget

https://downloads.sourceforge.net/project/lmbench/development/lmbench-3.0-a9/lmbench-3.0-a9.tgz

$ tar xvfz lmbench-3.0-a9.tgz

$ cd lmbench-3.0-a9/src

$ make debug
```

This generates executables in the `bin/armv7l-linux-gnu directory`.

2. Run the application, using these commands:

```
$ cd ..

$ bin/armv7l-linux-gnu/bw_mem  512M rd
```

3. Enable the Streamline capture and run the test.
4. Stop the test to see the results.

9 Source level profiling

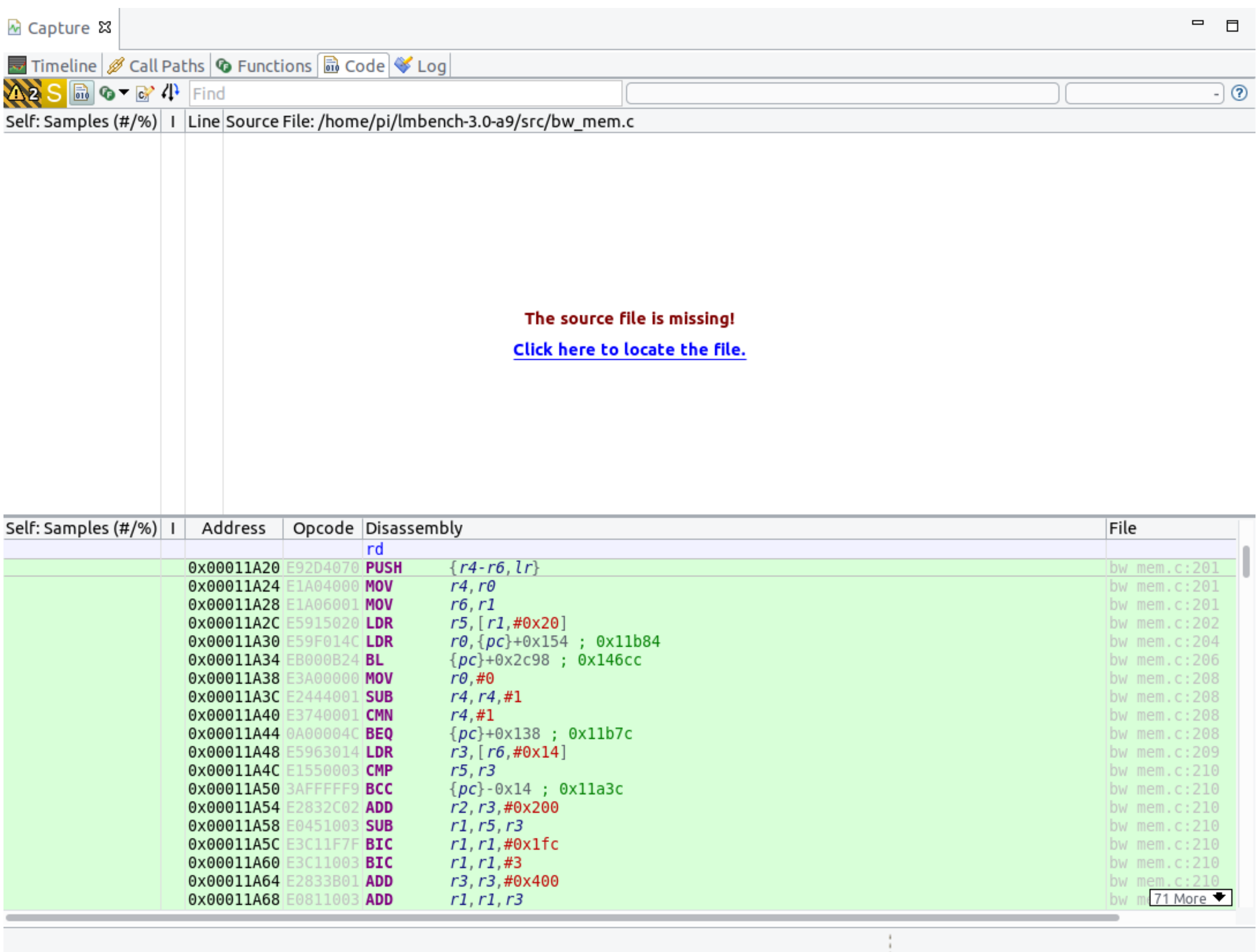
To see the application source code in Streamline, the files must be on the host machine where Streamline is running. To do this, follow these steps:

1. Copy the `lmbench-3.0-a9` directory from the Raspberry Pi to the host machine using `scp`. Again, substitute the IP address of the Pi in the following command:

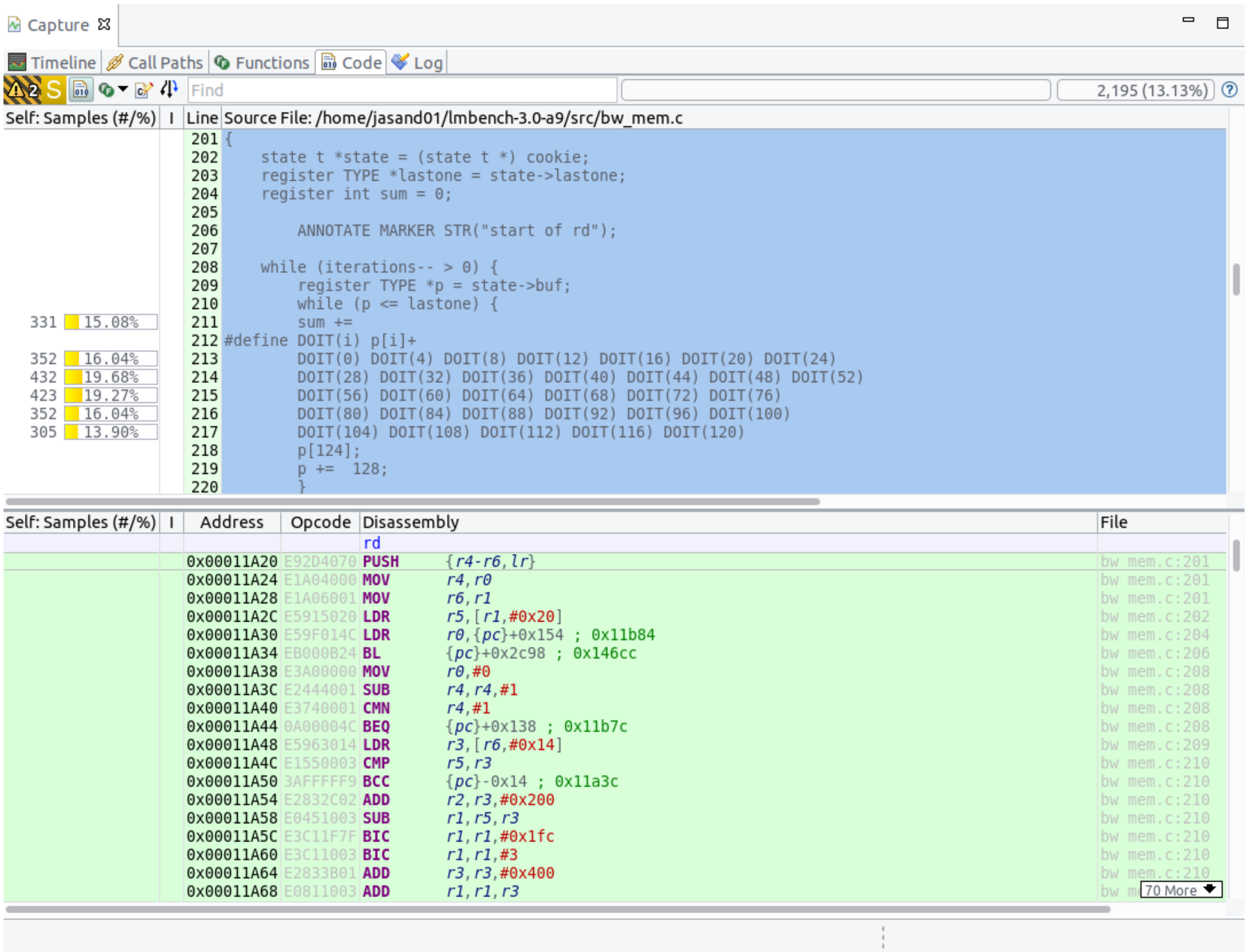
```
$ scp -r pi@192.168.68.121:~/lmbench-3.0-a9 .
```

   The **Code** tab in Streamline will not be able to find the source code. This is because the path on the target is different from the path on the host.

2. Use **Click here to locate source** and navigate to the file that is being referenced, in this case `bw_mem.c`. The following screenshot shows the missing source code and how to fix it:



When the source code is found, the window looks like what you can see in the following screenshot:


Capture
Timeline
Call Paths
Functions
Code
Log
Find
2,195 (13.13%)
Self: Samples (#/%)
Line
Source File: /home/jasand01/lmbench-3.0-a9/src/bw_mem.c
201 {
202 state_t *state = (state_t *) cookie;
203 register TYPE *lastone = state->lastone;
204 register int sum = 0;
205
206 ANNOTATE_MARKER_STR("start of rd");
207
208 while (iterations-- > 0) {
209 register TYPE *p = state->buf;
210 while (p <= lastone) {
331 15.08% 211 sum +=
212 #define DOIT(i) p[i]+
352 16.04% 213 DOIT(0) DOIT(4) DOIT(8) DOIT(12) DOIT(16) DOIT(20) DOIT(24)
432 19.68% 214 DOIT(28) DOIT(32) DOIT(36) DOIT(40) DOIT(44) DOIT(48) DOIT(52)
423 19.27% 215 DOIT(56) DOIT(60) DOIT(64) DOIT(68) DOIT(72) DOIT(76)
352 16.04% 216 DOIT(80) DOIT(84) DOIT(88) DOIT(92) DOIT(96) DOIT(100)
305 13.90% 217 DOIT(104) DOIT(108) DOIT(112) DOIT(116) DOIT(120)
218 p[124];
219 p += 128;
220 }
Self: Samples (#/%)
Address
Opcode
Disassembly
File
rd
0x00011A20 E92D4070 PUSH {r4-r6,lr} bw_mem.c:201
0x00011A24 E1A04000 MOV r4,r0 bw_mem.c:201
0x00011A28 E1A06001 MOV r6,r1 bw_mem.c:201
0x00011A2C E5915020 LDR r5,[r1,#0x20] bw_mem.c:202
0x00011A30 E59F014C LDR r0,{pc}+0x154 ; 0x11b84 bw_mem.c:204
0x00011A34 EB000B24 BL {pc}+0x2c98 ; 0x146cc bw_mem.c:206
0x00011A38 E3A00000 MOV r0,#0 bw_mem.c:208
0x00011A3C E2444001 SUB r4,r4,#1 bw_mem.c:208
0x00011A40 E3740001 CMN r4,#1 bw_mem.c:208
0x00011A44 0A00004C BEQ {pc}+0x138 ; 0x11b7c bw_mem.c:208
0x00011A48 E5963014 LDR r3,[r6,#0x14] bw_mem.c:209
0x00011A4C E1550003 CMP r5,r3 bw_mem.c:210
0x00011A50 3AFFFFF9 BCC {pc}-0x14 ; 0x11a3c bw_mem.c:210
0x00011A54 E2832C02 ADD r2,r3,#0x200 bw_mem.c:210
0x00011A58 E0451003 SUB r1,r5,r3 bw_mem.c:210
0x00011A5C E3C11F7F BIC r1,r1,#0x1fc bw_mem.c:210
0x00011A60 E3C11003 BIC r1,r1,#3 bw_mem.c:210
0x00011A64 E2833B01 ADD r3,r3,#0x400 bw_mem.c:210
0x00011A68 E0811003 ADD r1,r1,r3
70 More

10 Inserting markers

You can insert markers into the source code of any application, to make it easier to track progress on the Streamline timeline. You can find everything that you need in the `annotate/` directory of the gator software.

To insert a marker, follow these steps:

1. Add the following include file at the top of the source file, to add a marker to the LMbench source file `bw_mem.c`:

```
#include "streamline_annotate.h"
```

2. Add `ANNOTATE_SETUP`; during the setup, somewhere in the `main()` function before the test is run.
3. Put the markers where they are needed, to track the test on the Streamline timeline, as seen in the following code:

```
void
rd(iter_t iterations, void *cookie)
{
        state_t *state = (state_t *) cookie;
        register TYPE *lastone = state->lastone;
        register int sum = 0;
        ANNOTATE_MARKER_STR("start of rd");
        while (iterations-- > 0) {
            register TYPE *p = state->buf;
            while (p <= lastone) {
                sum +=
#define DOIT(i) p[i]+
                DOIT(0) DOIT(4) DOIT(8) DOIT(12) DOIT(16) DOIT(20) DOIT(24)
                DOIT(28) DOIT(32) DOIT(36) DOIT(40) DOIT(44) DOIT(48) DOIT(52)
                DOIT(56) DOIT(60) DOIT(64) DOIT(68) DOIT(72) DOIT(76)
                DOIT(80) DOIT(84) DOIT(88) DOIT(92) DOIT(96) DOIT(100)
                DOIT(104) DOIT(108) DOIT(112) DOIT(116) DOIT(120)
                p[124];
                p +=  128;
            }
```

4. Edit the `Makefile` to:
    - Add the directory containing streamline_anotate.h to the compiler include path.
    - Add `streamline_annotate.c` to the list of source files to compile.

11 Related information

Here are some resources related to material in this guide:

- Arm Development Studio
- Raspberry Pi
    - Raspberry Pi documentation
- Streamline:
    - Documentation on target setup for Streamline
    - Streamline Performance Analyzer