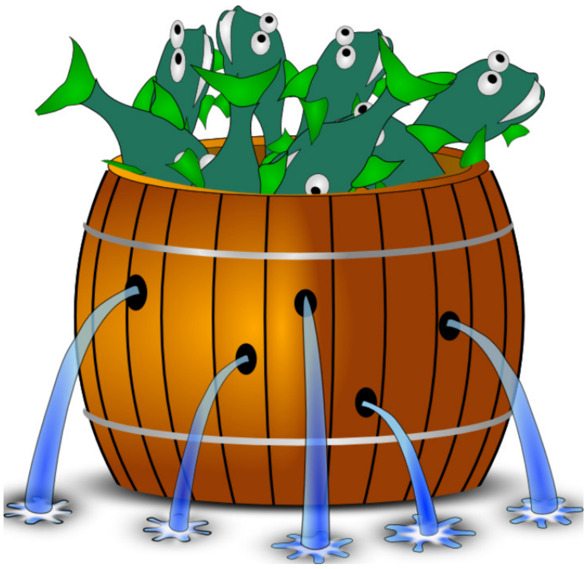
Barrelfish Project
ETH Zurich



Barrelfish Practical Guide

Barrelfish Technical Note 018

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Contents

Chapter 1

Introduction

This note describes how to build and boot Barrelfish on 64-bit PC hardware, which is the default configuration for Barrelfish. It then goes on to work through a simple "hello, world"-style application which illustrates client-server programming in C on Barrelfish, and the use of the message-passing subsystem.

Information on how to compile Barrelfish for other platforms, in particular ARM, are found in other documents. However, the application programming section in this guide is still relevant.

Chapter 2

PC compilation and installation

2.1 Supported PC hardware

Barrelfish supports following PC hardware :

- x86 CPUs in either IA-32 or AMD64 mode. The following are known to work:
  - Intel Xeon Clovertown, Gainestown, Beckton (X5355, E5520, X7560, L5520, L7555)
  - AMD Opteron Santa Rosa, Barcelona, Shanghai, Istanbul, Magny Cours (2220, 8350, 8374, 8380, 8431, 6174)

The biggest compatibility problems are likely to be in the PCI/ACPI code. We usually discover new quirks (or missing functionality in the ACPI glue code) on each new machine we test. The following systems are known to work:

- Intel x5000XVN
- Tyan n6650W and S4985
- Supermicro H8QM3-2
- Dell PowerEdge R610 and R905
- Sun Fire X2270 and X4440
- Intel/Quanta QSSC-S4R
- Lenovo X200 and X301 laptops
- ASUS Eee PC 1015PEM netbooks

The e1000n driver should work with most recent Intel gigabit ethernet controllers (see the list in devices/e1000.dev). We've mostly used the 82572EI (PCI device ID 0x1082).

You should also be able to boot Barrelfish on a recent version of QEMU (0.14); note that the e1000 device emulated by QEMU is not supported by our driver.

2.2 Required Tools

The following are required to build Barrelfish and its tools:

- GCC 4.x
  - 4.4.5, and 4.5.2 are known to work

    - cross-compiling between i386 and x86_64 works (requires libc6-dev-i386 to build 32 bit on 64 bit machine)
    - for the ARM port, we recommend the EABI tools available from CodeSourcery.
- GNU binutils (2.19 is known to work)
- GNU make
- GHC v7.4 and Parsec 3.1 - older versions of the tree supported v6.10 or v6.12.2 with Parsec 2.1 - GHC v6.12.1 has a known bug and is unable to build our tools - earlier versions of GHC are unsupported

Our build system may not be very portable; if in doubt, try building on a recent Debian or Ubuntu system, as these are what we use.

2.3 Building

1. Assuming you have already unpacked the sources, create a build directory

```
$ mkdir build && cd build
```

1. Run `hake.sh`, giving it the path to the source directory and target architecture(s)

```
$ ../hake/hake.sh -s ../ -a x86_64
```

This will configure the build directory and use GHC to compile and then run hake, a tool used to generate the `Makefile`.

3. Optionally, edit the configuration parameters in `hake/Config.hs` and run `make rehake` to apply them.

4. Run make, and wait

```
$ make
```

5. If everything worked, you should now be able to run Barrelfish inside QEMU

```
$ make sim
```

2.4 Installing and Booting

Barrelfish requires a Multiboot-compliant bootloader that is capable of loading an ELF64 image. At the time of writing, this doesn't include the default GRUB. Your options are either:

- use the pre-loader "elver" that can be found in the tools directory
- patch GRUB to support a 64-bit kernel image, using this patch.

"Installing" Barrelfish currently consists of copying the ELF files for the CPU driver and user programs to a location that the target machine can boot from, and writing a suitable menu.lst file that instructs the bootloader (GRUB) which programs to load and the arguments to pass them.

If you specify an appropriate INSTALL_PREFIX, `make install` will copy the binaries to the right place for you, eg

```
$ make install INSTALL_PREFIX=/tftpboot/barrelfish
```

We usually boot Barrelfish via PXE/TFTP, although loading from a local disk also works. Instructions for setting up GRUB to do this are beyond the scope of this document. Assuming you have such a setup, here is a sample menu.lst file for a basic diskless boot that doesn't do anything useful beyond probing the PCI buses and starting a basic shell

```
title   Barrelfish
root    (nd)
kernel /barrelfish/x86_64/sbin/elver
module /barrelfish/x86_64/sbin/cpu
module /barrelfish/x86_64/sbin/init
module /barrelfish/x86_64/sbin/mem_serv
module /barrelfish/x86_64/sbin/monitor
module /barrelfish/x86_64/sbin/ramfsd boot
module /barrelfish/x86_64/sbin/skb boot
modulenounzip /barrelfish/skb_ramfs.cpio.gz nospawn
module /barrelfish/x86_64/sbin/acpi boot
module /barrelfish/x86_64/sbin/pci boot
module /barrelfish/x86_64/sbin/spawnd boot
module /barrelfish/x86_64/sbin/serial
module /barrelfish/x86_64/sbin/fish
```

There are many other programs you can load (take a look around the usr tree for examples). To start a program on a core other than the BSP core, pass `core=N` as its first argument.

If things work, you should see output on both the VGA console and COM1.

Chapter 3

Writing Hello World application

3.1 Writing A Sample Barrelfish Application

Here we show how to write a simple program on Barrelfish. **XXX:** no error handling yet. Refer to `usr/tests/idctest` for code with proper error handling.

3.1.1 A Simple Hello World Program

The source for user domains is stored under

```
/usr
```

A simple hello world domain consists of a source file, and a Hakefile. e.g.,

```
usr/myapp
    myapp.c
    Hakefile
```

For a simple hello world app, the source is trivial: a simple printf in main will suffice (note that for output printf either uses a debug syscall to print to the serial output, or a proper serial server if one is available).

```
#include <stdio.h>
int main(void) {
    printf("Hello World\n");
    return 0;
}
```

To build the domain, call hake.sh in the build directory. This will create a Config.hs, Makefile, and symbolic_targets.mk. You can add myapp in the symbolic_tagets, then run make to build everything. You can also explicitly ask make to build the domain. e.g.:

```
make x86_64/sbin/myapp
```

After all is built, the menu.lst needs to be modified to add the domain and have it started. Run everything in a simulator using:

```
make sim
```

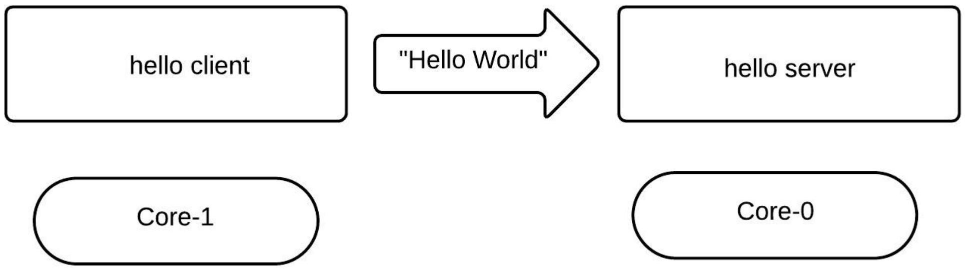

Figure 3.1: Hello world application overview

3.2 A Simple Hello World Program Using IDC

In this section, we talk how we can write an application that uses Barrelfish IDC mechanism to communicate with other applications. For purpose of this section, we will develop simple **Hello World** client and server application. The client running on core-0 will send an IDC message to a server running on core-1. This message will contain a string with contents `"Hello World"`.

Adding IDC (inter-dispatcher communication) is a bit more complicated. It requires defining an interface in Flounder IDL, updating the interfaces Hakefile, updating the domain's (myapp) Hakefile, and then adding initialization code as well as appropriate callbacks to the source file.

3.2.1 Interface

In this subsection, we will create a new interface for our use. We do this by creating a new interface file called `hello.if` in the `if`
directory. Following is simple interface that will suffice for our requirements of sending single string as a message.

```
interface hello "Hello World interface" {
    message hello_msg(string s);
};
```

You can find out more about how to write such interfaces by referring IDC-Technote.

You also need to modify the `if/Hakefile` to add this newly created interface into the compilation process.

```
[ flounderGenDefs (options arch) f
      | f <- [ "ahci_mgmt",
                ...
                ...
         "hello"],
             arch <- allArchitectures
] ++
```

Adding the name of your interface here will make sure that the communication stubs will be automatically generated for by the compilation process. These can be found in following location in your build directory:

```
BUILD/ARCH/include/if/hello_defs.h
BUILD/ARCH/include/if/hello_lmp_defs.h
BUILD/ARCH/include/if/hello_ump_defs.h
BUILD/ARCH/include/if/hello_multihop_defs.h
```

There will be one for each type of communication mechanism supported by the Barrelfish. You don't need to worry about these files as build mechanism will take care of these files. Only things developers need to do is write the interface file and include appropriate headers in the application code (discussed in following section)

3.2.2 Application

In this section, we discuss how would we write the application code, and how to compile it. For sake of simplicity, we will write both server and client code in same application. Following is the code for the `main` function, which runs the client code or server code based on the command line argument.

```
int main(int argc, char *argv[]) {
    errval_t err;
    if ((argc >= 2) && (strcmp(argv[1], "client") == 0)) {
        start_client();
    } else if ((argc >= 2) && (strcmp(argv[1], "server") == 0)) {
        start_server();
    } else {
        return EXIT_FAILURE;
    }
    /* The dispatch loop */
    struct waitset *ws = get_default_waitset();
    while (1) {
        err = event_dispatch(ws); /* get and handle next event */
        if (err_is_fail(err)) {
            DEBUG_ERR(err, "in event_dispatch");
            break;
        }
    }
    return EXIT_FAILURE;
}
```

The important part of the above is in the dispatch loop where application will wait for events on the default wait-set and handle those events in infinite while loop.

3.2.3 Server side

In this section, we will develop the server code in steps of ”exporting service”, ”registering the service” and ”handling actual requests”.

Exporting service

As a first step, server needs to export the service it wants to provide by calling export function on the service interface. In this case, server will call `hello_export` as we are providing *Hello World* service.

```
static void start_server(void)
{
    errval_t err;
    err = hello_export(NULL /* state for callbacks */,
            export_cb, /* Callback for export */
            connect_cb,  /* Callback for client connects */
            get_default_waitset(), /* waitset where events will be sent */
            IDC_EXPORT_FLAGS_DEFAULT);
    if (err_is_fail(err)) {
        USER_PANIC_ERR(err, "export failed");
    }
}
```

This call also registers two callback handles. Once the service is successfully exported, then the export callback provided. When any client connects with the service then the connect callback will be called. We will see the use of these callbacks in next few steps.

Registering service

Server also need to register the service so that other applications can find it. Following code registers the "hello_service" on the callback from successful completion of export:

```
const static char *service_name = "hello_service";
static void export_cb(void *st, errval_t err, iref_t iref)
{
    if (err_is_fail(err)) {
        USER_PANIC_ERR(err, "export failed");
    }
    err = nameservice_register(service_name, iref);
    if (err_is_fail(err)) {
        USER_PANIC_ERR(err, "nameservice_register failed");
    }
}
```

The nameservice_register is a blocking call which will connect to the global nameserver and publish the service name.

Connect and handling messages

This section describes how exactly the connection is established and requests are handled.

```
static void rx_hello_msg(struct hello_binding *b, char *str)
{
    printf("server: received hello_msg:\n\t%s\n", str);
    free(str);
}

static struct hello_rx_vtbl rx_vtbl = {
    .hello_msg = rx_hello_msg,
};

static errval_t connect_cb(void *st, struct hello_binding *b)
{
    b->rx_vtbl = rx_vtbl;
    return SYS_ERR_OK;
}
```

The above code defines a function rx_hello_msg which will be responsible to actually handle the requests. In our case, we are just printing out the string we received as part of the message.

We need to create a list of function pointers where one function pointer is assigned for every possible incoming message. So we are creating an instance rx_vtbl of type hello_rx_vtbl.

On arrival of new connection, we provide this list of function pointers to register which functions to call for handling particular type of message.

3.2.4 Client side

Client needs to find the service and connect to it. Once the connection is successfully established then it can send the actual requests. In this section, we show how it can be done.

Find and Bind

Following code finds the desired service with given name and binds with the service.

```
static void start_client(void)
{
    errval_t err;
    iref_t iref;
    err = nameservice_blocking_lookup(service_name,
            &iref);
    if (err_is_fail(err)) {
        USER_PANIC_ERR(err,
                "nameservice_blocking_lookup failed");
    }
    err = hello_bind(iref, bind_cb, /* Callback function */
            NULL /* State for the callback */,
            get_default_waitset(),
            IDC_BIND_FLAGS_DEFAULT);
    if (err_is_fail(err)) {
        USER_PANIC_ERR(err, "bind failed");
    }
}
```

As the name suggests `nameservice_blocking_lookup` is a blocking call which will connect with the nameserver and query for the given service name. The `iref` handle returned by this call can be used for binding with the service.

The `hello_bind` is part of the code generated from the interface file and will try and connect with the server on appropriate channel.

Following code is callback function which will be called when client successfully connects with the server. This code also creates a client state which stores pointer to the communication channel binding. This code then calls a function `run_client` with the client state.

```
struct client_state {
    struct hello_binding *binding;
    int count;
};

static void bind_cb(void *st, errval_t err, struct hello_binding *b)
{
    struct client_state *myst = malloc(sizeof(struct client_state));
    assert(myst != NULL);
    myst->binding = b;
    myst->count = 0;
    run_client(myst);   /* calling run_client for first time */
}
```

Sending messages

Most of the actual work of sending message is done from the `run_client` function which is described bellow:

```
static void run_client(void *arg)
{
    errval_t err;
    struct client_state *myst = arg;
    struct hello_binding *b = myst->binding;

    /* Creating a continuation which will call run_client */
    struct event_closure txcont = MKCONT(run_client, myst);

    err = b->tx_vtbl.hello_msg(b, txcont, "Hello World");
    if (err_is_fail(err)) {
        DEBUG_ERR(err, "error sending message %d\n", myst->count);
    }
}
```

This function first creates a continuation which calls itself and will be used as a callback function. The next step is to actually send the message by calling an appropriate function on the send side of interface binding (`tx_vtbl.hello_msg`) with actual message and above created continuation. This call will register a message to be sent and a callback that will be triggered when message is successfully.

As you can notice, callback function is calling `run_client` again, leading an infinite loop of sending messages.

Include files

Following is a typical set of include files that you will need to add in your code.

```
#include <stdio.h>
#include <barrelfish/barrelfish.h>
#include <barrelfish/nameservice_client.h>
#include <if/hello_defs.h>
```

The `barrelfish.h` file contains declaration of functionalities related to Barrelfish OS (eg: system calls, capability system related functionalities, etc.) `nameservice_client.h` file provides declarations for functions related to registering and looking up services. The `hello_defs.h` file includes the declarations for automatically generated code to support `if/hello.if` interface.

3.2.5 Building and running the application

In this section, we talk about how build your application. For this, you will need to create a `Hakefile` in the code directory which should look something like bellow:

```
    [ build application { target = "hello-cs",
                          cFiles = [ "hello.c" ],
                          flounderBindings = [ "hello" ]
                        }
    ]
```

This `Hakefile` specifies that you want to build an application with name `hellocs` from the `hello.c` file, and also it marks the dependency on the communication interface `hello`.

The next step is to modify the `barrelfish/hake/symbolic_targets.mk` file to include your newly created application into the build process. Here you can choose an architecture for which your application should be compiled, or you can also add your application in MODULES_COMMON list so that your application will be compiled for all architectures.

```
MODULES_COMMON= \
sbin/init_null \
        ...
        ...
sbin/xcorecapbench \
sbin/hello-cs \
```

After this, rebuild the Barrelfish to include newly added application. On successful compilation the binary will be created in sbin directory of desired architecture.

Next step is to edit one of the `barrelfish/hake/menu.lst.*` file based on which architecture you are targeting. Bellow is the minimal `menu.lst.x86_64` file to be able to run this newly created application.

```
title Barrelfish
root (nd)
kernel /x86_64/sbin/elver loglevel=3
module /x86_64/sbin/cpu loglevel=3
module /x86_64/sbin/init

# Domains spawned by init
module /x86_64/sbin/mem_serv
module /x86_64/sbin/monitor

# Special boot time domains spawned by monitor
module  /x86_64/sbin/ramfsd boot
module  /x86_64/sbin/skb boot
modulenounzip /skb_ramfs.cpio.gz nospawn
module  /x86_64/sbin/kaluga boot
module  /x86_64/sbin/acpi boot
module  /x86_64/sbin/spawnd boot
#bootapic-x86_64=1-15
module  /x86_64/sbin/startd boot
module /x86_64/sbin/routing_setup boot

# Drivers
module /x86_64/sbin/pci auto
module /x86_64/sbin/ahcid auto

# General user domains
module /x86_64/sbin/serial

# Your hello world application (both server and client)
module /x86_64/sbin/hello-cs core=0 server
module /x86_64/sbin/hello-cs core=1 client
```

Now, you can build your application and verify that binary is created as follows:

```
$ make
$ ls x86_64/sbin/hello-cs
```

If everything goes fine, you can run the application in `qemu` simulator with following command:

```
$ make sim
```

At this moment, you should be able see Barrelfish booting and starting your applications which are then able to communicate by sending "Hello World" message in infinite loop. Following is a sample output that you may expect while running this setup.

```
...
...
...
startd.0: starting app /x86_64/sbin/hello-cs on core 0
spawnd.0: spawning /x86_64/sbin/hello-cs on core 0
startd.0: starting app /x86_64/sbin/hello-cs on core 1
skb.0: waiting for: spawn.1
skb.0: waiting for: pci
spawnd.0: spawning /x86_64/sbin/ahcid on core 0
kernel: 0: installing handler for IRQ 1
kernel: 0: installing handler for IRQ 2
pci_client.c: got vector 2
ahcid: registered device 8086:2922
spawnd.1: spawning /x86_64/sbin/hello-cs on core 1
No bootscript
server: received hello_msg:
        Hello World
server: received hello_msg:
        Hello World
server: received hello_msg:
        Hello World
server: received hello_msg:
        Hello World
server: received hello_msg:
        Hello World
server: received hello_msg:
        Hello World
...
...
...
```