Definition of the term
Socket Primitive
In Distributed Systems

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Abstract

'Socket Primitive' is a heavily used term associated with network operations in computer science. A socket is a communication end point of a computer system. The word 'primitive' is often used to name an instruction which represents a self-contained unit on the current abstraction level. Therefore, a 'Socket Primitive' is a socket related function that is provided by various high-level programming language libraries. This technical report describes and ultimately defines the term 'Socket Primitive'.

Contents

1 Introduction

During my work on a technical report[1] I came across the term 'Socket Primitive' which was a heavily used term when describing operations with the Transmission Control Protocol / Internet Protocol (TCP/IP), which in one instance was used as follows (Tanenbaum & Steen, 2007, p. 141, ch. 4.3.1):

> [...] A socket forms an abstraction over the actual communication end point that is used by the local operating system for a specific transport protocol. In the following text, we concentrate on the socket primitives for TCP, which are shown in Fig. 4-14. [...]

Inevitably the question came up: What exactly does the term 'Socket Primitive' define? With this technical report, I will first clarify what a socket is and what 'primitive' means in such a context. Furthermore, I will describe the term 'Socket Primitive' by using examples and ultimately define the term.

I also would like to give special thanks to Maarten van Steen, co-author of the quoted book (Tanenbaum & Steen, 2007), who aided me with some clarification at the beginning of my research.

The reader is asked to keep in mind that although I am writing in a more abstract and general way about 'Socket Primitives', it is always considered to operate with a UNIX Operating System (OS).

2 Definition of the terms Socket and Primitive

2.1 Socket

A socket is a communication end point of a computer system. Whenever two computer systems shall communicate with each other, a connection between those systems has to be established by using interconnected sockets (Tanenbaum & Wetherall, 2011, p. 553, ch. 6.5.2).

A socket is always considered to be used associated with a protocol that implements a model of communication. Inter-Process Communication (IPC) will only be successful when both processes use the same protocol. Common protocols are the User Datagram Protocol (UDP) or TCP/IP for example. The used protocol determines which low-level mechanisms are used to transmit and receive data (Loosemore *et al.*, 2015, p. 427 - 427, ch. 16).

[1] Willich, Florian. 2015. Introductory Guide to Message Passing in Distributed Computer Systems. `https://github.com/c-bebop/message_passing/blob/master/technical_report/message-passing_distributed-systems_florian-willich.pdf`

2.2 PRIMITIVE

2.2.1 MEANING IN COMPUTER SCIENCE

In computer science, the word 'primitive' is often used to name an instruction which represents a self-contained unit on the current abstraction level. This also means that there is usually no need for further description of what this instruction is composed of, except for descriptions of the semantics and logic the primitive introduces.

For example: The GNU C Reference Manual uses the term 'Primitive Data Types' to describe the built-in data types in the programming language C (Rothwell & Youngman, 2015, p. 8, ch. 2). The following table shows a selection of 'Primitive Data Types' of a C language, as well as their characteristics and memory allocation on 64-bit systems:

Primitive	Stores	Memory Allocation
char	ASCII characters	1 byte
int	integers	4 byte
float	floating point real numbers	4 byte
double	double precision floating point real numbers	8 byte

As long as a C programmer knows what each built-in 'Primitive Data Type' represents and how to use it, he must not necessarily know what assembly code the compiler is generating to write code in a high level language. On the contrary, a compiler writer has to.

Please see Appendix A for the corresponding implementation of the application which prints out the bytes allocated by primitive data types in C++. See Appendix B for compilation details (Makefile build script).

2.2.2 MEANING IN LINGUISTIC SCIENCE

The *Oxford Advanced Learners Dictionary* has no definition of the word primitive that fits for the use in computer science (A S Hornby, 2005, p. 1197). The online version `http://www.oxfordlearnersdictionaries.com` offers[2] merely the basic etymology of 'primitive':

> late Middle English (in the sense 'original, not derivative'): from Old French primitif, -ive, from Latin primitivus 'first of its kind', from primus 'first'.

However, also this additional definition does not correspond to its use in computer science, which indicates that the term is commonly used in a *sloppy* way.

[2] Original URL: `http://www.oxfordlearnersdictionaries.com/definition/english/primitive_1?q=primitive`

3 TCP/IP Socket Primitives

As already mentioned above (chapter 2.1), a socket always communicates in association with a protocol. For the programmer in a high-level programming language, protocols specify the interface for operation with sockets.

The following table lists the most common TCP/IP 'Socket Primitives' with a short description ((Anupama, 2007) and (Tanenbaum & Steen, 2007, p. 142, ch. 4.3.1)):

Primitive	Service description
Socket	creates a new socket e.g. communication end point
Bind	associates a local address with a socket
Listen	allows to accept new incoming connections to a socket
Accept	blocks until a connection request
Connect	connects to a socket
Send	sends a message to a socket
Receive	reads a message from a socket
Close	aborts a connection

The following definition of the function *send(...)* represents the 'Socket Primitive' **Send** by the GNU C Library (Loosemore *et al.*, 2015, p. 457, ch. 16.9.5.1):

```
ssize_t send( int socket,
              const void *buffer,
              size_t size,
              int flags);
```

A short description of the parameters:

- socket: The socket file descriptor (Loosemore *et al.*, 2015, p. 427, ch. 16.2).
- buffer: Memory address of the data which shall be sent.
- size: The size in bytes of the data that shall be sent.
- flags: Additional information for the sending instruction (Loosemore *et al.*, 2015, p. 459, ch. 16.9.5.3).

The function either returns the number of bytes which have been transmitted or -1 if an error occurred. For more detailed information reading the referenced GNU C Library Reference Manual (Loosemore *et al.*, 2015, p. 487, ch. 16.9.5.1) is recommended.

The *send(...)* function is called by the application in user mode which will then call a number of other functions in kernel mode. These then operate on the socket layer, protocol layer and interface layer (Anupama, 2007, p. 2, 16). This implicitly means that even if the interface for sending a message to a socket

is relatively easy to use, the actual call stack and possible errors introduce another level of complexity. However, as long as the programmer does not want to treat every possible error he does not need to understand how the *send(...)* function actually performs the desired instruction but instead is able to completely rely on its provided functionality.

It is also important to mention that this was an example of how the **Send** 'primitive' could be defined as a function. Other C libraries can differ in their definition and provided functionality, not to mention other programming languages.

4 Definition

Now that the term 'Socket Primitive' is more clarified, the following definition of 'primitives' by Andrew S. Tanenbaum and David Wetherall gives a very good summary (Tanenbaum & Wetherall, 2011, p. 38, ch. 1.3.4):

> A service is formally specified by a set of 'primitives' (operations) available to user processes to access the service. These 'primitives' tell the service to perform some action or report on an action taken by a peer entity. If the protocol stack is located in the operating system, as it often is, the 'primitives' are normally system calls. These calls cause a trap to kernel mode, which then turns control of the machine over to the operating system to send the necessary packets.

The following therefore is the working definition of a 'Socket Primitive':

> *A 'Socket Primitive' is a socket related function that is provided by various high-level programming language libraries. A socket is a communication endpoint of a UNIX OS. 'Socket Primitives' are called 'primitive' because they represent self-contained low-level units that operate with sockets.*

A Primitive Data Types in C++

```cpp
#include <iostream>

/**
 * Prints the size of the transferred value in bytes as follows:
 *
 * Size of 'type_name': X byte
 *
 * Where X is the size that is returned by the function sizeof(T).
 *
 * @param   type_name        The name of the type.
 */
template <typename T>
void print_size(std::string type_name)
{
    std::cout << "Size of " << type_name << ": " << sizeof(T) << " byte" << std::endl;
}

/**
 * Prints out the following integer types:
 *
 * - signed char
 * - unsigned char
 * - char
 * - short
 * - short int
 * - unsigned short int
 * - int
 * - unsigned int
 * - long int
 * - unsigned long int
 * - long long int
 * - unsigned long long int
 */
void print_integer_types()
{
    print_size<signed char>             ("signed char");
    print_size<unsigned char>           ("unsigned char");
    print_size<char>                    ("char");
    print_size<short>                   ("short");
    print_size<short int>               ("short int");
    print_size<unsigned short int>      ("unsigned short int");
    print_size<int>                     ("int");
    print_size<unsigned int>            ("unsigned int");
    print_size<long int>                ("long int");
    print_size<unsigned long int>       ("unsigned long int");
    print_size<long long int>           ("long long int");
    print_size<unsigned long long int> ("unsigned long long int");
}

/**
 * Prints out the following real number types:
 *
 * - float
 * - double
```

```
 * - long double
 */
void print_real_number_types()
{
    print_size<float>       ("float");
    print_size<double>      ("double");
    print_size<long double> ("long double");
}

/**
 * This application prints all listed primitive data types of the
 * GNU C Reference Manual [1] excluding the complex number types
 * with information on their allocated memory:
 *
 * Integer Types:
 * - signed char
 * - unsigned char
 * - char
 * - short
 * - short int
 * - unsigned short int
 * - int
 * - unsigned int
 * - long int
 * - unsigned long int
 * - long long int
 * - unsigned long long int
 *
 * Real Number Types:
 * - float
 * - double
 * - long double
 *
 * [1] Rothwell, Trevis, & Youngman, James. 2015. The GNU C
     Reference Manual.
 * http://www.gnu.org/software/gnu-c-manual/gnu-c-manual.pdf . Free
     Software
 * Foundation, Inc. [Online. Accessed 1st July 2015].
 *
 * @author Florian Willich
 */
int main()
{
    print_integer_types();
    print_real_number_types();

    return 0;
}
```

B Build Script (Makefile) of the C++ Application

```
# Compilers
CC=gcc
CXX=g++

# Application name
NAME=primitive_data_types

# Header
HEADER=

STANDARD=-std=c++11
EXTENSIONS=-pedantic
ERRORS=-Wall -Wextra -g -O2
CFLAGS=$(STANDARD) $(EXTENSIONS) $(ERRORS)
CXXFLAGS=$(STANDARD) $(EXTENSIONS) $(ERRORS)

# All .c files
CCSRC=

# All .cpp files
CXXSRC=primitive_data_types_main.cpp

# List of all .o files
OBJS=$(CCSRC:%.c=%.o) $(CXXSRC:%.cpp=%.o)

# Additional libs
LIBS=

# Compiles all .c files
.c.o:
  $(CC) $(CFLAGS) -c $< -o $@

# Compiles all .cpp files
.cpp.o:
  $(CXX) $(CXXFLAGS) -c $< -o $@

# Links
$(NAME): $(OBJS)
  $(CXX) -o $(NAME) $(OBJS) $(LIBS)

# Cleanes up
clean:
  rm $(OBJS)
```

Acronyms

ASCII American Standard Code for Information Interchange. 2

IPC Inter-Process Communication. 1

OS Operating System. 1, 4

TCP/IP Transmission Control Protocol / Internet Protocol. 1, 3

UDP User Datagram Protocol. 1

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