Preface

Introduction

Most nontrivial programs involve some form of IPC or Interprocess Communication. This is a natural effect of the design principle that the better approach is to design an application as a group of small pieces that communicate with each other, instead of designing one huge monolithic program. Historically, applications have been built in the following ways:

1. One huge monolithic program that does everything. The various pieces of the program can be implemented as functions that exchange information as function parameters, function return values, and global variables.

2. Multiple programs that communicate with each other using some form of IPC. Many of the standard Unix tools were designed in this fashion, using shell pipelines (a form of IPC) to pass information from one program to the next.

3. One program comprised of multiple threads that communicate with each other using some type of IPC. The term IPC describes this communication even though it is between threads and not between processes.

Combinations of the second two forms of design are also possible: multiple processes, each consisting of one or more threads, involving communication between the threads within a given process and between the different processes.

What I have described is distributing the work involved in performing a given application between multiple processes and perhaps among the threads within a process. On a system containing multiple processors (CPUs), multiple processes might be
able to run at the same time (on different CPUs), or the multiple threads of a given process might be able to run at the same time. Therefore, distributing an application among multiple processes or threads might reduce the amount of time required for an application to perform a given task.

This book describes four different forms of IPC in detail:

1. message passing (pipes, FIFOs, and message queues),
2. synchronization (mutexes, condition variables, read–write locks, file and record locks, and semaphores),
3. shared memory (anonymous and named), and
4. remote procedure calls (Solaris doors and Sun RPC).

This book does not cover the writing of programs that communicate across a computer network. This form of communication normally involves what is called the sockets API (application program interface) using the TCP/IP protocol suite; these topics are covered in detail in Volume 1 of this series [Stevens 1998].

One could argue that single-host or nonnetworked IPC (the subject of this volume) should not be used and instead all applications should be written as distributed applications that run on various hosts across a network. Practically, however, single-host IPC is often much faster and sometimes simpler than communicating across a network. Techniques such as shared memory and synchronization are normally available only on a single host, and may not be used across a network. Experience and history have shown a need for both nonnetworked IPC (this volume) and IPC across a network (Volume 1 of this series).

This current volume builds on the foundation of Volume 1 and my other four books, which are abbreviated throughout this text as follows:

• UNPv1: UNIX Network Programming, Volume 1 [Stevens 1998],
• APUE: Advanced Programming in the UNIX Environment [Stevens 1992],
• TCPv1: TCP/IP Illustrated, Volume 1 [Stevens 1994],
• TCPv2: TCP/IP Illustrated, Volume 2 [Wright and Stevens 1995], and
• TCPv3: TCP/IP Illustrated, Volume 3 [Stevens 1996].

Although covering IPC in a text with “network programming” in the title might seem odd, IPC is often used in networked applications. As stated in the Preface of the 1990 edition of UNIX Network Programming, “A requisite for understanding how to develop software for a network is an understanding of interprocess communication (IPC).”

Changes from the First Edition

This volume is a complete rewrite and expansion of Chapters 3 and 18 from the 1990 edition of UNIX Network Programming. Based on a word count, the material has expanded by a factor of five. The following are the major changes with this new edition:
In addition to the three forms of “System V IPC” (message queues, semaphores, and shared memory), the newer Posix functions that implement these three types of IPC are also covered. (I say more about the Posix family of standards in Section 1.7.) In the coming years, I expect a movement to the Posix IPC functions, which have several advantages over their System V counterparts.

The Posix functions for synchronization are covered: mutex locks, condition variables, and read–write locks. These can be used to synchronize either threads or processes and are often used when accessing shared memory.

This volume assumes a Posix threads environment (called “Pthreads”), and many of the examples are built using multiple threads instead of multiple processes.

The coverage of pipes, FIFOs, and record locking focuses on their Posix definitions.

In addition to describing the IPC facilities and showing how to use them, I also develop implementations of Posix message queues, read–write locks, and Posix semaphores (all of which can be implemented as user libraries). These implementations can tie together many different features (e.g., one implementation of Posix semaphores uses mutexes, condition variables, and memory-mapped I/O) and highlight conditions that must often be handled in our applications (such as race conditions, error handling, memory leaks, and variable-length argument lists). Understanding an implementation of a certain feature often leads to a greater knowledge of how to use that feature.

The RPC coverage focuses on the Sun RPC package. I precede this with a description of the new Solaris doors API, which is similar to RPC but on a single host. This provides an introduction to many of the features that we need to worry about when calling procedures in another process, without having to worry about any networking details.

Readers

This text can be used either as a tutorial on IPC, or as a reference for experienced programmers. The book is divided into four main parts:

- message passing,
- synchronization,
- shared memory, and
- remote procedure calls

but many readers will probably be interested in specific subsets. Most chapters can be read independently of others, although Chapter 2 summarizes many features common to all the Posix IPC functions, Chapter 3 summarizes many features common to all the System V IPC functions, and Chapter 12 is an introduction to both Posix and System V shared memory. All readers should read Chapter 1, especially Section 1.6, which describes some wrapper functions used throughout the text. The Posix IPC chapters are
independent of the System V IPC chapters, and the chapters on pipes, FIFOs, and record
locking belong to neither camp. The two chapters on RPC are also independent of the
other IPC techniques.

To aid in the use as a reference, a thorough index is provided, along with sum-
maries on the end papers of where to find detailed descriptions of all the functions and
structures. To help those reading topics in a random order, numerous references to
related topics are provided throughout the text.

Source Code and Errata Availability

The source code for all the examples that appear in this book is available from the
author’s home page (listed at the end of this Preface). The best way to learn the IPC
techniques described in this book is to take these programs, modify them, and enhance
them. Actually writing code of this form is the only way to reinforce the concepts and
techniques. Numerous exercises are also provided at the end of each chapter, and most
answers are provided in Appendix D.

A current errata for this book is also available from the author’s home page.

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Colophon

I produced camera-ready copy of the book (PostScript), which was then typeset for the final book. The formatting system used was James Clark’s wonderful groff package, on a SparcStation running Solaris 2.6. (Reports of troff’s death are greatly exaggerated.) I typed in all 138,897 words using the vi editor, created the 72 illustrations using the gpic program (using many of Gary Wright’s macros), produced the 35 tables using the gtbl program, performed all the indexing (using a set of awk scripts written by Jon Bentley and Brian Kernighan), and did the final page layout. Dave Hanson’s loom program, the GNU indent program, and some scripts by Gary Wright were used to include the 8,046 lines of C source code in the book.

I welcome email from any readers with comments, suggestions, or bug fixes.

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