Inter-Process Communication (IPC)

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IPC Fundamentals

- What is IPC?
  - Mechanisms to transfer data between processes
- Why is it needed?
  - Not all procedures can be easily built in a single process

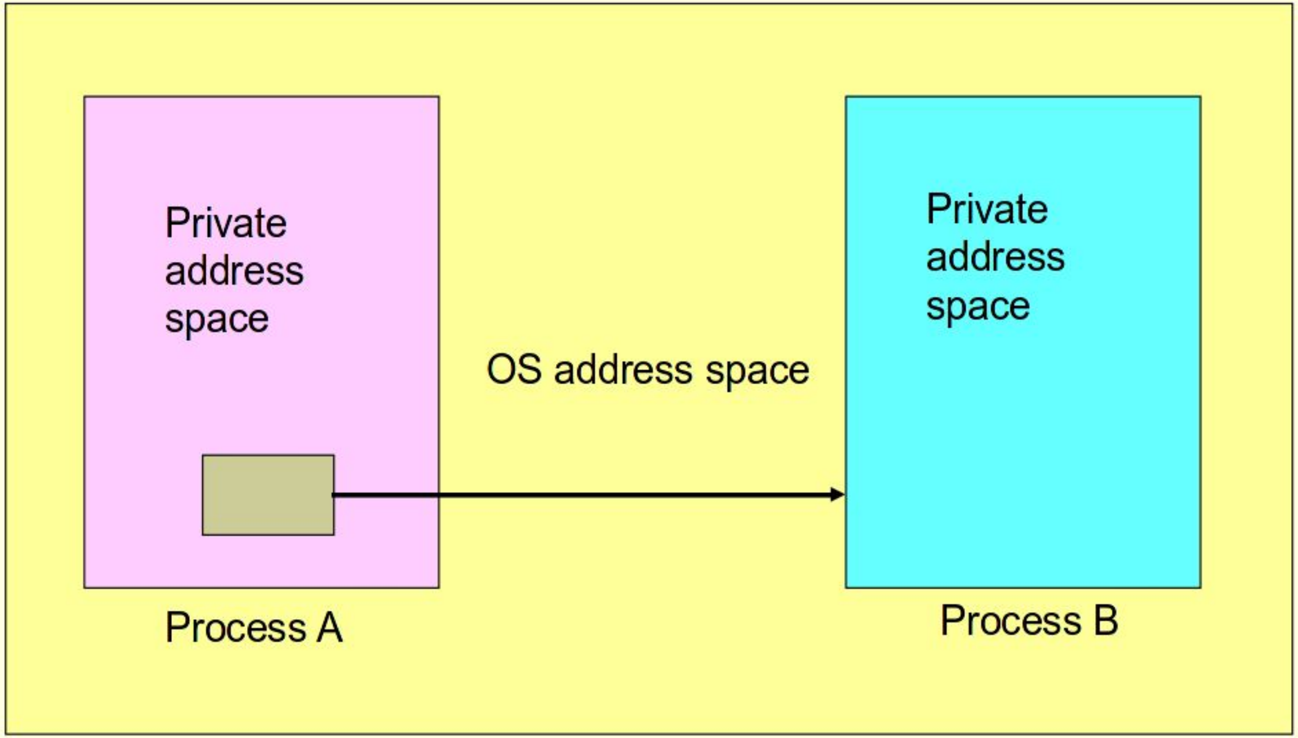
Why do processes communicate?

- To share resources
- Client/server paradigms
- Inherently distributed applications
- Reusable software components
- Other good software engineering reasons

The Basic Concept of IPC

- A process needs to send data to a receiving process
  - Sender wants to avoid details of receiver’s condition
  - Receiver wants to get the data in an organized way

IPC from the OS Point of View



Fundamental IPC Problem for the OS

- Each process has a private address space
- Normally, no process can write to another process's space
- How to get important data from process A to process B?

OS Solutions to IPC Problem

- Fundamentally, two options

1. Support some form of shared address space
   - Shared memory
2. Use OS mechanisms to transport data from one address space to another
   - Files, messages, pipes, RPC, signal, ...

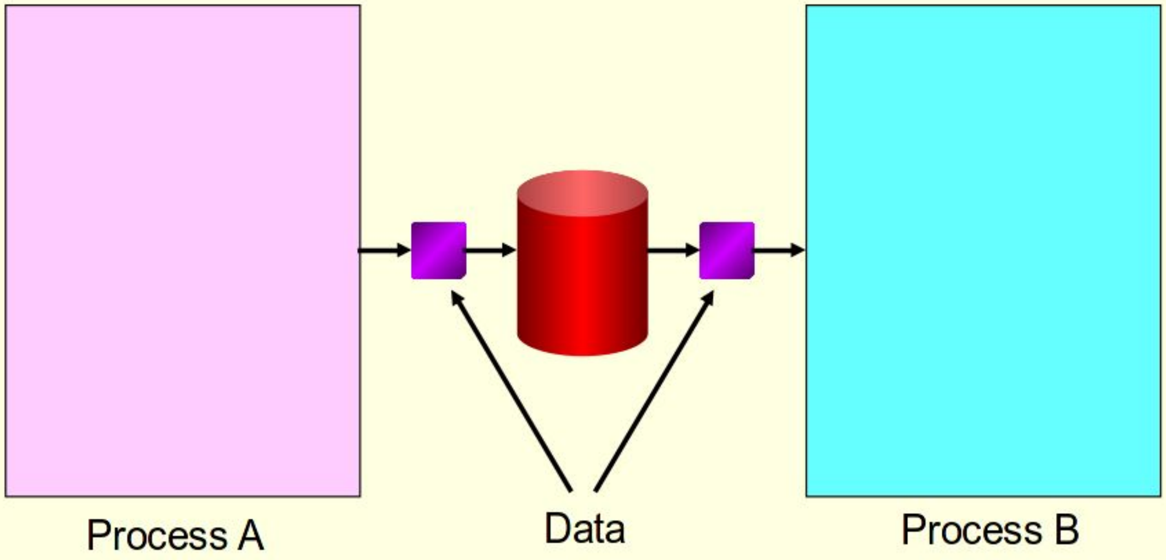
Fundamental Differences in OS Treatment of IPC Solutions

- Shared memory
  - OS has job of setting it up
  - And perhaps synchronizing
  - But not transporting data
- Messages, etc
  - OS involved in every IPC
  - OS transports data

IPC Through the File System

- Sender writes to a file
- Receiver reads from it
- But when does the receiver do the read?
  - Often synchronized with file locking or lock files
- Special types of files can make file-based IPC easier

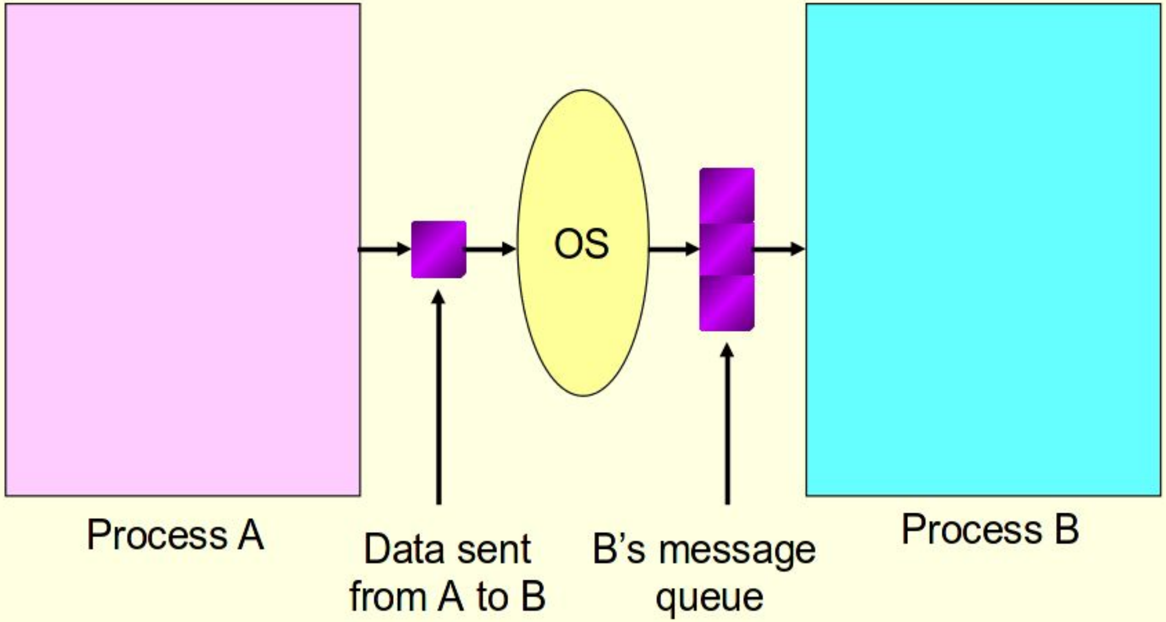
File IPC Diagram



Message-based IPC

- Sender formats data into a formal message
  - With some form of address for receiver
- OS delivers message to receiver's message input queue (might signal too)
- Receiver (when ready) reads a message from the queue
- Sender might or might not block

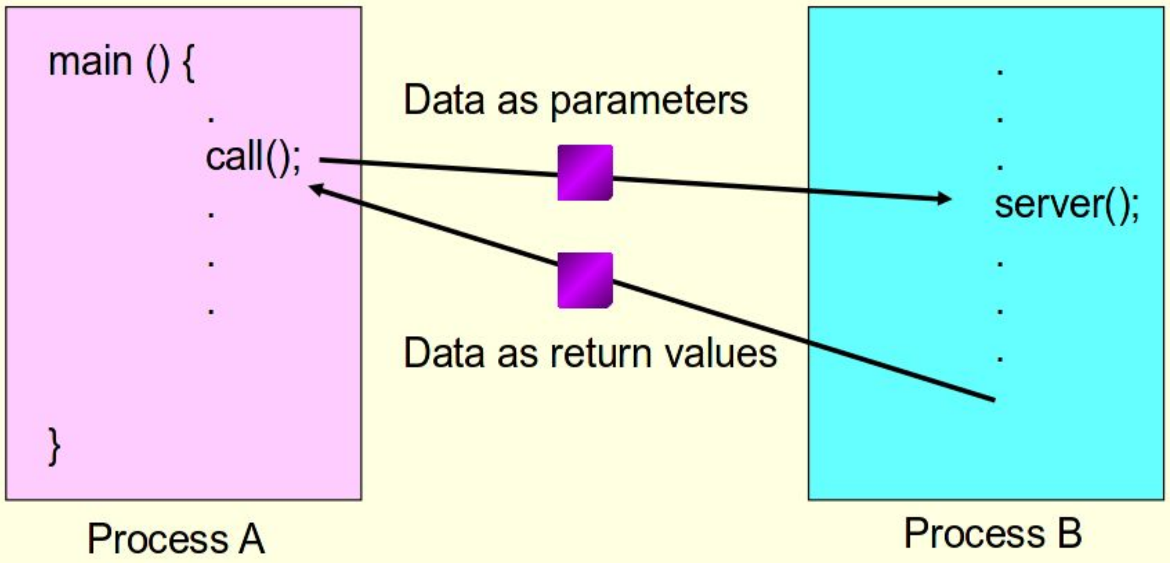
Message-based IPC Diagram



Procedure Call IPC

- Uses same procedure call interface as intraprocess
  - Data passed as parameters
  - Info returned via return values
- Complicated since destination procedure is in a different address space
- Generally, calling procedure blocks till call returns

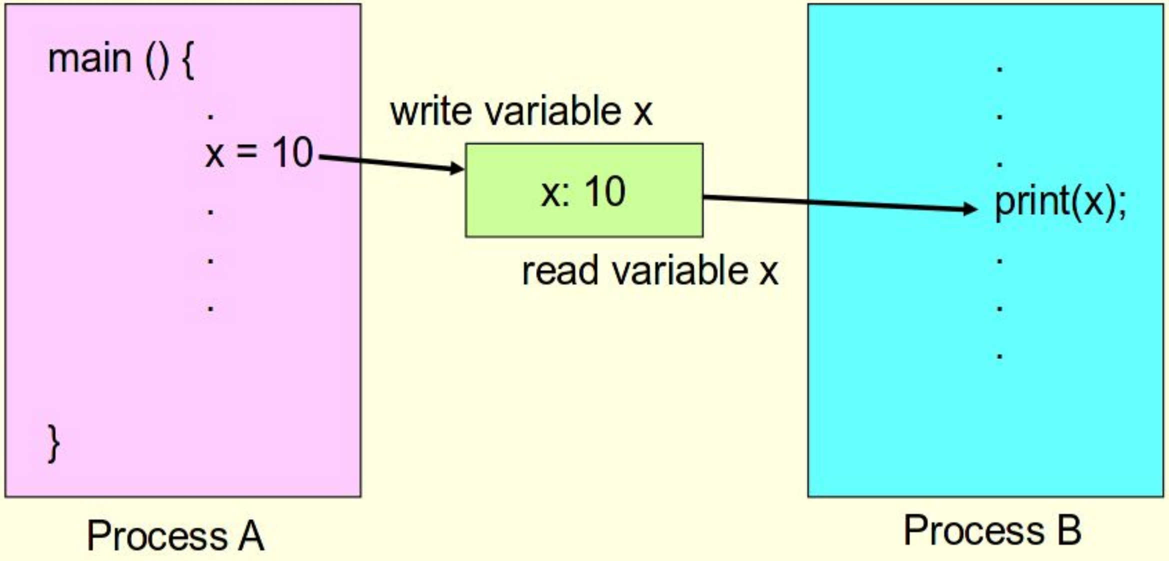
File IPC Diagram

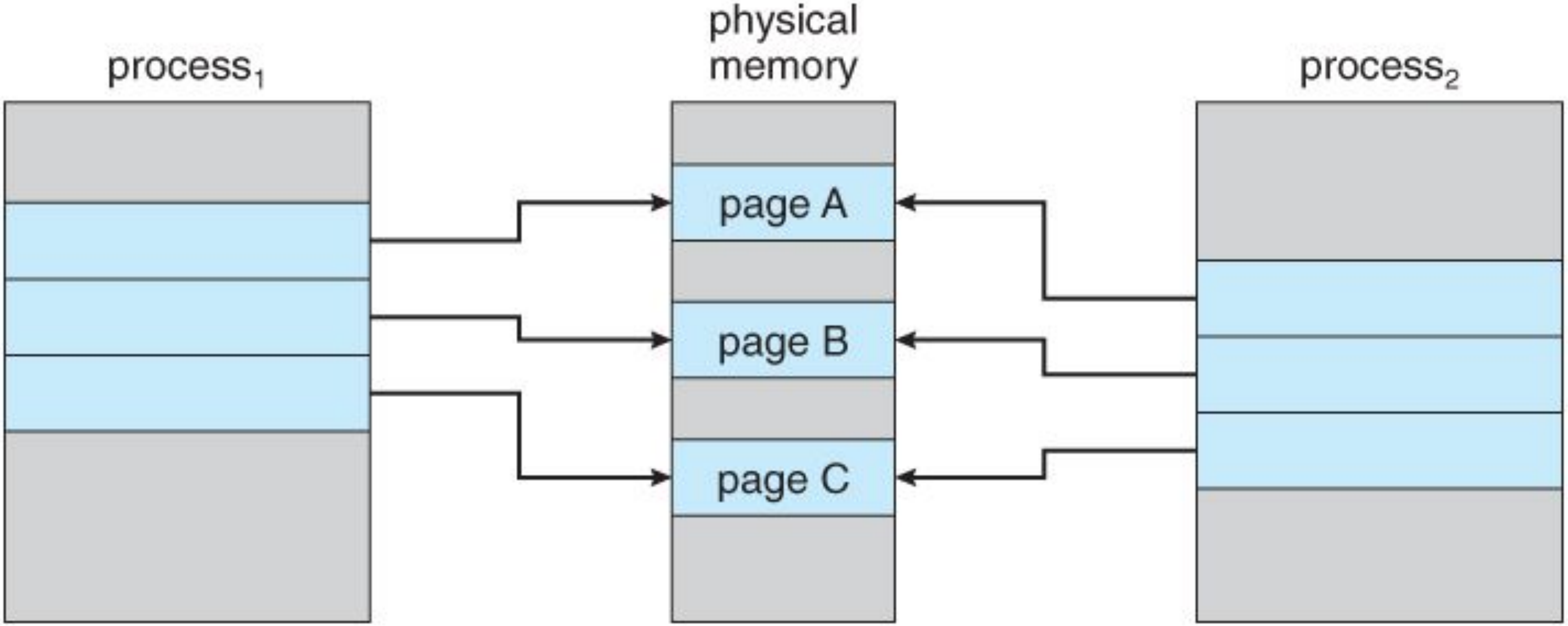


Shared Memory IPC

- Different processes share a piece of memory
  - Either physically or virtually
- Communications via normal reads/writes
- May need semaphores or locks
  - In or associated with the shared memory

Shared Memory IPC Diagram




process$_1$
physical memory
process$_2$
page A
page B
page C

```
int main() {
// ftok to generate unique key
key_t key = ftok("shmfile",65);

// shmget returns an identifier in shmid
int shmid = shmget(key,1024,0666|
IPC_CREAT);

// shmat to attach to shared memory
char *str = (char*)
shmat(shmid,(void*)0,0);
```

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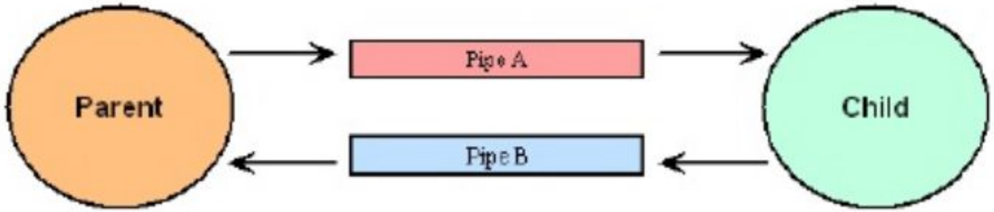
Pipes

- Only IPC mechanism in early UNIX systems (other than files)
  - Uni-directional
  - Unformatted
  - Uninterpreted
  - Interprocess byte streams
- Accessed in file-like way

What is PIPE

- A **pipeline** is a set of processes chained by their standard streams, so that the output of each process (*stdout*) feeds directly as input (*stdin*) to the next one.
- Each connection is implemented by an anonymous pipe.



Pipe Details

- One process feeds bytes into pipe
  - A second process reads the bytes from it
- Potentially blocking communication mechanism
- Requires close cooperation between processes to set up
  - Named pipes allow more flexibility

Sockets

- Introduced in 4.3 BSD
- A socket is an IPC channel with generated endpoints
- Great flexibility in its characteristics
  - Intended as building block for communication
- Endpoints established by the source and destination processes

Socket

- Sockets provide point-to-point, two-way communication between two processes.
- Sockets are very versatile and are a basic component of inter process and intersystem communication.
- A socket is an endpoint of communication to which a name can be bound.
- It has a type and one or more associated processes.
- Sockets exist in communication domains.
- A socket domain is an abstraction that provides an addressing structure and a set of protocols. Sockets connect only with sockets in the same domain.

More on Sockets

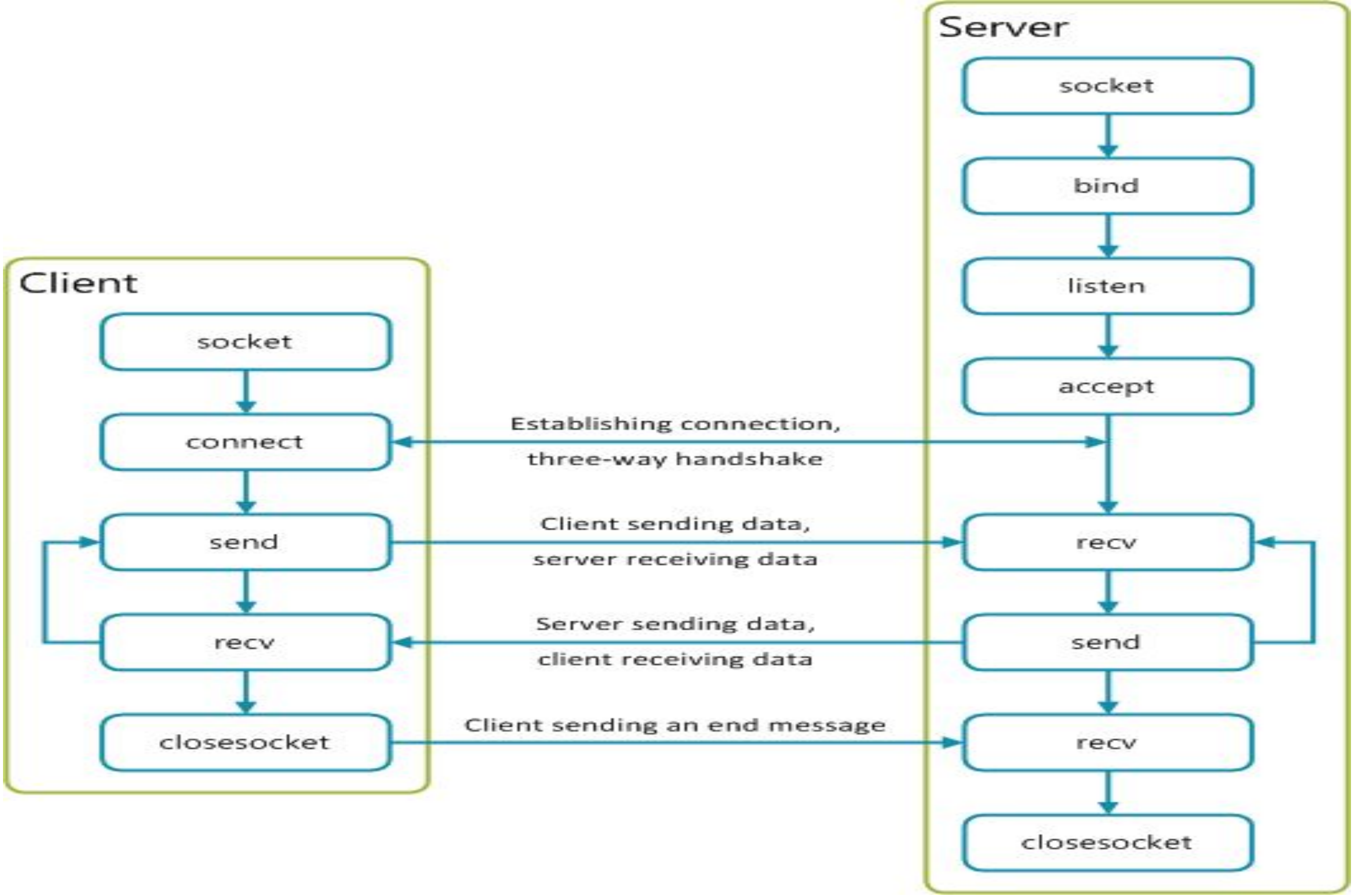
- Created using the socket() system call
- Specifying domain, type, and protocol
- Sockets can be connected or connectionless
  - Each side responsible for proper setup/access

Socket Domains

- the socket domain describes a protocol family used by the socket
  - Generally related to the address family
- Domains can be:
  - Internal protocols
  - Internet protocols
  - IMP (interface message processors) link layer protocols

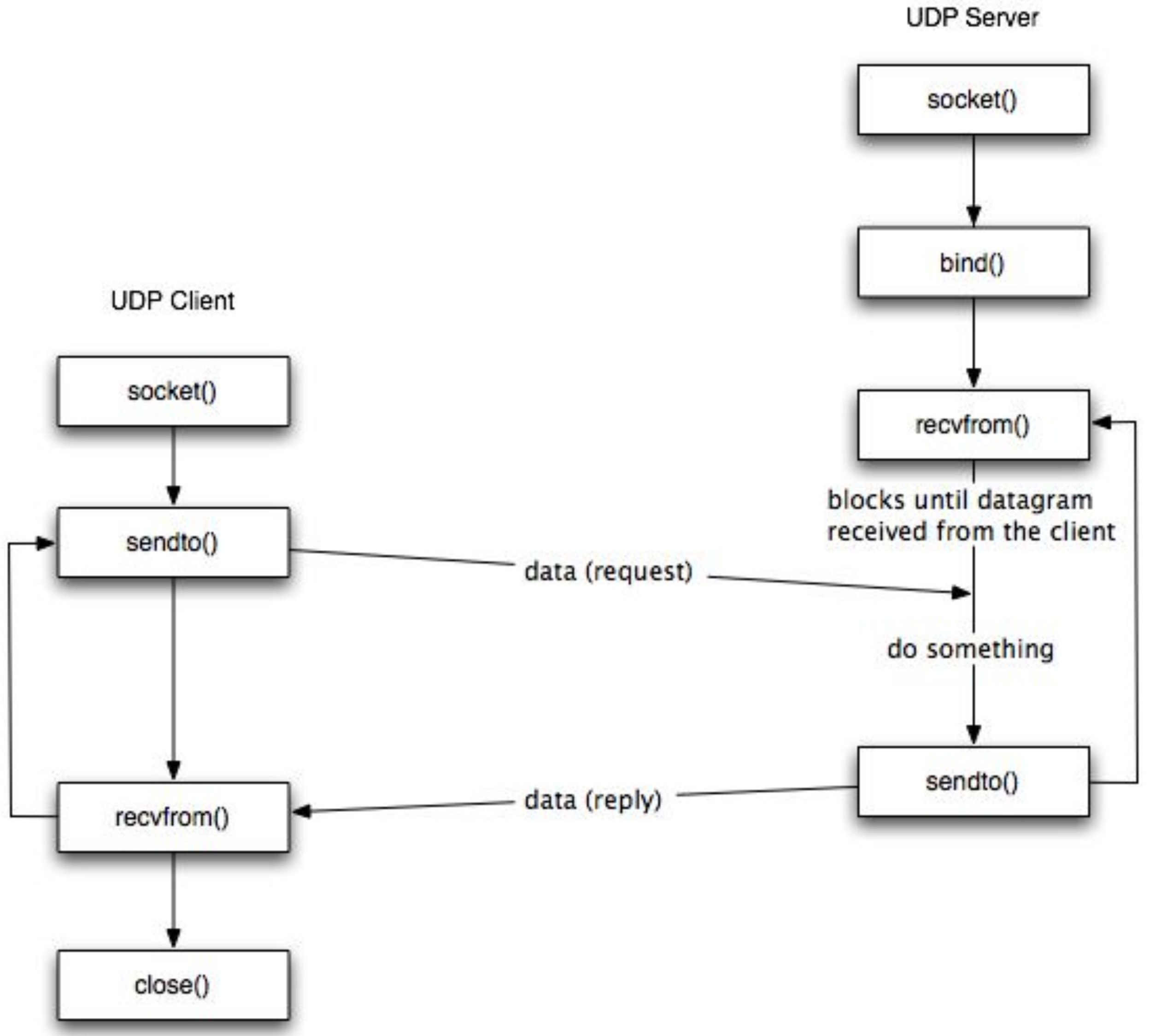
Socket Types

- The socket type describes what the socket does
- Several types are defined
  - SOCK_STREAM
  - SOCK_DGRAM
  - SOCK_SEQPACKET
  - SOCK_RAW
  - SOCK_RDM


Server
socket
bind
listen
accept
Client
socket
connect
Establishing connection,
three-way handshake
send
Client sending data,
server receiving data
recv
recv
Server sending data,
client receiving data
send
closesocket
Client sending an end message
recv
closesocket

BSD Server

- The BSD server creates a socket, uses bind to attach that socket to a port, and configures it as a listening socket. This allows the server to receive incoming connection requests.
- Afterwards, accept is called, which will block the socket, until an incoming connection request is received.
- When accept returns, the SOCKADDR structure will have been filled out with the originating IP Address and port of the incoming connection.
- Then, accept creates a new socket, which is then used to receive data until the connection


UDP Server
socket()
bind()
recvfrom()
blocks until datagram
received from the client
do something
sendto()
UDP Client
socket()
sendto()
data (request)
data (reply)
recvfrom()
close()

Signal

- S**ignal** is a limited form of IPC used in Unix and Unix-like operating systems.

- Essentially it is an asynchronous notification sent to a process in order to notify it of an event that occurred.

- When a signal is sent to a process, the operating system interrupts the process's normal flow of execution.

- Execution can be interrupted during any instruction.

Signal	Portable number	Default action	Description
SIGABRT	6	Terminate (core dump)	Process abort signal
SIGALRM	14	Terminate	Alarm clock
SIGBUS	N/A	Terminate (core dump)	Access to an undefined portion of a memory object
SIGCHLD	N/A	Ignore	Child process terminated, stopped, or continued
SIGCONT	N/A	Continue	Continue executing, if stopped
SIGFPE	8	Terminate (core dump)	Erroneous arithmetic operation
SIGHUP	1	Terminate	Hangup
SIGILL	4	Terminate (core dump)	Illegal instruction
SIGINT	2	Terminate	Terminal interrupt signal
SIGKILL	9	Terminate	Kill (cannot be caught or ignored)
SIGPIPE	13	Terminate	Write on a pipe with no one to read it