PennOS

1.0

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Chapter 4

Data Structure Documentation

4.1 pcb_t Struct Reference

This structure stores all required information about a running process.

`#include <kernel.h>`

Data Fields

- spthread_st handle
  This stores a handle to the spthread.
- pid_t pid
  This stores the PID of the process.
- pid_t ppid
  This stores the PPID of the process.
- int priority
  This the priority level of the process. (0, 1, or 2)

4.1.1 Detailed Description

This structure stores all required information about a running process.

4.1.2 Field Documentation

4.1.2.1 handle

`spthread_st pcb_t::handle`

This stores a handle to the spthread.

4.1.2.2 pid

```
pid_t pcb_t::pid
```

This stores the PID of the process.

4.1.2.3 ppid

```
pid_t pcb_t::ppid
```

This stores the PPID of the process.

4.1.2.4 priority

```
int pcb_t::priority
```

This the priority level of the process. (0, 1, or 2)

The documentation for this struct was generated from the following file:

- src/util/kernel.h

4.2 spthread_fwd_args_st Struct Reference

Data Fields

- pthread_fn actual_routine
- void * actual_arg
- bool setup_done
- pthread_mutex_t setup_mutex
- pthread_cond_t setup_cond
- spthread_meta_t * child_meta

4.2.1 Field Documentation

4.2.1.1 actual_arg

```
void* spthread_fwd_args_st::actual_arg
```

4.2.1.2 actual_routine

```
pthread_fn spthread_fwd_args_st::actual_routine
```

4.2.1.3 child_meta

```
spthread_meta_t* spthread_fwd_args_st::child_meta
```

4.2.1.4 setup_cond

```
pthread_cond_t spthread_fwd_args_st::setup_cond
```

4.2.1.5 setup_done

```
bool spthread_fwd_args_st::setup_done
```

4.2.1.6 setup_mutex

```
pthread_mutex_t spthread_fwd_args_st::setup_mutex
```

The documentation for this struct was generated from the following file:

- src/util/spthread.c

4.3 spthread_meta_st Struct Reference

Data Fields

- sigset_t suspend_set
- volatile sig_atomic_t state
- pthread_mutex_t meta_mutex

4.3.1 Field Documentation

4.3.1.1 meta_mutex

```
pthread_mutex_t spthread_meta_st::meta_mutex
```

4.3.1.2 state

```
volatile sig_atomic_t spthread_meta_st::state
```

4.3.1.3 suspend_set

```
sigset_t spthread_meta_st::suspend_set
```

The documentation for this struct was generated from the following file:

- src/util/spthread.c

4.4 spthread_signal_args_st Struct Reference

Data Fields

- const int signal
- volatile sig_atomic_t ack
- pthread_mutex_t shutup_mutex

4.4.1 Field Documentation

4.4.1.1 ack

```
volatile sig_atomic_t spthread_signal_args_st::ack
```

4.4.1.2 shutup_mutex

```
pthread_mutex_t spthread_signal_args_st::shutup_mutex
```

4.4.1.3 signal

```
const int spthread_signal_args_st::signal
```

The documentation for this struct was generated from the following file:

- src/util/spthread.c

4.5 spthread_st Struct Reference

```
#include <spthread.h>
```

Data Fields

- pthread_t thread
- spthread_meta_t * meta

4.5.1 Field Documentation

4.5.1.1 meta

```
spthread_meta_t* spthread_st::meta
```

4.5.1.2 thread

```
pthread_t spthread_st::thread
```

The documentation for this struct was generated from the following file:

- src/util/spthread.h

Chapter 5

File Documentation

5.1 doc/README.md File Reference

5.2 src/pennfat.c File Reference

5.3 src/pennos.c File Reference

5.4 src/util/kernel.c File Reference

```
#include "kernel.h"
```

5.5 src/util/kernel.h File Reference

```
#include "spthread.h"
```

Data Structures

- struct pcb_t

  This structure stores all required information about a running process.

Typedefs

- typedef struct pcb_t pcb_t

Enumerations

- enum process_state_t { RUNNING , STOPPED , BLOCKED , ZOMBIED }

  Defines the possible states of a process in the system.

Functions

- pcb_t * k_proc_create (pcb_t *parent)

  Create a new child process, inheriting applicable properties from the parent.
- void k_proc_cleanup (pcb_t *proc)

  Clean up a terminated/finished thread's resources. This may include freeing the PCB, handling children, etc.

5.5.1 Typedef Documentation

5.5.1.1 pcb_t

```
typedef struct pcb_t pcb_t
```

5.5.2 Enumeration Type Documentation

5.5.2.1 process_state_t

```
enum process_state_t
```

Defines the possible states of a process in the system.

This enumeration lists all the possible states that a process could be in at any given time. It is used within the pcb_t structure to track the current state of each process.

Enumerator

RUNNING	Process is currently executing. A process enters the RUNNING state when the scheduler selects it for execution, typically from the READY state.
STOPPED	Process is not executing, but can be resumed. A process should only become STOPPED if signaled by s_kill, recieving the P_SIGSTOP signal.
BLOCKED	Process is not executing, waiting for an event to occur. A process should only be blocked if it made a call to either s_waitpid or s_sleep.
ZOMBIED	Process has finished execution but awaits resource cleanup. A process enters the ZOMBIED state after it has finished its execution and is waiting for the parent process to read its exit status. If the parent process ever exits prior to reading exit status, this process should immediately cleaned up.

5.5.3 Function Documentation

5.5.3.1 k_proc_cleanup()

```
void k_proc_cleanup (
            pcb_t * proc )
```

Clean up a terminated/finished thread's resources. This may include freeing the PCB, handling children, etc.

Parameters

proc	This is a pointer to the process control block of a process that has terminated.

5.5.3.2 k_proc_create()

```
pcb_t * k_proc_create (
            pcb_t * parent )
```

Create a new child process, inheriting applicable properties from the parent.

Parameters

parent	This is a pointer to the process control block of the parent, from which it inherits.

Returns

Reference to the child PCB.

5.6 kernel.h

Go to the documentation of this file.

```
00001 #include "spthread.h"
00002
00011 typedef enum {
00012     RUNNING,
00016     STOPPED,
00021     BLOCKED,
00026     ZOMBIED
00031 } process_state_t;
00032
00033
00038 typedef struct pcb_t {
00039     spthread_st handle;
00040     pid_t pid;
00041     pid_t ppid;
00042     // need to store child pids
00043     int priority;
00044     // need to store all open file descriptors
00045 } pcb_t;
00046
00047
00053 pcb_t* k_proc_create(pcb_t *parent);
00054
00061 void k_proc_cleanup(pcb_t *proc);
```

5.7 src/util/spthread.c File Reference

```
#include <errno.h>
#include <pthread.h>
#include <signal.h>
#include <stdbool.h>
#include <stdlib.h>
#include "./spthread.h"
#include <string.h>
#include <stdio.h>
```

Data Structures

- struct spthread_fwd_args_st
- struct spthread_signal_args_st
- struct spthread_meta_st

Macros

- #define _GNU_SOURCE
- #define _XOPEN_SOURCE 700
- #define MILISEC_IN_NANO 100000
- #define SPTHREAD_RUNNING_STATE 0
- #define SPTHREAD_SUSPENDED_STATE 1
- #define SPTHREAD_TERMINATED_STATE 2
- #define SPTHREAD_SIG_SUSPEND -1
- #define SPTHREAD_SIG_CONTINUE -2

Typedefs

- typedef void *(* pthread_fn) (void *)
- typedef struct spthread_fwd_args_st spthread_fwd_args
- typedef struct spthread_signal_args_st spthread_signal_args
- typedef struct spthread_meta_st spthread_meta_t

Functions

- int spthread_create (spthread_t *thread, const pthread_attr_t *attr, pthread_fn start_routine, void *arg)
- int spthread_suspend (spthread_t thread)
- int spthread_suspend_self ()
- int spthread_continue (spthread_t thread)
- int spthread_cancel (spthread_t thread)
- bool spthread_self (spthread_t *thread)
- int spthread_join (spthread_t thread, void **retval)
- void spthread_exit (void *status)

5.7.1 Macro Definition Documentation

5.7.1.1 _GNU_SOURCE

```
#define _GNU_SOURCE
```

5.7.1.2 _XOPEN_SOURCE

```
#define _XOPEN_SOURCE 700
```

5.7.1.3 MILISEC_IN_NANO

```
#define MILISEC_IN_NANO 100000
```

5.7.1.4 SPTHREAD_RUNNING_STATE

```
#define SPTHREAD_RUNNING_STATE 0
```

5.7.1.5 SPTHREAD_SIG_CONTINUE

```
#define SPTHREAD_SIG_CONTINUE -2
```

5.7.1.6 SPTHREAD_SIG_SUSPEND

```
#define SPTHREAD_SIG_SUSPEND -1
```

5.7.1.7 SPTHREAD_SUSPENDED_STATE

```
#define SPTHREAD_SUSPENDED_STATE 1
```

5.7.1.8 SPTHREAD_TERMINATED_STATE

```
#define SPTHREAD_TERMINATED_STATE 2
```

5.7.2 Typedef Documentation

5.7.2.1 pthread_fn

```
typedef void *(* pthread_fn) (void *)
```

5.7.2.2 spthread_fwd_args

```
typedef struct spthread_fwd_args_st spthread_fwd_args
```

5.7.2.3 spthread_meta_t

```
typedef struct spthread_meta_st spthread_meta_t
```

5.7.2.4 spthread_signal_args

```
typedef struct spthread_signal_args_st spthread_signal_args
```

5.7.3 Function Documentation

5.7.3.1 spthread_cancel()

```
int spthread_cancel (
            spthread_t thread )
```

5.7.3.2 spthread_continue()

```
int spthread_continue (
            spthread_t thread )
```

5.7.3.3 spthread_create()

```
int spthread_create (
            spthread_t * thread,
            const pthread_attr_t * attr,
            pthread_fn start_routine,
            void * arg )
```

5.7.3.4 spthread_exit()

```
void spthread_exit (
            void * status )
```

5.7.3.5 spthread_join()

```
int spthread_join (
            spthread_t thread,
            void ** retval )
```

5.7.3.6 spthread_self()

```
bool spthread_self (
            spthread_t * thread )
```

5.7.3.7 spthread_suspend()

```
int spthread_suspend (
            spthread_t thread )
```

5.7.3.8 spthread_suspend_self()

```
int spthread_suspend_self ( )
```

5.8 src/util/spthread.h File Reference

```
#include <pthread.h>
#include <stdbool.h>
```

Data Structures

- struct spthread_st

Macros

- #define SIGPTHD SIGUSR1

Typedefs

- typedef struct spthread_meta_st spthread_meta_t
- typedef struct spthread_st spthread_t

Functions

- int spthread_create (spthread_t *thread, const pthread_attr_t *attr, void *(*start_routine)(void *), void *arg)
- int spthread_suspend (spthread_t thread)
- int spthread_suspend_self ()
- int spthread_continue (spthread_t thread)
- int spthread_cancel (spthread_t thread)
- bool spthread_self (spthread_t *thread)
- int spthread_join (spthread_t thread, void **retval)
- void spthread_exit (void *status)

5.8.1 Macro Definition Documentation

5.8.1.1 SIGPTHD

```
#define SIGPTHD SIGUSR1
```

5.8.2 Typedef Documentation

5.8.2.1 spthread_meta_t

```
typedef struct spthread_meta_st spthread_meta_t
```

5.8.2.2 spthread_t

```
typedef struct spthread_st spthread_t
```

5.8.3 Function Documentation

5.8.3.1 spthread_cancel()

```
int spthread_cancel (
            spthread_t thread )
```

5.8.3.2 spthread_continue()

```
int spthread_continue (
            spthread_t thread )
```

5.8.3.3 spthread_create()

```
int spthread_create (
            spthread_t * thread,
            const pthread_attr_t * attr,
            void *(*)(void *) start_routine,
            void * arg )
```

5.8.3.4 spthread_exit()

```
void spthread_exit (
            void * status )
```

5.8.3.5 spthread_join()

```
int spthread_join (
            spthread_t thread,
            void ** retval )
```

5.8.3.6 spthread_self()

```
bool spthread_self (
            spthread_t * thread )
```

5.8.3.7 spthread_suspend()

```
int spthread_suspend (
            spthread_t thread )
```

5.8.3.8 spthread_suspend_self()

```
int spthread_suspend_self ( )
```

5.9 spthread.h

Go to the documentation of this file.

```
00001 #ifndef SPTHREAD_H_
00002 #define SPTHREAD_H_
00003
00004 #include <pthread.h>
00005 #include <stdbool.h>
00006
00007 // CAUTION: according to `man 7 pthread`:
00008 //
00009 //   On older Linux kernels, SIGUSR1 and SIGUSR2
00010 //   are used.  Applications must avoid the use of whichever set of
00011 //   signals is employed by the implementation.
00012 //
00013 // This may not work on other linux versions
00014
00015 // SIGNAL PTHREAD
00016 // NOTE: if within a created spthread you change
00017 // the behaviour of SIGUSR1, then you will not be able
00018 // to suspend and continue a spthread
00019 #define SIGPTHD SIGUSR1
00020
00021 // declares a struct, but the internals of the
00022 // struct cannot be seen by functions outside of spthread.c
00023 typedef struct spthread_meta_st spthread_meta_t;
00024
00025 // The spthread wrapper struct.
00026 // Sometimes you may have to access the inner pthread member
00027 // but you shouldn't need to do that
00028 typedef struct spthread_st {
00029   pthread_t thread;
00030   spthread_meta_t* meta;
00031 } spthread_t;
00032
00033 // NOTE:
00034 // None of these are signal safe
00035 // Also note that most of these functions are not safe to suspension,
00036 // meaning that if the thread calling these is an spthread and is suspended
00037 // in the middle of spthread_continue or spthread_suspend, then it may not work.
00038 //
00039 // Make sure that the calling thread cannot be suspended before calling these functions.
00040 // Exceptions to this are spthread_exit(), spthread_self() and if a thread is
00041 // continuing or suspending itself.
00042
00043 // spthread_create:
00044 // this function works similar to pthread_create, except for two differences.
00045 // 1) the created pthread is able to be asychronously suspended, and continued
00046 //    using the functions:
00047 //      - spthread_suspend
00048 //      - spthread_continue
00049 // 2) The created pthread will be suspended before it executes the specified
00050 //    routine. It must first be continued with `spthread_continue` before
00051 //    it will start executing.
00052 //
00053 // It is worth noting that this function is not signal safe.
00054 // In other words, it should not be called from a signal handler.
00055 //
00056 // to avoid repetition, see pthread_create(3) for details
00057 // on arguments and return values as they are the same here.
00058 int spthread_create(spthread_t* thread,
00059                     const pthread_attr_t* attr,
00060                     void* (*start_routine)(void*),
00061                     void* arg);
00062
00063 // The spthread_suspend function will signal to the
00064 // specified thread to suspend execution.
00065 //
00066 // Calling spthread_suspend on an already suspended
00067 // thread does not do anything.
00068 //
00069 // It is worth noting that this function is not signal safe.
00070 // In other words, it should not be called from a signal handler.
00071 //
00072 // args:
00073 // - pthread_t thread: the thread we want to suspend
00074 //   This thread must be created using the spthread_create() function,
00075 //   if created by some other function, the behaviour is undefined.
00076 //
00077 // returns:
00078 // - 0 on success
00079 // - EAGAIN if the thread could not be signaled
00080 // - ENOSYS if not supported on this system
00081 // - ESRCH if the thread specified is not a valid pthread
00082 int spthread_suspend(spthread_t thread);
```

```
00083
00084 // The spthread_suspend_self function will cause the calling
00085 // thread (which should be created by spthread_create) to suspend
00086 // itself.
00087 //
00088 // returns:
00089 // - 0 on success
00090 // - EAGAIN if the thread could not be signaled
00091 // - ENOSYS if not supported on this system
00092 // - ESRCH if the calling thread is not an spthread
00093 int spthread_suspend_self();
00094
00095 // The spthread_continue function will signal to the
00096 // specified thread to resume execution if suspended.
00097 //
00098 // Calling spthread_continue on an already non-suspended
00099 // thread does not do anything.
00100 //
00101 // It is worth noting that this function is not signal safe.
00102 // In other words, it should not be called from a signal handler.
00103 //
00104 // args:
00105 // - spthread_t thread: the thread we want to continue
00106 //   This thread must be created using the spthread_create() function,
00107 //   if created by some other function, the behaviour is undefined.
00108 //
00109 // returns:
00110 // - 0 on success
00111 // - EAGAIN if the thread could not be signaled
00112 // - ENOSYS if not supported on this system
00113 // - ESRCH if the thread specified is not a valid pthread
00114 int spthread_continue(spthread_t thread);
00115
00116 // The spthread_cancel function will send a
00117 // cancellation request to the specified thread.
00118 //
00119 // as of now, this function is identical to pthread_cancel(3)
00120 // so to avoid repitition, you should look there.
00121 //
00122 // Here are a few things that are worth highlighting:
00123 // - it is worth noting that it is a cancellation __request__
00124 //   the thread may not terminate immediately, instead the
00125 //   thread is checked whenever it calls a function that is
00126 //   marked as a cancellation point. At those points, it will
00127 //   start the cancellation procedure
00128 // - to make sure all things are de-allocated properly on
00129 //   normal exiting of the thread and when it is cancelled,
00130 //   you should mark a defered de-allocation with
00131 //   pthread_cleanup_push(3).
00132 //   consider the following example:
00133 //
00134 //     void* thread_routine(void* arg) {
00135 //        int* num = malloc(sizeof(int));
00136 //        pthread_cleanup_push(&free, num);
00137 //        return NULL;
00138 //     }
00139 //
00140 //    this program will allocate an integer on the heap
00141 //    and mark that data to be de-allocated on cleanup.
00142 //    This means that when the thread returns from the
00143 //    routine specified in spthread_create, free will
00144 //    be called on num. This will also happen if the thread
00145 //    is cancelled and not able to be exited normally.
00146 //
00147 //    Another function that should be used in conjunction
00148 //    is pthread_cleanup_pop(3). I will leave that
00149 //    to you to read more on.
00150 //
00151 // It is worth noting that this function is not signal safe.
00152 // In other words, it should not be called from a signal handler.
00153 //
00154 // args:
00155 // - spthread_t thread: the thread we want to cancel.
00156 //   This thread must be created using the spthread_create() function,
00157 //   if created by some other function, the behaviour is undefined.
00158 //
00159 // returns:
00160 // - 0 on success
00161 // - ESRCH if the thread specified is not a valid pthread
00162 int spthread_cancel(spthread_t thread);
00163
00164 // Can be called by a thread to get two peices of information:
00165 // 1. Whether or not the calling thread is an spthread (true or false)
00166 // 2. The spthread_t of the calling thread, if it is an spthread_t
00167 //
00168 // almost always the function will be called like this:
00169 // spthread_t self;
```

```
00170 // bool i_am_spthread = spthread_self(&self);
00171 //
00172 // args:
00173 // - spthread_t* thread: the output parameter to get the spthread_t
00174 //   representing the calling thread, if it is an spthread
00175 //
00176 // returns:
00177 // - true if the calling thread is an spthread_t
00178 // - false otherwise.
00179 bool spthread_self(spthread_t* thread);
00180
00181 // The equivalent of pthread_join but for spthread
00182 // To make sure all resources are cleaned up appropriately
00183 // spthreads that are created must at some ppoint have spthread_join
00184 // called on them. Do not use pthread_join on an spthread.
00185 //
00186 // to avoid repetition, see pthread_join(3) for details
00187 // on arguments and return values as they are the same as this function.
00188 int spthread_join(spthread_t thread, void** retval);
00189
00190 // The equivalent of pthread_exit but for spthread
00191 // spthread_exit must be used by spthreads instead of pthread_exit.
00192 // Otherwise, calls to spthread_join or other functions (like spthread_suspend)
00193 // may not work as intended.
00194 //
00195 // to avoid repetition, see pthread_exit(3) for details
00196 // on arguments and return values as they are the same as this function.
00197 void spthread_exit(void* status);
00198
00199 #endif  // SPTHREAD_H_
```

5.10 src/util/sys_call.c File Reference

```
#include "kernel.h"
```

5.11 src/util/sys_call.h File Reference

Functions

- pid_t s_spawn (void ∗(∗func)(void ∗), char ∗argv[ ], int fd0, int fd1)

  Create a child process that executes the function `func`. The child will retain some attributes of the parent.
- pid_t s_waitpid (pid_t pid, int ∗wstatus, bool nohang)

  Wait on a child of the calling process, until it changes state. If `nohang` is true, this will not block the calling process and return immediately.
- int s_kill (pid_t pid, int signal)

  Send a signal to a particular process.
- void s_exit (void)

  Unconditionally exit the calling process.
- int s_nice (pid_t pid, int priority)

  Set the priority of the specified thread.
- void s_sleep (unsigned int ticks)

  Suspends execution of the calling proces for a specified number of clock ticks.

5.11.1 Function Documentation

5.11.1.1 s_exit()

```
void s_exit (
            void  )
```

Unconditionally exit the calling process.

5.11.1.2 s_kill()

```
int s_kill (
            pid_t pid,
            int signal )
```

Send a signal to a particular process.

Parameters

pid	Process ID of the target proces.
signal	Signal number to be sent.

Returns

0 on success, -1 on error.

5.11.1.3 s_nice()

```
int s_nice (
            pid_t pid,
            int priority )
```

Set the priority of the specified thread.

Parameters

pid	Process ID of the target thread.
priority	The new priorty value of the thread (0, 1, or 2)

Returns

0 on success, -1 on failure.

5.11.1.4 s_sleep()

```
void s_sleep (
            unsigned int ticks )
```

Suspends execution of the calling proces for a specified number of clock ticks.

This function is analogous to `sleep(3)` in Linux, with the behavior that the system clock continues to tick even if the call is interrupted. The sleep can be interrupted by a P_SIGTERM signal, after which the function will return prematurely.

Parameters

ticks	Duration of the sleep in system clock ticks. Must be greater than 0.

5.11.1.5 s_spawn()

```
pid_t s_spawn (
            void *(*)(void *) func,
            char * argv[],
            int fd0,
            int fd1 )
```

Create a child process that executes the function `func`. The child will retain some attributes of the parent.

Parameters

func	Function to be executed by the child process.
argv	Null-terminated array of args, including the command name as argv[0].
fd0	Input file descriptor.
fd1	Output file descriptor.

Returns

pid_t The process ID of the created child process.

5.11.1.6 s_waitpid()

```
pid_t s_waitpid (
            pid_t pid,
            int * wstatus,
            bool nohang )
```

Wait on a child of the calling process, until it changes state. If `nohang` is true, this will not block the calling process and return immediately.

Parameters

pid	Process ID of the child to wait for.
wstatus	Pointer to an integer variable where the status will be stored.
nohang	If true, return immediately if no child has exited.

Returns

pid_t The process ID of the child which has changed state on success, -1 on error.

5.12 sys_call.h

Go to the documentation of this file.

```
00001 /*============================ system call functions for interacting with PennOS process creation
      ==================================*/
00012 pid_t s_spawn(void* (*func)(void*), char *argv[], int fd0, int fd1);
00013
00023 pid_t s_waitpid(pid_t pid, int* wstatus, bool nohang);
00024
00032 int s_kill(pid_t pid, int signal);
```

```
00033
00037 void s_exit(void);
00038
00039 /*============================ system calls for interacting with the scheduler
      ==================================*/
00040
00048 int s_nice(pid_t pid, int priority);
00049
00060 void s_sleep(unsigned int ticks);
```

5.13 test/sched-demo.c File Reference

```
#include <pthread.h>
#include <signal.h>
#include <stdio.h>
#include <stdlib.h>
#include <sys/time.h>
#include <unistd.h>
#include <stdbool.h>
#include "util/spthread.h"
```

Macros

- #define _POSIX_C_SOURCE 200809L
- #define _DEFAULT_SOURCE 1
- #define NUM_THREADS 4
- #define BUF_SIZE 4096

Functions

- void cancel_and_join (spthread_t thread)
- int main (void)

5.13.1 Macro Definition Documentation

5.13.1.1 _DEFAULT_SOURCE

```
#define _DEFAULT_SOURCE 1
```

5.13.1.2 _POSIX_C_SOURCE

```
#define _POSIX_C_SOURCE 200809L
```

5.13.1.3 BUF_SIZE

```
#define BUF_SIZE 4096
```

5.13.1.4 NUM_THREADS

```
#define NUM_THREADS 4
```

5.13.2 Function Documentation

5.13.2.1 cancel_and_join()

```
void cancel_and_join (
            spthread_t thread )
```

5.13.2.2 main()

```
int main (
            void  )
```

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