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Real-Time Computer Systems (ENG3043)

Lecture 18

Operation Systems

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INSPIRING PEOPLE

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Overview

- What is an OS?
- OS Components?
  I. **Process management**
  II. **Memory management**
  III. **File System**
  IV. **I/O**
  V. **Network**
  VI. **Security**
  VII. **GUI**

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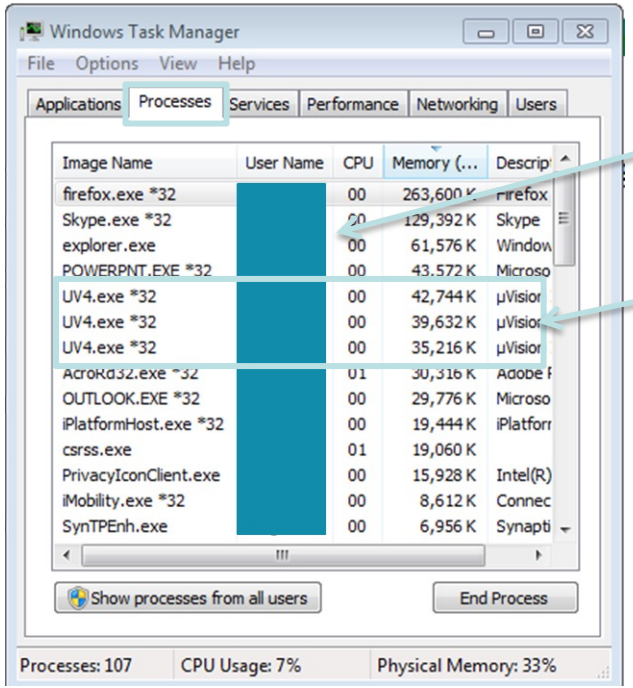
Overview

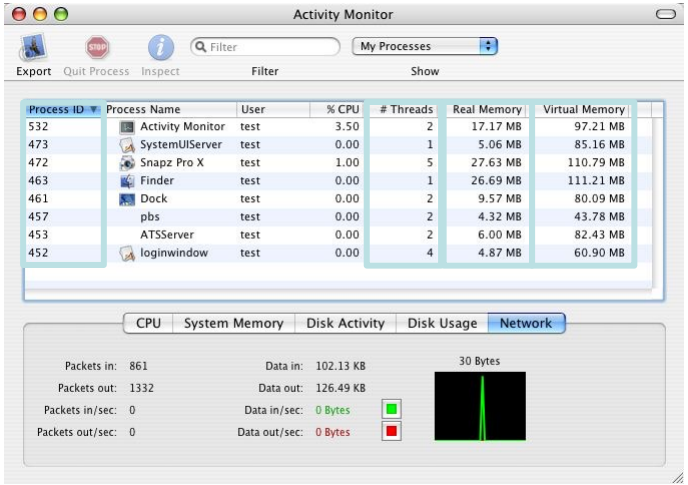
- Process– What is it
- Memory lay out
- Switching between Processes
- RTX and Linux Examples
- Process Termination
- Context Switching and States

An Instance of a Running Program



Your user name or SYSTEM/LOCAL SERVICE/NETWORK SERVICE

Multiple instances of the µVision5
Independent memory for each process
"Memory(Private Working Set)"



Try to explore the task manager, activity monitor, or similar utility on your favourite OS

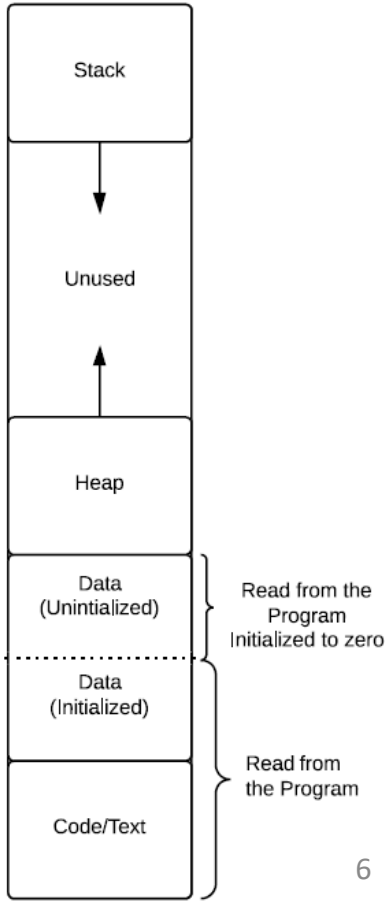
An Instance of a Running Program

- A process can have
  - A CPU time allocation (virtual CPU, the role of OS)
  - Memory (real or virtual)
  - Process ID
  - Threads

- Are they aware of the existence of other processes?
  - The operating system's role is to create an "illusion" that a process has all it needs to be executed
  - An abstraction of hardware resources
  - Each process sees one dedicated processor and one segment of memory (although they are often shared with others)
  - But they can be aware of each other – inter-process communication (IPC)

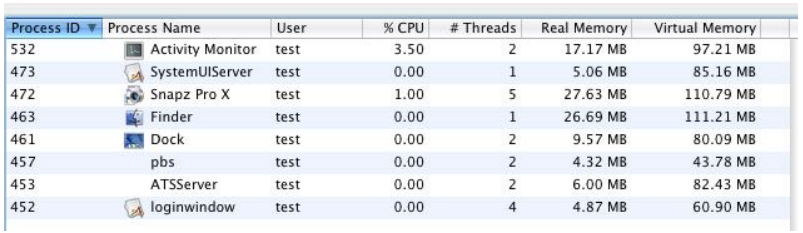
Memory Layout of an Executing Program

- Code or Text
  - Binary instructions to be executed
  - A clone of the program
  - Usually read-only
  - Program counter (PC), points to the next instruction
- Static Data
  - Global/Constant/Static variables - shared between threads
  - If not initialized by program, will be zero or null pointer
- Heap
  - malloc/free
- Stack
  - Used for procedure calls and return
  - Stack Pointer(SP)
  - FILO (First In, Last Out)



Process – The Abstraction

- Switching between executions means the operating system has to keep track of all the execution context
- Includes:
  - Memory State (code, data, heap and stack)
  - CPU state (PC, SP and other registers)
  - Also the OS state



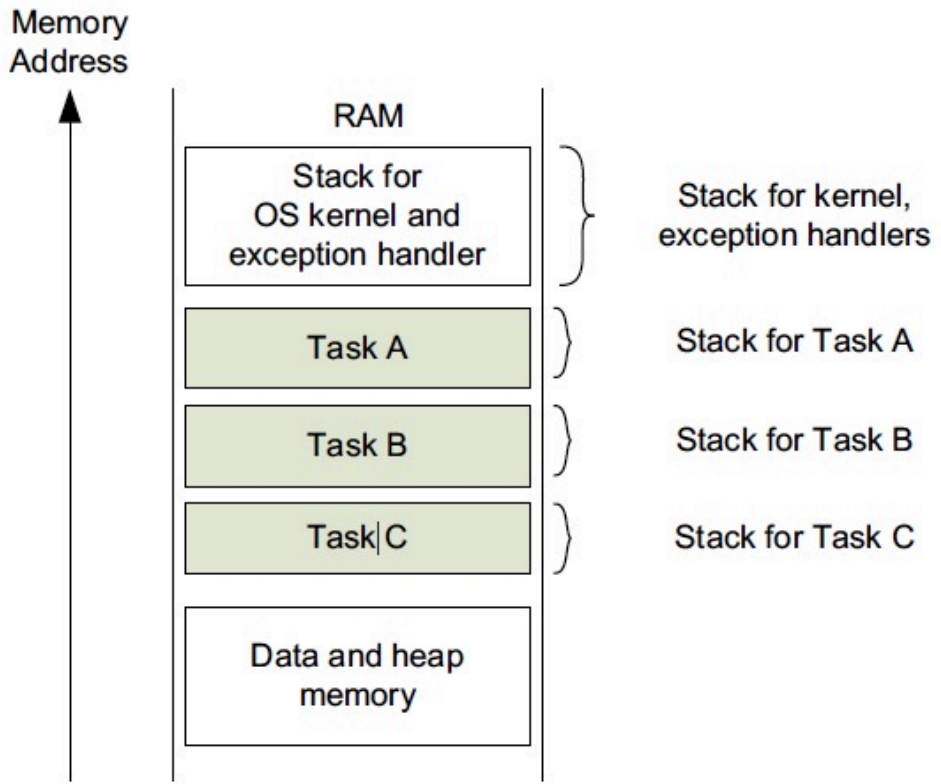
Process ID	Process Name	User	% CPU	# Threads	Real Memory	Virtual Memory
532	Activity Monitor	test	3.50	2	17.17 MB	97.21 MB
473	SystemUIServer	test	0.00	1	5.06 MB	85.16 MB
472	Snapz Pro X	test	1.00	5	27.63 MB	110.79 MB
463	Finder	test	0.00	1	26.69 MB	111.21 MB
461	Dock	test	0.00	2	9.57 MB	80.09 MB
457	pbs	test	0.00	2	4.32 MB	43.78 MB
453	ATSServer	test	0.00	2	6.00 MB	82.43 MB
452	loginwindow	test	0.00	4	4.87 MB	60.90 MB

- Hence the abstraction of the process
- Programme usually refers to the instructions that are stored on disk
- Process is the programme with execution context
- Some OSs may use the term “task”, particularly in an embedded system context. We will use both terms interchangeably for this course
- Thread: a lightweight process; a process may have multiple threads which share the same system resources - faster creation, termination, switching and communication

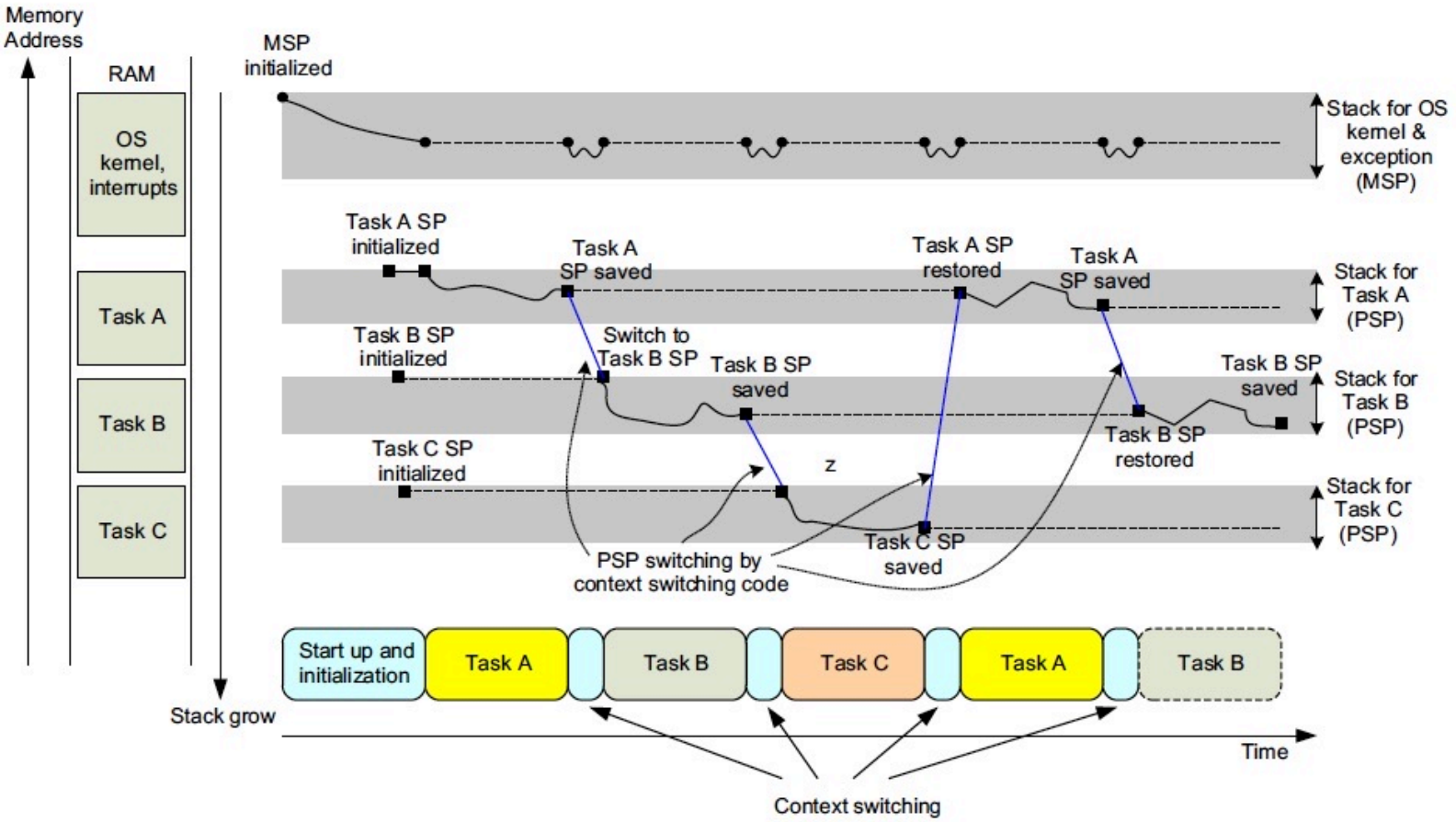
Memory Layout of an Executing Program

A typical OS environment has Ma
Stack Pointer (MSP) and
Process Stack Pointer (PSP)

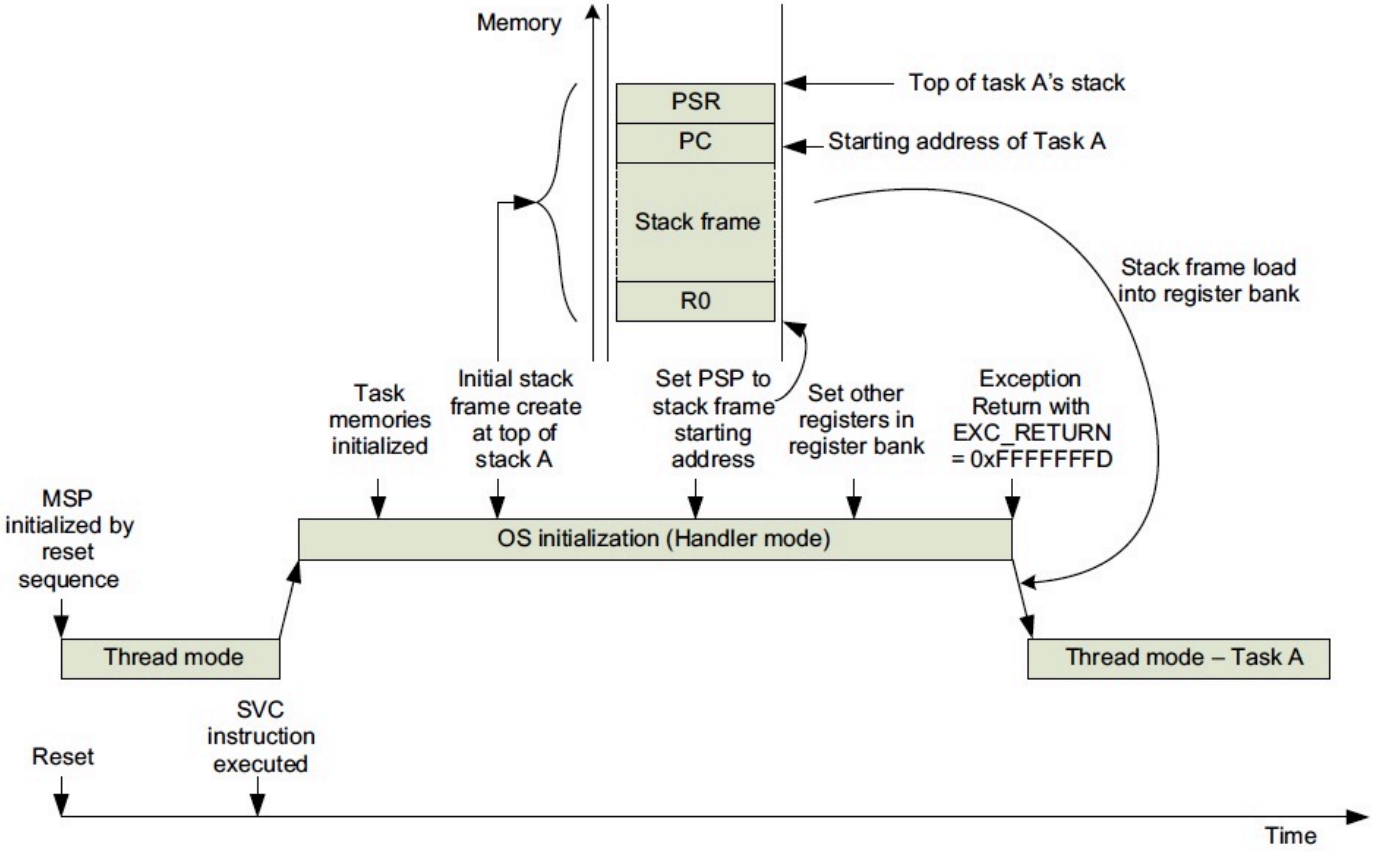
- *MSP, for the OS kernel and exception handlers*
- *PSP, for application tasks*



Memory Layout of an Executing Program



Memory Layout of an Executing Program



Process Control Block

- The **Process Control Block (PCB)** or **Task Control Block (TCB)** maintains all the relevant information for the process:
  - Process ID
  - Process state
  - PC, SP and other registers (stored)
  - Scheduling information (priority)
  - Memory management information
  - Accounting information
  - User information
  - Inter-Process Communication (IPC)
  - Other information
- The ID points to the entry in the process table where the pointer to the PCB is stored

Linux Example: Task Control Block

```
1164 struct task_struct {
1165        volatile long state;    /* -1 unrunnable, 0 runnable, >0 stopped */
1166        void *stack;
1167        atomic_t usage;
1168        unsigned int flags;     /* per process flags, defined below */
1169        unsigned int ptrace;
1170
1171 #ifdef CONFIG_SMP
1172        struct llist_node wake_entry;
1173        int on_cpu;
1174        struct task_struct *last_wakee;
1175        unsigned long wakee_flips;
……
1234 /* task state */
1235        int exit_state;
1236        int exit_code, exit_signal;
1237        int pdeath_signal;  /*  The signal sent when the parent dies  */
1238        unsigned int jobctl;    /* JOBCTL_*, siglock protected */
1239
1240        /* Used for emulating ABI behavior of previous Linux versions */
1241        unsigned int personality;
1242
1243        unsigned in_execve:1;   /* Tell the LSMs that the process is doing an
1244                                 * execve */
1245        unsigned in_iowait:1;
1246
1247        /* task may not gain privileges */
1248        unsigned no_new_privs:1;
1249
1250        /* Revert to default priority/policy when forking */
1251        unsigned sched_reset_on_fork:1;
1252        unsigned sched_contributes_to_load:1;
1253
1254        pid_t pid;
1255        pid_t tgid;
……
1577 #ifdef CONFIG_UPROBES
1578        struct uprobe_task *utask;
1579 #endif
1580 #if defined(CONFIG_BCACHE) || defined(CONFIG_BCACHE_MODULE)
1581        unsigned int    sequential_io;
1582        unsigned int    sequential_io_avg;
1583 #endif
1584 };
```

linux3.14:http://lxr.free-electrons.com/source/include/linux/sched.h

RTX Example: Task Control Block

```
typedef struct OS_TCB {
 /* General part: identical for all implementations.                */
 U8     cb_type;            /* Control Block Type                   */
 U8     state;              /* Task state                           */
 U8     prio;               /* Execution priority                   */
 U8     task_id;            /* Task ID value for optimized TCB access */
 struct OS_TCB *p_lnk;      /* Link pointer for ready/sem. wait list  */
 struct OS_TCB *p_rlnk;     /* Link pointer for sem./mbx lst backwards */
 struct OS_TCB *p_dlnk;     /* Link pointer for delay list          */
 struct OS_TCB *p_blnk;     /* Link pointer for delay list backwards  */
 U16    delta_time;         /* Time until time out                  */
 U16    interval_time;      /* Time interval for periodic waits     */
 U16    events;             /* Event flags                          */
 U16    waits;              /* Wait flags                           */
 void   **msg;              /* Direct message passing when task waits */
 struct OS_MUCB *p_mlnk;    /* Link pointer for mutex owner list    */
 U8     prio_base;          /* Base priority                        */
 U8     ret_val;            /* Return value upon completion of a wait */
 /* Hardware dependant part: specific for CM processor              */
 U8     ret_upd;            /* Updated return value                 */
 U16    priv_stack;         /* Private stack size, 0= system assigned */
 U32    tsk_stack;          /* Current task Stack pointer (R13)     */
 U32    *stack;             /* Pointer to Task Stack memory block   */

 /* Task entry point used for uVision debugger                      */
 FUNCP  ptask;              /* Task entry address                   */
} *P_TCB;
```

- We will come back to this later
- Check with the source code yourself - not really as intimidating as you might expect!

<<Your Keil Directory>>\ARM\RL\RTX\SRC\CM\rt_TypeDef.h

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Process Creation

- By initialization, by request of a process, or by request of a user

- Unique ID for the process
  - init_task_pid() in Linux
- Allocate memory for the PCB and other control structures (kernel) and user memory
- Initialize the PCB and memory management
- Link the PCB in the queue (see later)

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Process Termination

- Stopped by the OS/user (why?) or terminate itself
- Handle the output of the process
- Release the resources and reclaim the memory
- Unlink the PCB
- In embedded software, some processes may never terminate. Terminating implies a fault.

Context Switching

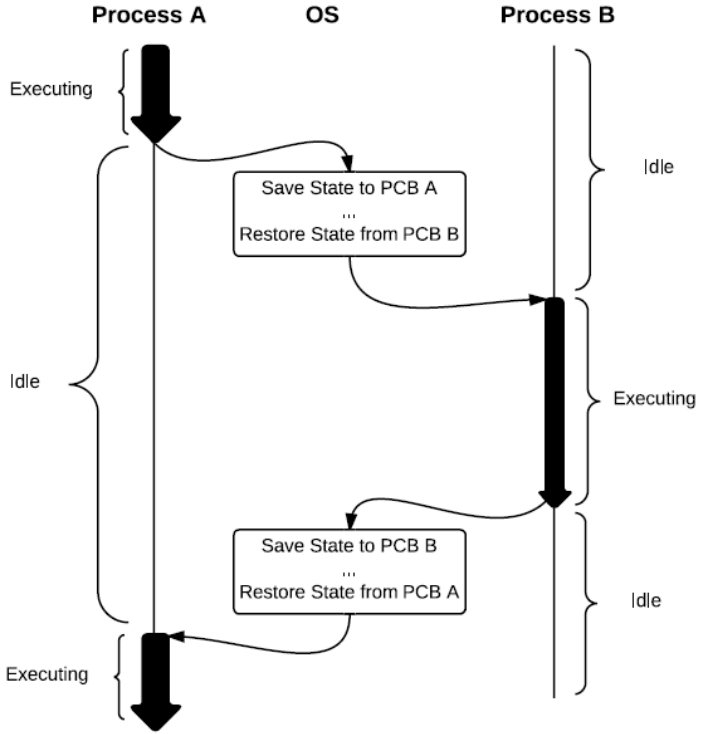
The PCB makes context switching a bit easier

- Scheduler will start or stop a process accordingly
- Stores necessary information in the PCB to stop
  - **Hardware registers**
  - **Program Counter**
  - **Memory states, stack and heap**
  - **State**
- Similarly, loads necessary information from the PCB

Notice that context switching does consume time!

- Could be up to several thousand CPU cycles
- Overhead and bottleneck
- Hardware support is also needed

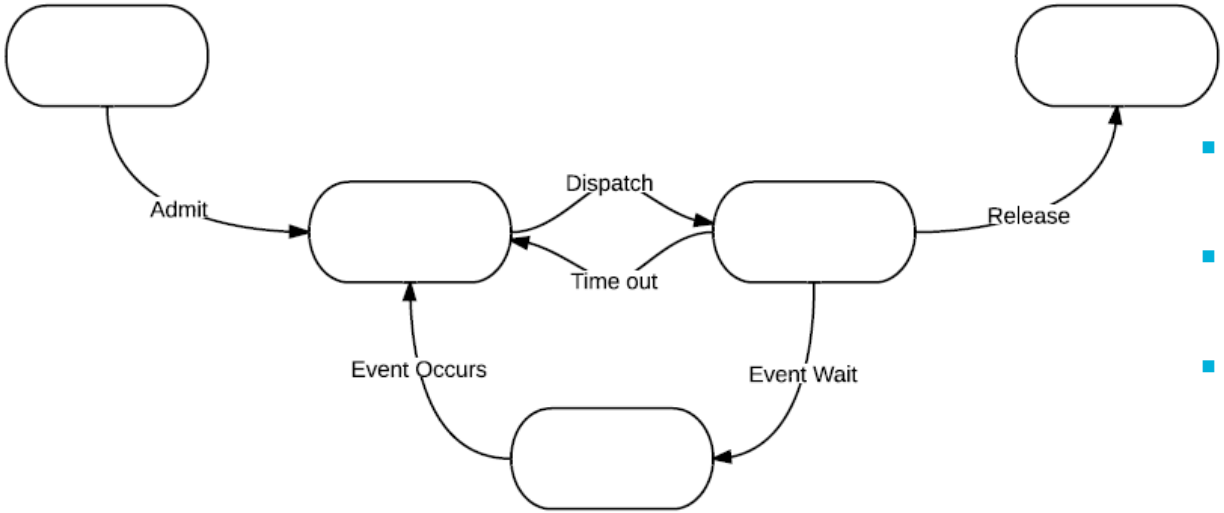
Multiprogramming, although only one active process at any given time



Process States

- Different process states during the lifetime cycle
- Many variants but a standard model has five states:
  - New: just been created, not ready for the queue
  - Ready: can be loaded by the OS
  - Running: scheduler has picked this process from the queue and executed it, usually only one
  - Blocked: not in the queue, waiting
  - Exit: finished, needs to terminate
- Linux Example:
  - TASK_RUNNING; TASK_INTERRUPTIBLE; TASK_UNINTERRUPTIBLE; __TASK_STOPPED; __TASK_TRACED; EXIT_ZOMBIE; EXIT_DEAD; TASK_DEAD; TASK_WAKEKILL; TASK_WAKING; TASK_PARKED; TASK_STATE_MAX

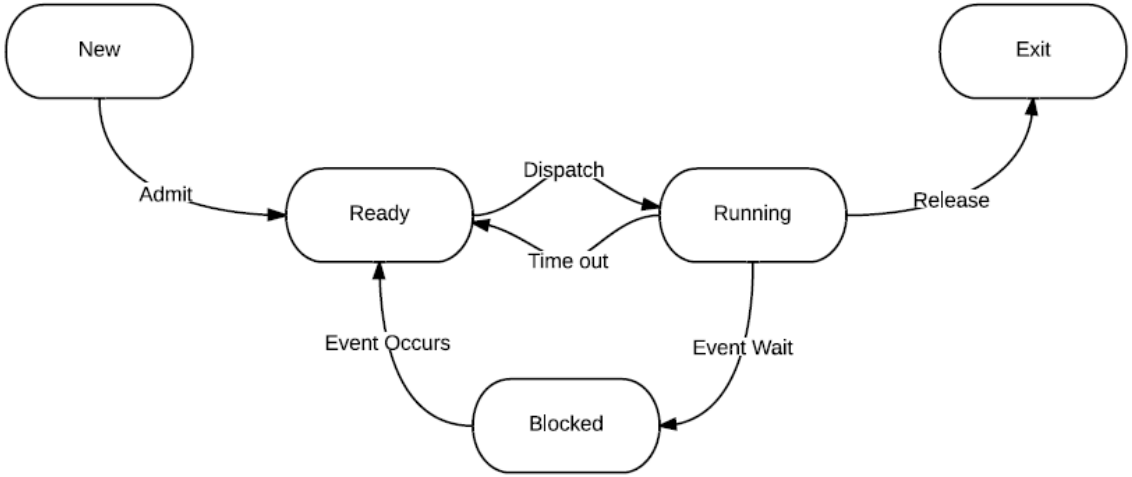
State Transition



- State transition as a result of OS scheduling, external interrupts or program requests
- Try to fill in the states in each block

- **New:** just been created, not ready for the queue
- **Ready:** can be loaded by the OS
- **Running:** scheduler has picked this process from the queue and executed it, usually only one
- **Blocked:** not in the queue, waiting
- **Exit:** finished, needs to terminate

State Transition



- Admit signal: process is fully loaded into memory and control is established
- Dispatch signal: scheduler assigns CPU to the process
- Time out signal: expired or preempted, pushed back to the queue
- Event Wait/Event Occurs: generally requests that cannot be met at the moment, has to wait until something occurs
  - OS not ready for a service
  - Unavailable resource
  - Wait for an input
- Release Signal: release resources and end the process

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Process State

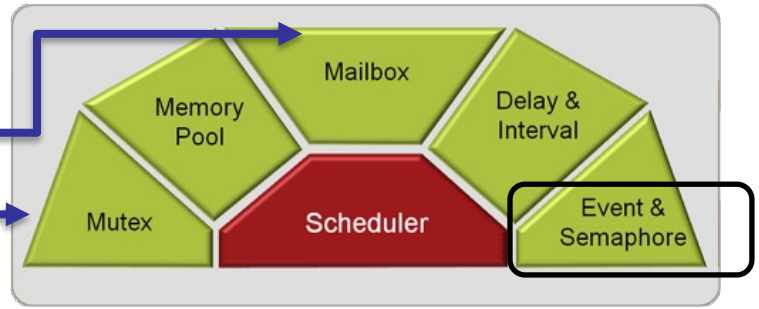
- State information is also recorded by the PCB (Process Control Block)
- Context switch takes place whenever a process leaves/enters the running state
- Processes may make a transition voluntarily or involuntarily, e.g., end the program vs error
- OS typically maintains queue or queue-like (list) structures for processes in the same states (many pointers in the PCB)
  - RTX: rt_list.c
- More complicated models possible:
  - Some processes are stored in the secondary storage in their Ready or Blocked states
  - “Suspended” Ready and Blocked – the seven states model
  - To support swapping
  - Scheduler prefer those sit in main the memory

RTX Example

```
/* Values for 'state'   */
#define INACTIVE      0
#define READY         1
#define RUNNING       2
#define WAIT_DLY      3
#define WAIT_ITV      4
#define WAIT_OR       5
#define WAIT_AND      6
#define WAIT_SEM      7
#define WAIT_MBX      8
#define WAIT_MUT      9
```

- No Exit state
- Embedded software don't really enjoy the concept of termination

Variants of blocked States:
The name indicates the event to invoke the process



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Discussions and
Questions Time