

# Processes

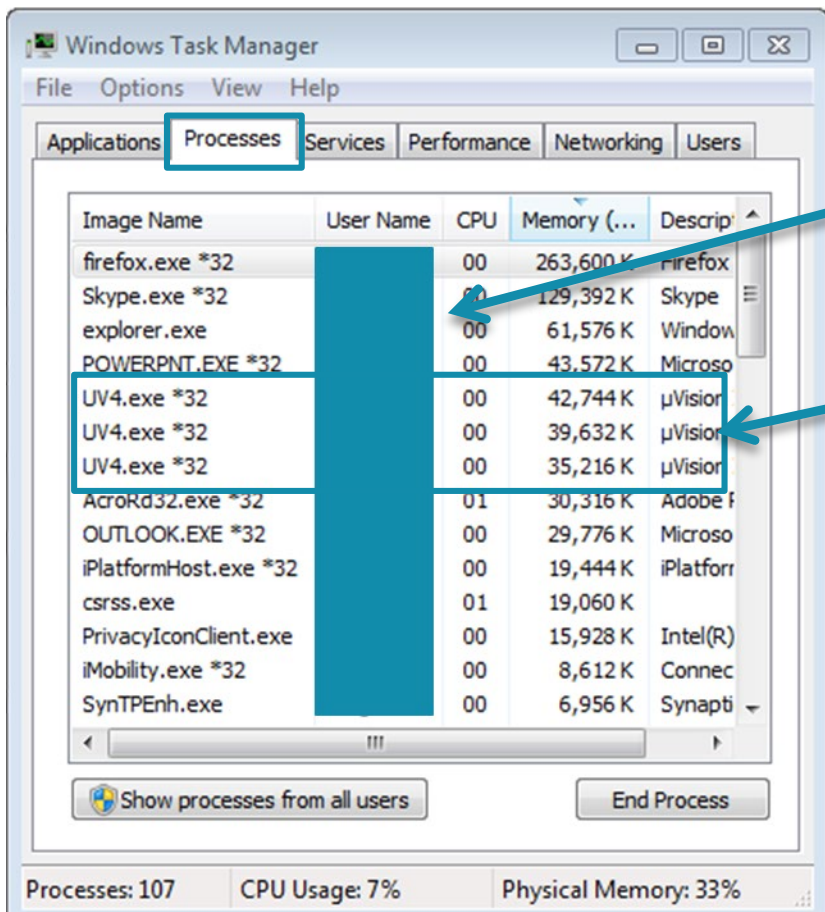
## Operating System Principles

Ravi Suppiah  
Lecturer, NUS SoC

# Lecture Contents

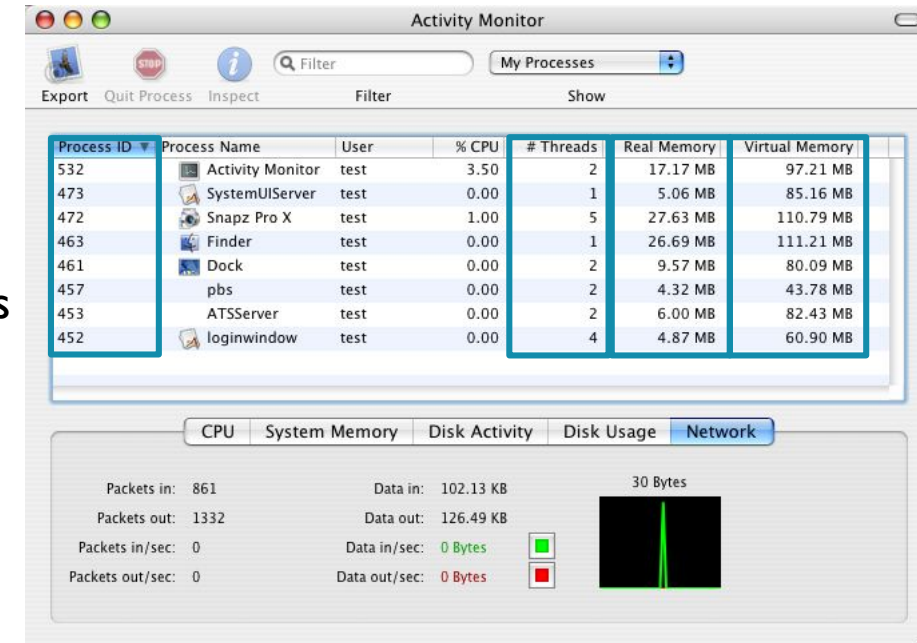
- Process—What is it
- Memory lay out
- Switching between Processes
- RTX Examples
- Process Termination
- Context Switching and States

# An Instance of a Running Program



Your user name or SYSTEM/LOCAL SERVICE/NETWORK SERVICE

Multiple instances of the µVision4  
Independent memory for each process  
“Memory(Private Working Set)”



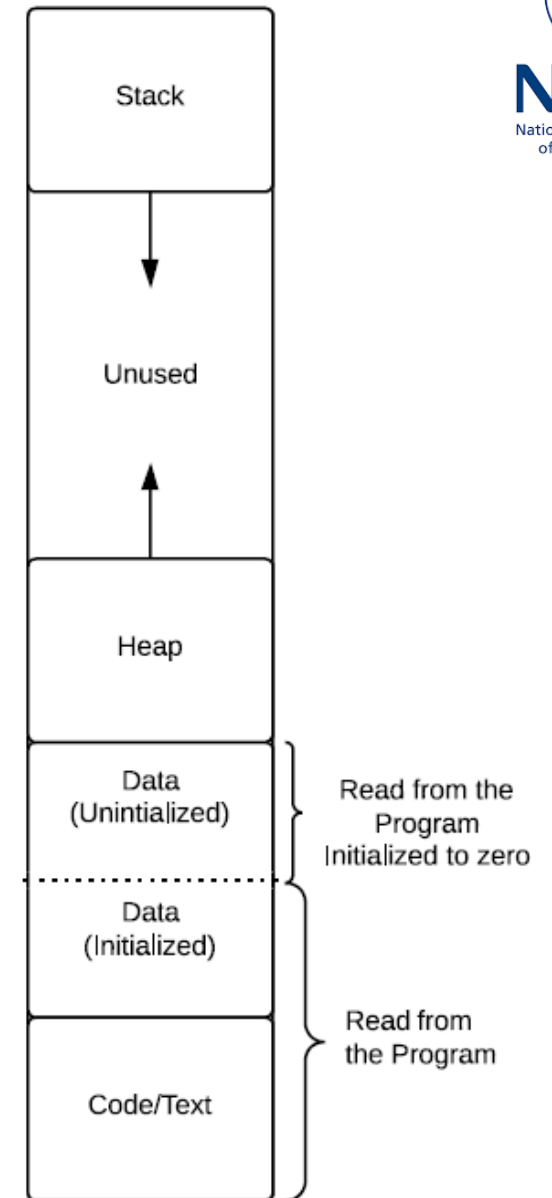
Try to explore the task manager, activity monitor, or similar utility on your favourite OS

# 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
- Hence the abstraction of the process
- Program usually refers to the instructions that are stored on disk
- Process is the program 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

# 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

# RTX Example

```
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!



# Process Creation

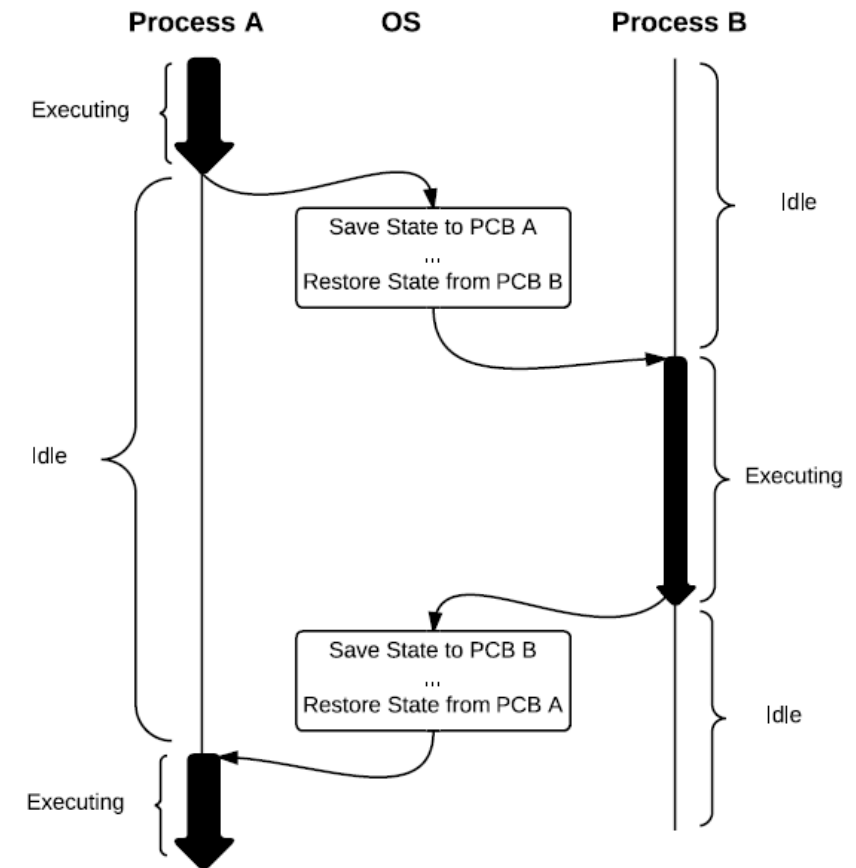
- By initialization, or by request of a process.
- Unique ID for the process
- Allocate memory for the PCB and other control structures (kernel) and user memory
- Initialize the PCB and memory management
- Link the PCB in the queue (see later)

# 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

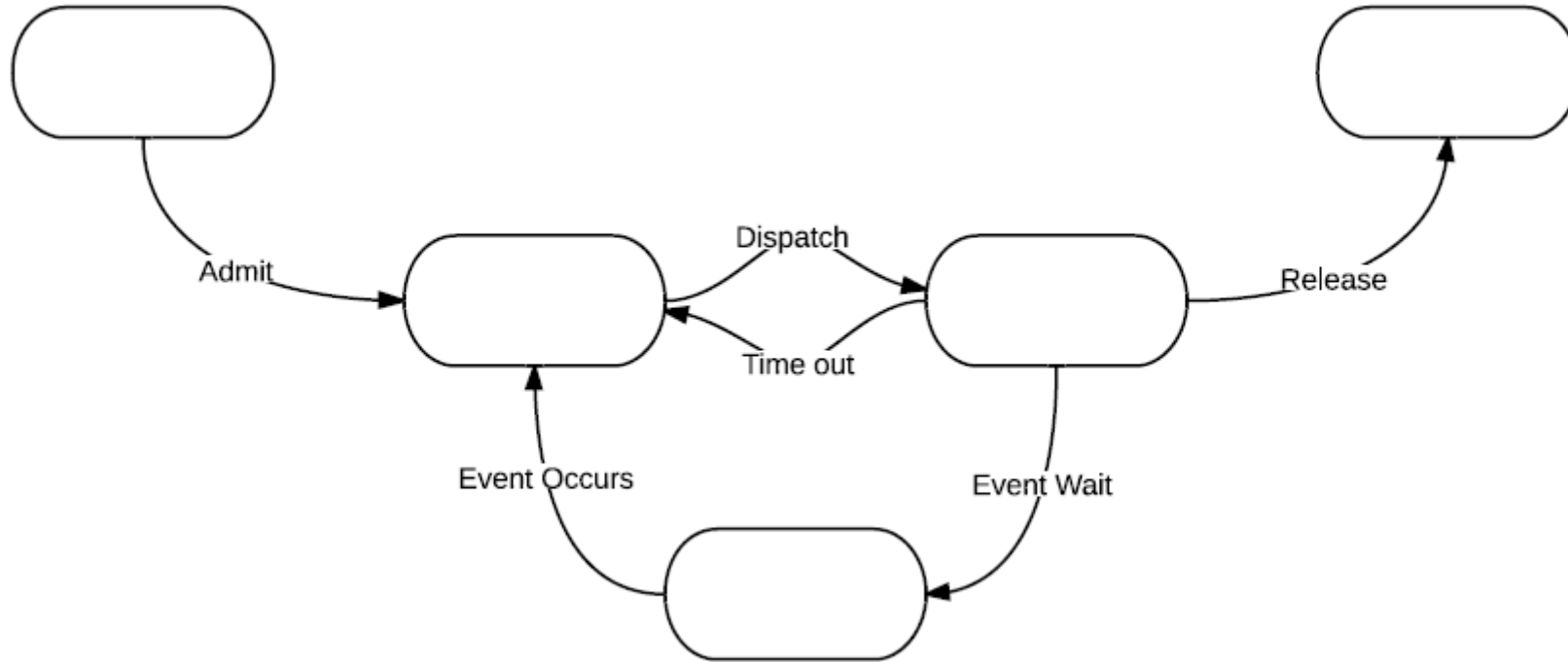
- The PCB makes context switching a bit easier
  - Scheduler will start or stop a process accordingly
  - Stores necessary information in the PCB to stop
    - Hardware registers
    - Program Counter
    - Memory states, stack and heap
    - State
  - Similarly, loads necessary information from the PCB
- Notice that context switching does consume time!
  - Could be up to several thousand CPU cycles
  - Overhead and bottleneck
  - Hardware support is also needed



# Process States

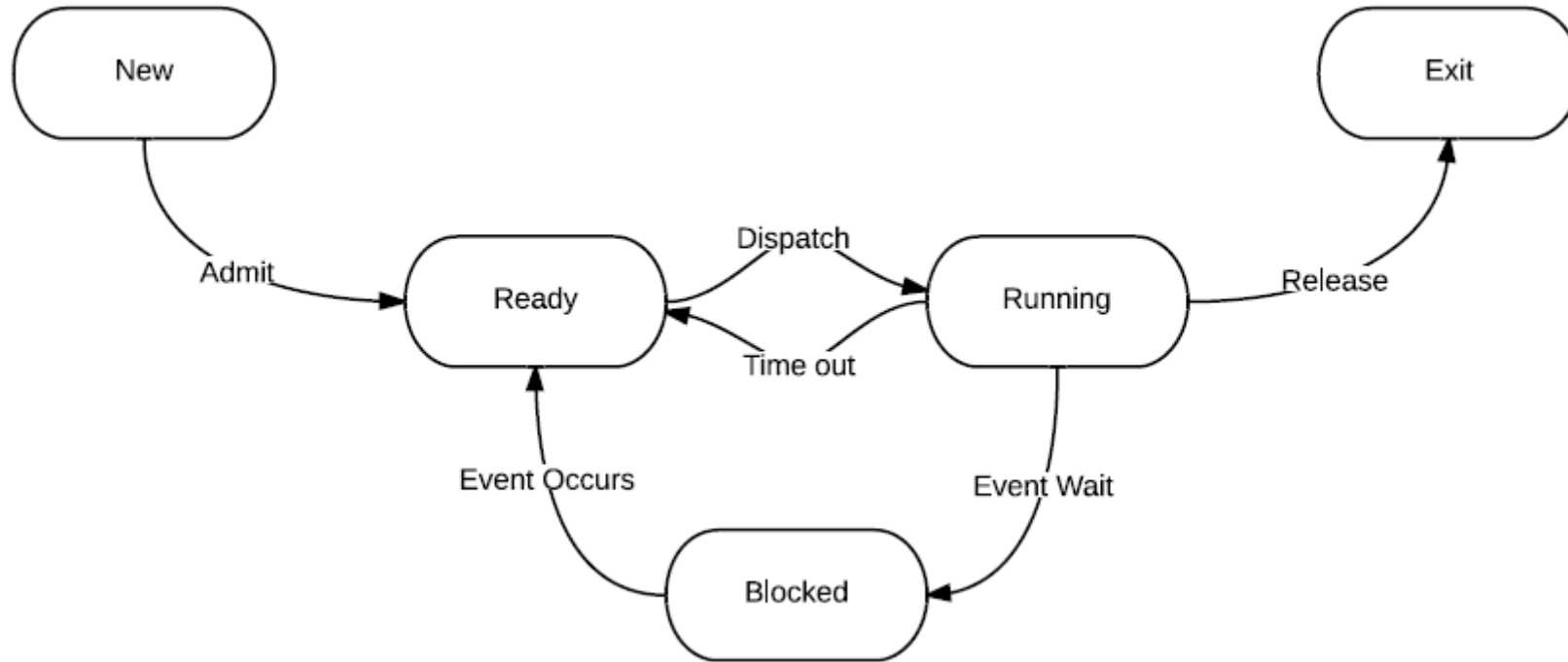
- Different process states during the lifetime cycle
- Many variants but a standard model has five states:
  - New: just been created, not ready for the queue
  - Ready: can be loaded by the OS
  - Running: scheduler has picked this process from the queue and executed it, usually only one
  - Blocked: not in the queue, waiting
  - Exit: finished, needs to terminate

# State Transition



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

# State Transition



- **Admit:** process is fully loaded into memory and control is established
- **Dispatch:** scheduler assigns CPU to the process
- **Time out:** 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:** release resources and end the process

# Process State

- State information is also recorded by the PCB
- 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`

# 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
```

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

- No Exit state
- Embedded software don't really enjoy the concept of termination
- More on this in later lectures and labs



# The End!

- Next, we will look at Scheduling!