Politecnico di Torino

FreeRTOS: Rate Monotonic Scheduling

Computer Architectures and Operating Systems Project (Track 1.2: HaclOSsim)

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Rate Monotonic (RM) Scheduling

Rate Monotonic (RM) Scheduling

Rate Monotonic (RM) Scheduling is a **fixed-priority algorithm** used in real-time systems. In RM, each task is assigned a static priority at compilation time, which remains constant throughout its execution.

The scheduler is **preemptive**, so it can interrupt the execution of a currently running task to start another one that has a higher priority.

In RM:

- Shorter period $\rightarrow$ higher priority
- Longer period $\rightarrow$ lower priority

This ensures that tasks with more frequent execution requirements are prioritized over those with longer periods.

Rate Monotonic Task Creation

Rate Monotonic Task Definition

```
BaseType_t xTaskCreate(TaskFunction_t pxTaskCode,
                       const char *const pcName,
                       const configSTACK_DEPTH_TYPE usStackDepth,
                       void *const pvParameters,
                       UBaseType_t uxPriority,
                       TaskHandle_t *const pxCreatedTask,
                       int pxCpuBurst,
                       int period)
```

Rate Monotonic Task Creation

Define new fields in the task to store the estimated **CPU burst** of the task and its **period**. The period is expressed in tenth of second and limited to ten only for debug purposes.

```
#if (configUSE_RM == 1)
if (pxCpuBurst < 1) {
    pxNewTCB->CpuBurst = 1;
} else {
    pxNewTCB->CpuBurst = pxCpuBurst;
}

if (period < 1) {
    pxNewTCB->period = 1;
} else if (period > 10) {
    pxNewTCB->period = 10;
} else {
    pxNewTCB->period = period;
}
#endif
```

New Functions Implemented

New Functions Implemented

Retrieve the CPU burst of a specified task.

```c
int uxTaskCpuBurstGet(const TaskHandle_t xTask) {
    TCB_t const *pxTCB;
    int uxReturn;

    taskENTER_CRITICAL();
    {
        /* If null is passed in here then it is the priority of the task
         * that called uxTaskPriorityGet() that is being queried */
        pxTCB = prvGetTCBFromHandle(xTask);
        uxReturn = pxTCB->CpuBurst;
    }
    taskEXIT_CRITICAL();

    return uxReturn;
}
```

Retrieve the period of a specified task.

```c
int uxTaskPeriodGet(const TaskHandle_t xTask) {
    TCB_t const *pxTCB;
    int uxReturn;

    taskENTER_CRITICAL();
    {
        /* If null is passed in here then it is the priority of the task
         * that called uxTaskPriorityGet() that is being queried */
        pxTCB = prvGetTCBFromHandle(xTask);
        uxReturn = pxTCB->period;
    }
    taskEXIT_CRITICAL();

    return uxReturn;
}
```

Implementation of Rate Monotonic Scheduling

Rate Monotonic Select Function (1)

```c
/* New scheduler function following the Rate Monotic Scheduler */

#define taskSELECT_TASK_RM() {
    UBaseType_t uxTopPriority = uxTopReadyPriority;
    int overallPriority = 100; /* Initialize to the maximum value possible */
    int tempOverallPriority = 0;
    ListItem_t *highestPriorityBurst = NULL;

    /* Find the highest priority queue that contains ready tasks */
    portGET_HIGHEST_PRIORITY(uxTopPriority, uxTopReadyPriority);
    configASSERT(listCURRENT_LIST_LENGTH(&(pxReadyTasksLists[uxTopPriority])) > 0);

    /* Following code obtained and adapted from listGET_OWNER_OF_NEXT_ENTRY */
    List_t *pxConstList = &(pxReadyTasksLists[uxTopPriority]);

    /* We want to start by looking always at the first task => listGET_HEAD_ENTRY */
    ListItem_t *pxListItem = listGET_HEAD_ENTRY(pxConstList); /* return ListItem */
```

Rate Monotonic Select Function (2)

```
1      for (UBaseType_t i = 0; i < listCURRENT_LIST_LENGTH(pxConstList); i++) {
2          (pxCurrentTCB) = (pxListItem)->pvOwner;
3          tempOverallPriority = (pxCurrentTCB)->period;
4          if (tempOverallPriority < overallPriority) {
5              overallPriority = tempOverallPriority;
6              highestPriorityBurst = pxListItem;
7          }
8          pxListItem = (pxListItem)->pxNext; /* Move to the next list item */
9      }
10
11     /* To select the correct task to run */
12     if (highestPriorityBurst != NULL) {
13         (pxCurrentTCB) = (highestPriorityBurst)->pvOwner;
14     }
15 }
```

Starting the Scheduler & Switching Context

Starting the Scheduler & Switching Context

```
#if (configUSE_RM == 1)
{
    taskSELECT_TASK_RM();
}
#else
{
    taskSELECT_HIGHEST_PRIORITY_TASK();
}
#endif
```

Simulation of Rate Monotonic Task

How Rate Monotonic Tasks are Simulated (1)

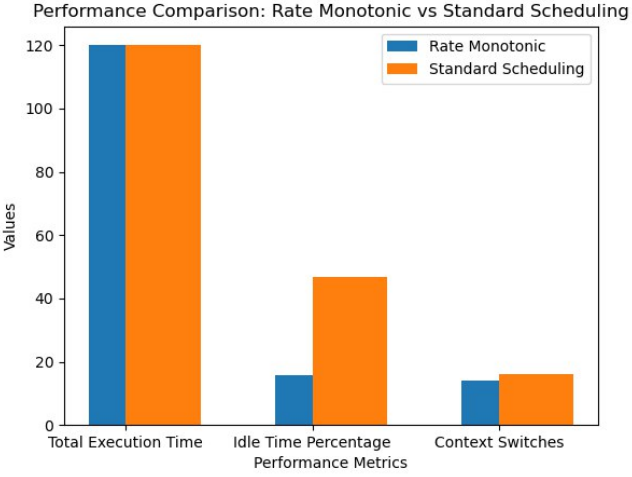
```c
void vTask(void *pvParameters) {
    TickType_t xNextWakeTime;
    xNextWakeTime = xTaskGetTickCount();
    const TickType_t xBlockTime = pdMS_TO_TICKS(10000 * uxTaskPeriodGet(NULL));
    int timeSpent = 0;
    int runTime = uxTaskCpuBurstGet(NULL);

    // Obtain the tick count corresponding to one second
    const TickType_t xOneSecondTicks = pdMS_TO_TICKS(1000);

    for (;;) {
        // Run until the specified time has elapsed
        printf("%s is running. Start time: %d\n", uxTaskNameGet(NULL), xTaskGetTickCount() / 1000);

        while (timeSpent < runTime) {
            TickType_t xStartTick = xTaskGetTickCount();

            // Busy-wait for one second (tick count equivalent to one second)
            while ((xTaskGetTickCount() - xStartTick) < xOneSecondTicks) {
                // Ensure the task does not yield the CPU during this period
                // (This loop will keep running until one second has passed)
            }

            // One second has passed, increment timeSpent
            timeSpent++;
        }
```

How Rate Monotonic Tasks are Simulated (2)

```
        printf("%s finished at time %d.\n", uxTaskNameGet(NULL), xTaskGetTickCount() / 1000);

        /* Place this task in the blocked state until it is time to run again.
        The block time is specified in ticks, pdMS_TO_TICKS() was used to
        convert a time specified in milliseconds into a time specified in ticks.
        While in the Blocked state this task will not consume any CPU time */
        vTaskDelayUntil(&xNextWakeTime, ((int)pvParameters * xBlockTime) - xNextWakeTime);

        xTaskCreate(vTask1, "vTask1", STACK_SIZE, (void *)pvParameters + 1, TASK_PRIORITY, &xHandle_1, 8, 2);

        break;
    }

    vTaskDelete(NULL);
}
```

Performance Comparison

Rate Monotonic Scheduling VS Standard FreeRTOS Scheduling Algorithm



Thanks for your attention!