

Elevator Control System

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Schedule(3/3)

- March 12
 - 13:00 Unified Process and COMET
 - 14:30 Case Study of Elevator Control System
(problem definition, use case model)
- March 13
 - 13:00 Case Study of Elevator Control System
(finding analysis classes by developing a consolidated communication diagram)
 - 14:30 Case Study of Elevator Control System
(sub-system structuring and task structuring)
- March 14
 - 13:00 Case Study of Elevator Control System
(performance analysis)
 - 14:30 UML2.0 and MDA

Performance Analysis of Non- Distributed Elevator Control System

- A building with 10 floors and three elevators10
- The Worst-Case Scenario
 - Elevator button interrupts arrive with a maximum frequency of 10 times a second, which represents a minimum inter-arrival time of 100 msec. This worst-case scenario assumes that all 30 buttons are pressed within 3 seconds.
 - Floor button interrupts arrive with a maximum frequency of 5 times a second, which represents a minimum inter-arrival time of 200 msec. There are 18 floor buttons ($2 \times 8 + 1 + 1$). This worst-case scenario assumes that all 18 buttons are pressed within 3.6 seconds.
 - All three elevators are in motion and arrive at floors simultaneously. Three floor-arrival interrupts arrive within 50 msec of each other. This is the most time-critical aspect of the **problem**, because when a floor arrival interrupt is received, the Elevator Controller has to determine whether the elevator should stop at this floor or not. If it need to stop, the controller must stop the elevator before the floor has been past.
 - Related usecases are “Select Destination”, “Request Elevator”, and “Stop Elevator at Floor”.

Event Sequences in Three UseCases

- Stop Elevator at Floor (Period = T_a)
 - A1: The Arrival Sensors Interface receives and process the interrupt
 - A2: The Arrival Sensors Interface sends “approaching Floor” message to the Elevator Controller.
 - A3: The Elevator Controller receives message and checks the Elevator Status & Plan object to determine whether the elevator should stop or not.
 - A4: The Elevator Controller invokes “stop Motor” operation if it should stop.

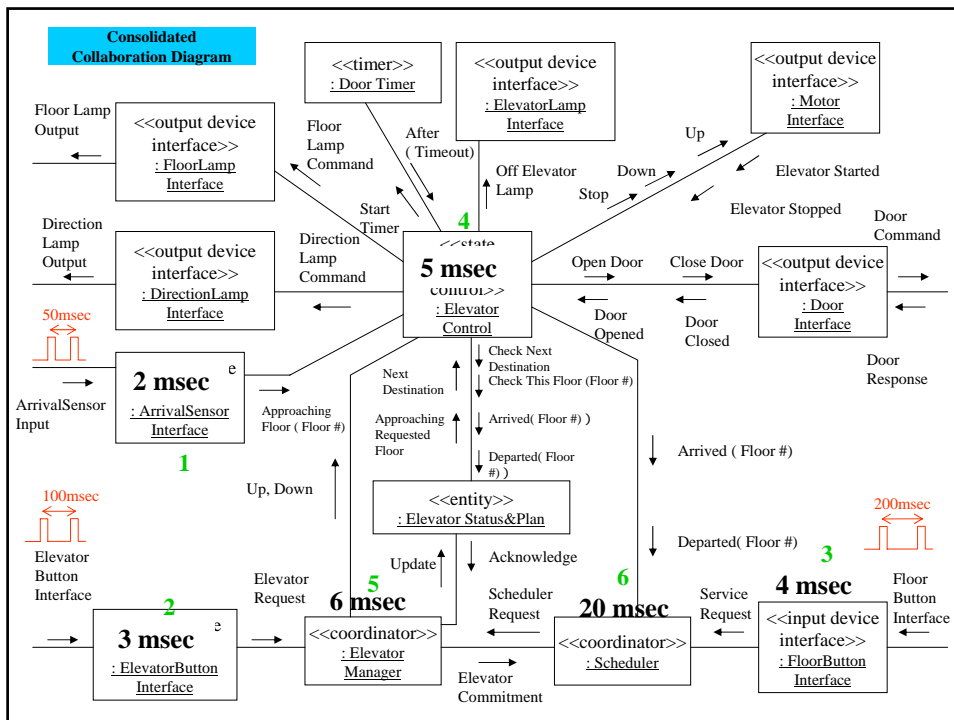
Event Sequences in Three UseCases

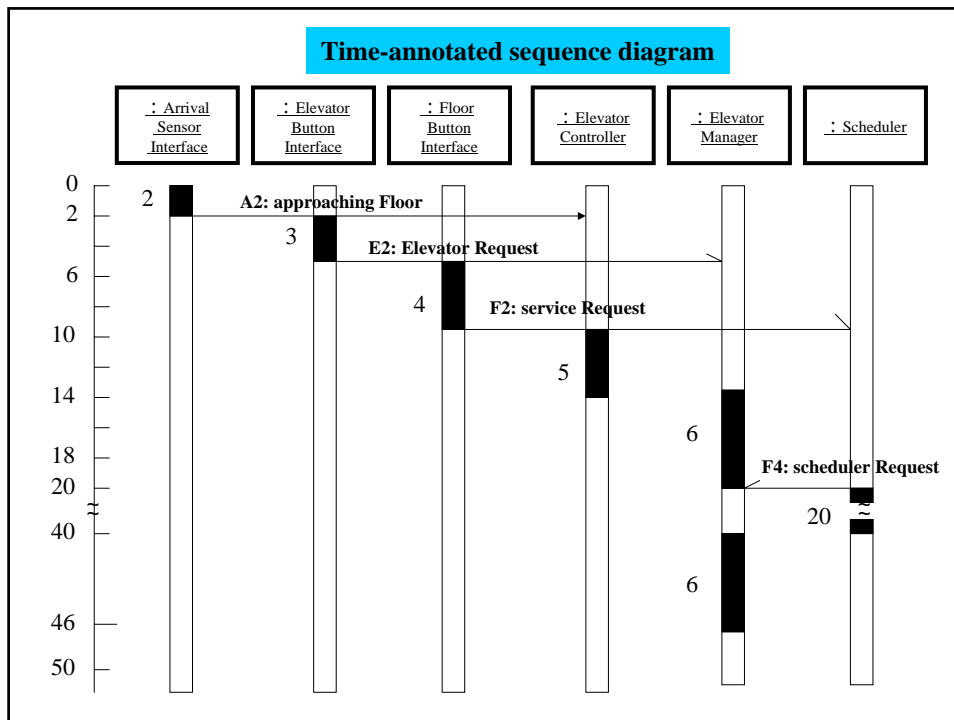
- Select Destination (Period = T_b)
 - E1: The Elevator Buttons Interface receives and processes the interrupt.
 - E2: The Elevator Buttons Interface sends “elevator Request” message to the Elevator Manager.
 - E3: The Elevator Manager receives message and records destination in Elevator Status & Plan object.

Event Sequences in Three UseCases

- Request Elevator (Period = T_c)
 - F1: The Floor Buttons Interface receives and processes the interrupt.
 - F2: The Floor Buttons Interface sends “service Request” message to the Scheduler.
 - F3: The Scheduler receives message and interrogates Elevator Status & Plan object to determine whether an elevator is on its way to this floor. Assume not, so that the Scheduler selects an elevator.
 - F4: The Scheduler sends a “scheduler Request” message identifying the selected elevator to the Elevator Manager.
 - F5: The Elevator Manager receives message and records destination in Elevator Status & Plan object.

Task Parameters				
Task	CPU time C_i	Period T_i	Utilization U_i	Assigned Priority
Stop Elevator at Floor				
Arrival Sensors Interface	2	50	0.04	1
Elevator Controller	5	50	0.10	4
Total elapsed time = 34 msec			Total utilization = 0.68	
Select Destination				
Elevator Buttons Interface	3	100	0.03	2
Elevator Manager(Case b)	6	100	0.06	5
Total elapsed time = 47 msec			Total utilization = 0.47	
Request Elevator				
Floor Buttons Interface	4	200	0.02	3
Scheduler	20	200	0.10	6
Elevator Manager(Case c)	6	200	0.03	
Total elapsed time = 76msec			Total utilization = 0.38	
Other Tasks				
Floor Lamps Monitor	5	500	0.01	7
Direction Lamps Monitor	5	500	0.01	8





Result of Analysis(1/3)

- Stop elevator at Floor ($T_a=50\text{msec}$)
 - Execution time: Total execution time $C_a = 2\text{msec}$ (Arrival Sensors Interface)+ 5msec (Elevator Controller). Execution utilization $U_e=C_a/T_a=7/50=0.14$
 - Preemption by higher priority tasks: Total preemption time $P_a=3$ (Elevator Buttons Interface)+ 4 (Floor Buttons Interface)= 7msec 。 Preemption utilization $U_p=P_a/T_a=7/50=0.14$
 - Blocking time: Total worst-case blocking time $B_a=20\text{msec}$ (Scheduler). Worst-blocking utilization $U_b = B_a/T_a=20/50=0.40$
 - Total Utilization= $U_e+U_p+U_b=0.14+0.14+0.40=0.68$

Result of Analysis(2/3)

- Select Destination ($T_b=100\text{msec}$)
 - Execution time: Total execution time $C_b = 3\text{msec}$ (Elevator Buttons Interface) + 6msec (Elevator Manager). Execution Utilization $U_e=C_b/T_b=9/100=0.09$
 - Preemption by higher priority tasks with shorter periods: Arrival Sensors Interface and Elevator Controller (preempts Elevator Manager) can each execute twice during 100 msec period, giving a preemption time of 14 msec.
 - Preemption by higher priority tasks with longer periods: 4 msec from Floor Buttons Interface to handle floor Button interrupt.
 - Total preemption time $C_p=14+4=18$ 。 Total preemption utilization $U_p= C_p/T_b = 18/100 = 0.18$
 - Blocking time: Worst-case blocking time $B_a= 20\text{msec}$ (Scheduler). Worst-case blocking utilization $U_b = B_b/T_b=20/100=0.20$
 - Total Utilization= $U_e+U_p+U_b=0.09+0.18+0.20=0.47$

Results of Analysis(3/3)

- Request Elevator ($T_c=200\text{msec}$)
 - Execution time: Total execution time $C_c = 4\text{msec}$ (Floor Buttons Interface) + 20msec (Scheduler) + 6msec (Elevator Manager). Execution utilization $U_e=C_c/T_c=30/200=0.15$
 - Preemption by higher priority tasks with shorter periods: Arrival Sensors Interface and Elevator Controller (preempts Elevator Manager and Scheduler) can each execute four times for a total of 28 msec.
 - Total preemption time $C_p=28+18=46$. Preemption utilization $U_p=C_p/T_p=0.23$
 - Total elapsed time= $30+46+0=76$
 - Total Utilization= $U_e+U_p=0.15+0.23=0.38$

Performance Analysis of Distributed Elevator Control System

- one node per elevator, one node per floor, one scheduler node.
- 40 floors and 12 elevators

Task Parameters

Task	CPUtime C_i	Period T_i	Utilization U_i	Assigned Priority
Elevator Subsystem				
Arrival Sensors Interface	2	50	0.04	1
Elevator Controller	5	50	0.10	3
Elevator Buttons Interface	3	100	0.03	2
Elevator Manager	6	100	0.06	4
Floor Subsystem				
Floor Buttons Interface	4	200	0.02	1
Floor Lamps Monitor	5	500	0.01	7
Direction Lamps Monitor	5	500	0.01	8
Scheduler Subsystem				
Elevator Status and Plan Server	2	10	0.20	1
Elevator Scheduler	20	50	0.40	2

Network transmission delay = 2 msec

Elapsed time for Stop Elevator at Floor = 41 msec < 50 msec

Elapsed time for Select Destination = 48 msec < 100 msec

Elapsed time for Request Elevator = 82 msec < 200 msec

Event Sequences for three Usecases

- Stop Elevator at Floor (Period = T_a)
 - A1: The Arrival Sensors Interface receives and process the interrupt
 - A2: The Arrival Sensors Interface sends “approaching Floor” message to the Elevator Controller.
 - A3: The Elevator Controller receives message and checks the **Local** Elevator Status & Plan object to determine whether the elevator should stop or not.
 - A4: The Elevator Controller invokes “stop Motor” operation if it should stop.
 - A5: The Elevator controller sends arrived message over the LAN to the Scheduler subsystem, where it is received by the Elevator Status & Plan Server.
 - A6: The Elevator Status & Plan Server calls the arrived operation of the **Overall** Elevator Status & Plan data abstraction object.

Event Sequences for three Usecases

- Select Destination (Period = T_b)
 - E1: The Elevator Buttons Interface receives and processes the interrupt.
 - E2: The Elevator Buttons Interface sends “elevator Request” message to the Elevator Manager.
 - E3: The Elevator Manager receives message and records destination in **Local** Elevator Status & Plan object.
 - E4: The Elevator Manager sends an “elevator Commitment” message over the LAN to the Scheduler subsystem, where it is received by the Elevator Status & Plan Server.
 - E5: The Elevator Status & Plan Server calls the update Plan operation of the **Overall** Elevator Status & Plan data abstraction object.

Event Sequences for three Usecases

- Request Elevator (Period = T_c)
 - F1: The Floor Buttons Interface receives and processes the interrupt.
 - F2: The Floor Buttons Interface sends “service Request” message **over the LAN to the Elevator Scheduler task in the Scheduler subsystem.**
 - F3: The Elevator Scheduler receives message and interrogates **Overall** Elevator Status & Plan object to determine whether an elevator is on its way to this floor. Assume not, so that the Scheduler selects an elevator.
 - F4: The Elevator Scheduler sends a “scheduler Request” message identifying the selected elevator **over the LAN to the Elevator Manager task in the selected elevator’s instance of the Elevator subsystem**
 - F5: The Elevator Manager receives message and records destination in the **Local** Elevator Status & Plan object.
 - F6: **The Elevator Manager sends an “elevator Commitment” message over the LAN to the Scheduler subsystem, where it is received by the Elevator Status & Plan Server**
 - F7: **The Elevator Status & Plan Server calls the update Plan operation of the Overall Elevator Status & Plan data abstraction object.**

Result of Analysis(1/3)

- Stop elevator at Floor ($T_a=50\text{msec}$)
 - Execution time: Total execution time $C_a = 2\text{msec}$ (Arrival Sensors Interface) + 5msec (Elevator Controller) Execution utilization $U_e = C_a/T_a = 7/50 = 0.14$
 - Preemption by higher priority tasks with longer periods.
Preemption time $P_a = 3$ (Elevator Buttons Interface). Preemption utilization $U_p = 3/50 = 0.06$
 - Blocking time: Total worst-case blocking time $B_a = 6\text{msec}$ (Elevator Manager). Worst-case blocking utilization $U_b = B_a/T_a = 6/50 = 0.12$
 - Total elapsed time = $7 + 3 + 6 = 16\text{msec} < 50$. Total Utilization = $U_e + U_p + U_b = 0.14 + 0.06 + 0.12 = 0.32$
 - Total elapsed time for Stop elevator at Floor = 16 (Total elapsed time for Elevator Subsystem) + 2 (Transmission Delay, 25byte, 100Mbps, Transmission Delay $D_t = 200/100000 = 2\text{msec}$ + 23 Worst-case elapsed time of Scheduler system) = $16 + 2 + 23 = 41\text{msec}$

Result of Analysis(2/3)

- Select Destination ($T_b=100\text{msec}$)
 - Execution time: Total execution time $C_b = 3\text{msec}$ (Elevator Buttons Interface) + 6msec (Elevator Manager).
 - Execution utilization $U_e=C_b/T_b=9/100=0.09$
 - Preemption time by higher priority tasks with shorter periods: Arrival Sensors Interface and Elevator Controller can each execute twice during the 100 msec period, giving a total preemption time of 14 msec.
 - $U_p=0.14$.
 - Total elapsed time $=9+14=23$. Total utilization = $U_e+U_p =0.09+0.14=0.23$
 - Total elapsed time for Select Destination $E_b =23$ (Elevator subsystem elapsed time) + $2(\text{transmission delay}) + 23$ (Scheduler subsystem elapsed time) $=48\text{msec}$.

Result of Analysis(3/3)

- Request Elevator ($T_c=200\text{msec}$)
 - Total elapsed time for floor subsystem $E_f=4\text{msec}$ (floor buttons Interface) + 1msec (transmission delay) $=5\text{msec}$.
 - Total elapsed time for scheduler subsystem $E_s=1\text{msec}$ (transmission delay) + 20msec (elevator Scheduler)+ 1 msec (transmission delay) + 2msec (Blocking time by Elevator Status & Plan subsystem) $= 1+20+1+2= 24\text{msec}$.
 - Execution time of Elevator Manager = $1+6+1=8$.
 - Total elapsed time of Elevator subsystem = $16+8=24$.
 - Total elapsed time for Request Elevator = $5+2+24+2+24+2+23=82$