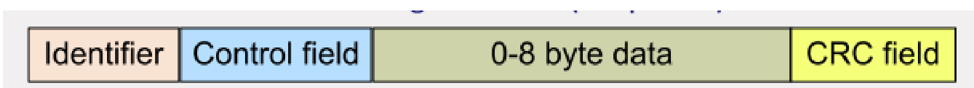
3_2_Distributed control systems over Controller Area Network (CAN) communication bus

1. CAN

Introduction

- simple and robust broadcast bust
- speed up to 1 Mbit

Message Frame



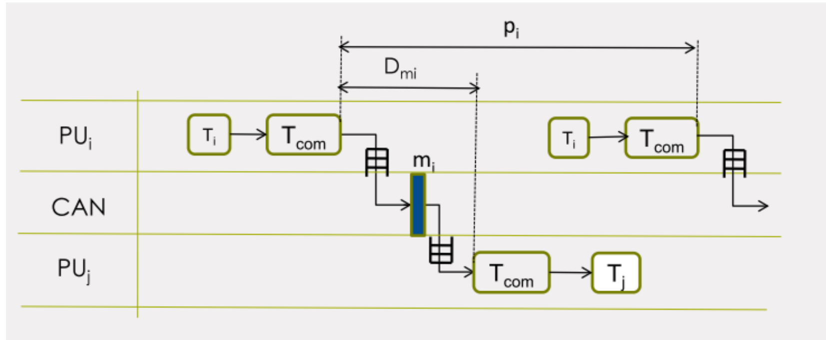
- Identifier indicates the priority of the message
- It helps the receiving PU to filter out the messages that they not interested in

Arbitration Mechanism

- messages are sent as if **all the PUs on the network shared a single global priority-based queue**
- fixed priority non-preemptive scheduling

Scheduling Model

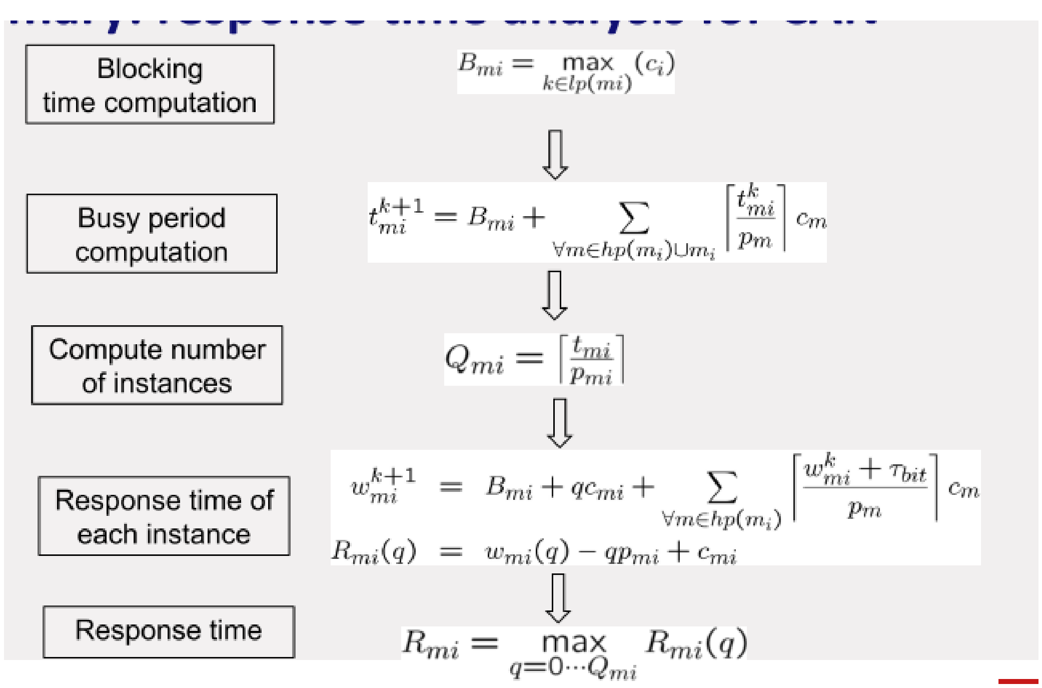
- message size s_i: $c_i = s_i \tau_{bit}$
- period p_i with unique priority i and hard deadline D_{m_i}



Schedulability

- A message is said to be **schedulable** if and only if $R_{mi} \leq D_{mi}$
- The system is **schedulable** if and only if all of the messages in the system are schedulable
- The timing behavior of the CAN messages is considered to be a same as **scheduling periodic non-preemptive tasks on uniprocessor.**
- The **worst-case scenario** for CAN message is the one arising at the critical instant when all the messages are generated simultaneously

2. FPNP Policies



Response Time Analysis

$$R_{mi} = w_{mi} + c_i$$

where

w_{mi} is queuing delay

Busy Period

Block Time

The queuing delay w_{mi} includes blocking time B_{mi}due to lower priority messages which may be in the process of being transmitted when message m_i is queued:

$$B_{mi} = \max_{k \in lp(mi)} c_i$$

Busy Period

$$t_{mi}^{k+1} = B_{mi} + \sum_{\forall m \in hp(m_i) \cup m_i} \left\lceil \frac{t_{mi}^k}{p_{mi}} \right\rceil c_{mi}$$

- start as $t_{mi}^0 = c_{mi}$
- stop when $t_{mi}^{k+1} = t_{mi}^k$
- converge guaranteed when $U_{mi} = \sum_{\forall m \in hp(m_i) \cup m_i} \frac{c_{mi}}{p_{mi}} < 1$

Response Time

$t_{mi} < p_i$:

one instance the message m_i arrives at within busy period, the busy period wil be the response time

$t_{mi} > p_i$

- multiple instance of the message arrives within the busy period

$$Q_{mi} = \left\lceil \frac{t_{mi}}{p_{mi}} \right\rceil$$

- In this case, the response time analysis should compute the response time all Q_{mi} instances, the response time of the message is the **longest** among them

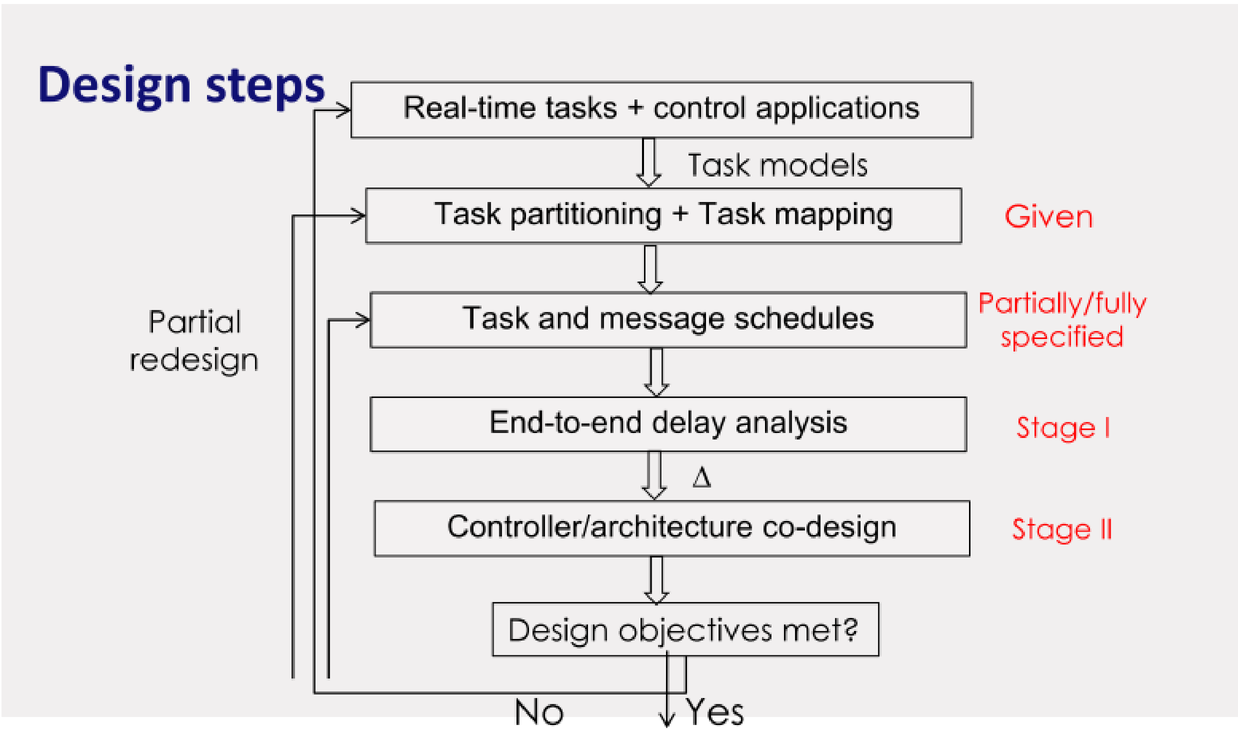
$$w_{mi}^{k+1} = B_{mi} + qc_{mi} + \sum_{\forall m \in hp(m_i)} \left\lceil \frac{w_{mi}^k(q) + \tau_{bit}}{p_{mi}} \right\rceil c_{mi}$$

$$R_{mi}(q) = w_{mi}(q) - qp_{mi} + c_{mi}$$

initialization and termination:

$$w^0_{mi}(q) = B_{mi} + qc_{mi}$$
$$w^{k+1}_{mi}(q) = w^k_{mi}(q)$$

3. Distributed Embedded Controllers



Design Example