Modelling the network

Embedded Systems Specification and Design

David Kendall

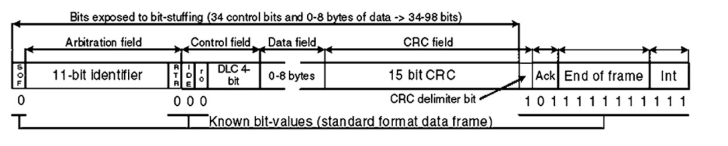
Northumbria University

Introduction

- How to model a Controller Area Network in UPPAAL
- Goal:
  - A general, flexible model of CAN that can be incorporated with a variety of process models for simulation and verification of properties
- Example based on [DBB07] to show its utility

Preliminaries

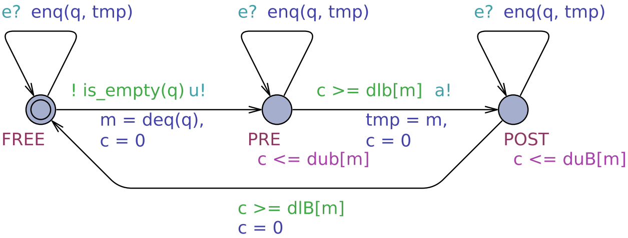
CAN Frame



Example system

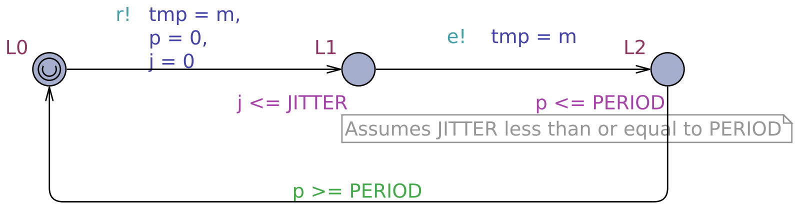
Message	Priority	Period	Deadline	TX time
A	1	2.5 ms	2.5 ms	1 ms
B	2	3.5 ms	3.25 ms	1 ms
C	3	3.5 ms	3.25 ms	1 ms

CAN Channel




```
const int dlb[3] = {4, 4, 4};
const int dub[3] = {4, 4, 4};
const int dlB[3] = {0, 0, 0};
const int duB[3] = {0, 0, 0};
message_t m = MIN_INVALID_CAN_ID;
queue_t   q = {MIN_INVALID_CAN_ID, MIN_INVALID_CAN_ID,
               MIN_INVALID_CAN_ID};
clock c;
```

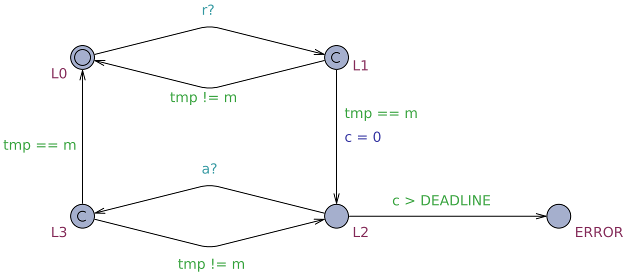
Node(const message_t m, const int PERIOD, const int JITTER)




```
clock p;
clock j;
```

- A computing node periodically enqueues its message
- The notional *release* of the message is represented by the synchronisation action `r!`
- The jitter in the software task that is responsible for enqueuing the message is modelled by the interval $[0, \mathit{JITTER}]$.

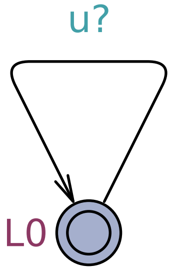
RTobserver(const message_t m, const int DEADLINE)




```
clock c;
```

- The observer examines every message that is enqueued
- If an enqueued message is the one of interest the observer waits for the message to become available for acceptance
- If this happens before the deadline, all is well; otherwise ERROR

Aux



- This is an auxiliary process that is always prepared to engage in a urgent action u
- u – ensures that enqueued messages begin transmission without delay when the channel is free

Global declarations

```
const int MIN_INVALID_CAN_ID = 3;
const int QSIZE = MIN_INVALID_CAN_ID;

typedef int queue_t[QSIZE];
typedef int[0, MIN_INVALID_CAN_ID] message_t;
typedef int[0, QSIZE - 1] qindex_t;

broadcast chan        r;
chan                  e;
broadcast chan        a;
urgent chan           u;


message_t tmp = MIN_INVALID_CAN_ID;

bool is_empty(queue_t q) {
  return forall (i : qindex_t) q[i] == MIN_INVALID_CAN_ID;
}
```

Global declarations ctd.

```
void enq(queue_t& q, message_t m) {
  q[m] = m;
}

message_t deq(queue_t& q) {
  message_t result = MIN_INVALID_CAN_ID;
  for (i : qindex_t) {
    if (q[i] != MIN_INVALID_CAN_ID) {
      result = q[i];
      q[i] = MIN_INVALID_CAN_ID;
      return result;
    }
  }
  return MIN_INVALID_CAN_ID;
}
```

System declarations

```
// System declarations

K = CanChannel();

// Node(m, p, j) releases message m periodically with period p
// and queueing jitter j
A = Node(0, 10, 0);
B = Node(1, 14, 0);
C = Node(2, 14, 0);

// Simple observers
// Only reliable if DEADLINE <= PERIOD
O_A = RTobserver(0, 10);
O_B = RTobserver(1, 13);
O_C = RTobserver(2, 13);

// The system should have a CAN channel, one node per message,
// an observer for a message of interest and
// an Aux process for urgent actions.
system K, A, B, C, O_C, Aux;
```

Checking the message response time

- The verifier can be used to check the message response time
- It immediately reveals the error in Tindell's original analysis . . .
- . . . and easily allows the discovery of the correct response time
- The property of interest is `E<> O_C.ERROR`
- Note `E<> O_C.ERROR` is *true* if and only if `A[] not O_C.ERROR` is *false*

Reasoning about jitter in a distributed system

- *Jitter* in some system response is the difference between the longest time and the shortest time between the occurrence of the event marking the start of the response and the event marking the end of the response.
- Taking account of jitter when reasoning about the behaviour of a distributed embedded system is a challenging problem
- This model shows one of the simpler approaches

System declarations

```
// System declarations

K = CanChannel();

// Node(m, p, j) releases message m periodically with period p
// and queueing jitter j
A = Node(0, 10, 2);
B = Node(1, 14, 0);
C = Node(2, 14, 0);

// Simple observers
// Only reliable if DEADLINE <= PERIOD
O_A = RTobserver(0, 10);
O_B = RTobserver(1, 13);
O_C = RTobserver(2, 14);

// The system should have a CAN channel, one node per message,
// an observer for a message of interest and
// an Aux process for urgent actions.
system K, A, B, C, O_B, Aux;
```

Discovering the effects of jitter

- This model shows that jitter in the release time of message A can have a detrimental effect on the response time of messages B and C
- Check the property `E<> O_B.ERROR` with a variety of deadlines for `O_B` to discover the new worst-case response time for B messages