Highly accurate time synchronisation through SpaceWire

l r f u

cea

saclay

Current SpaceWire Time-Code distribution

➢ The SpaceWire defines "Time-Code" to transmit time reference

➢ A Time-Code transmission request will occur asynchronously from the transmitted character stream.

➢ The delay between the Time-Code request and its transmission depends on the time left for the transmission of the current character.

➢ The delay difference between the best and the worst cases is **13 transmission bit periods**

Improvement Proposal

➤How to improve this figure ?

➤Principle is to send along with the initial Time-Code its transmission delay to the receiver

- This transmission delay is sent by the mean of a second Time-Code (jitter-correction Time-Code)

- The destination node takes into account this delay to create a synchronisation signal with a fixed delay with respect to initial Time-Code request (Tick-In rising edge)

I r f u

cea

saclay

Improvement Proposal requirements (character level)

- ➢ On the transmitter part:
    - When a high resolution synchronisation is needed a jitter-correction Time-Code must be sent just after the initial Time-Code.
    - This jitter-correction Time-Code is built as follow:
        - the two control flags are set to one of the remaining reserved states (TBD).
        - The four lowest bits are set to the delay M (in number of transmitted bits) between the Tick-In signal assertion and the transmission of the first data-control flag bit of the initial Time-Code.
        - The two left bits are set to zero.
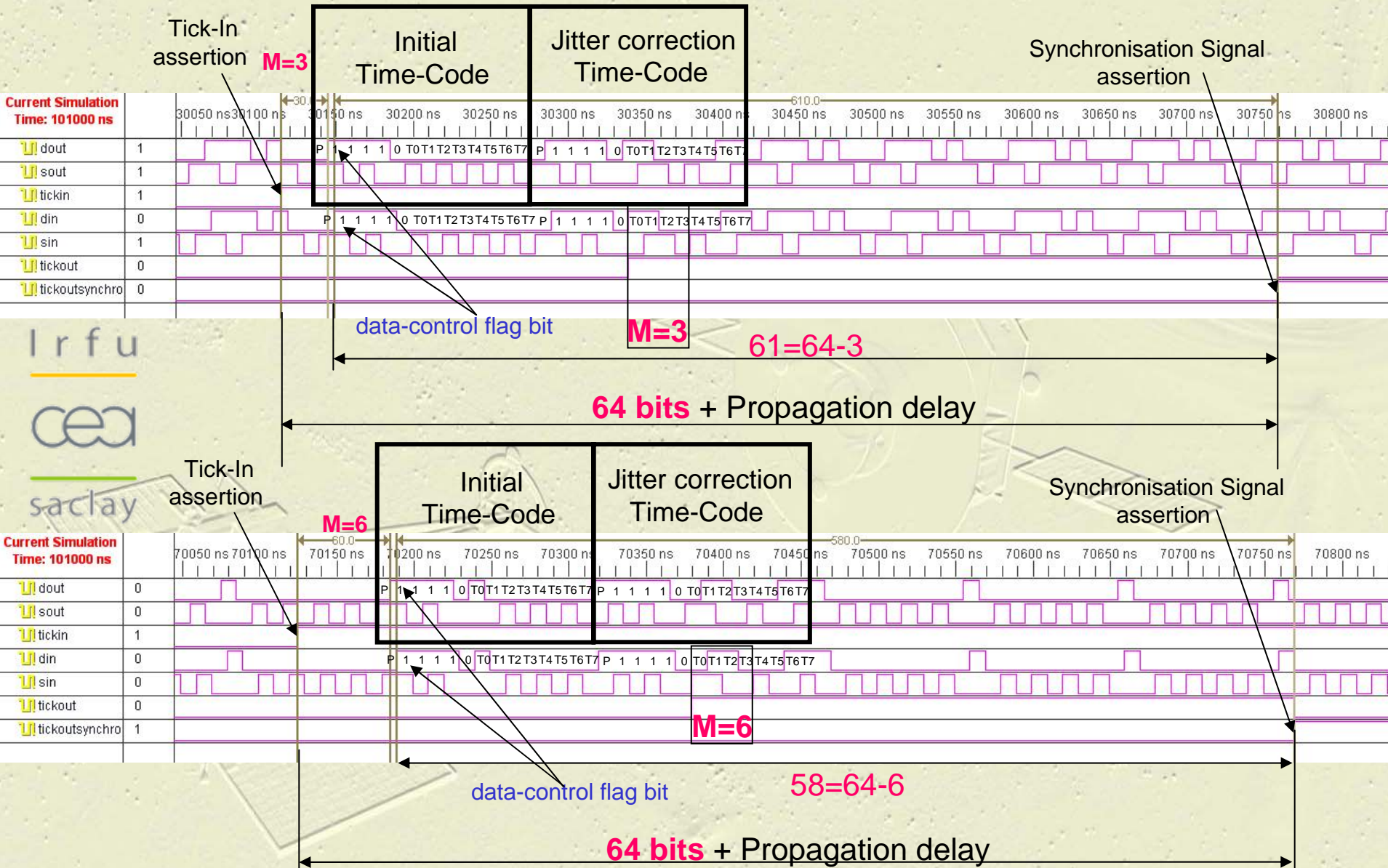- ➢ On the receiver part:
    - A synchronisation signal shall be asserted after a number (64 minus M) of receiver bits from the reception of the first data-control flag bit of the initial Time-Code.
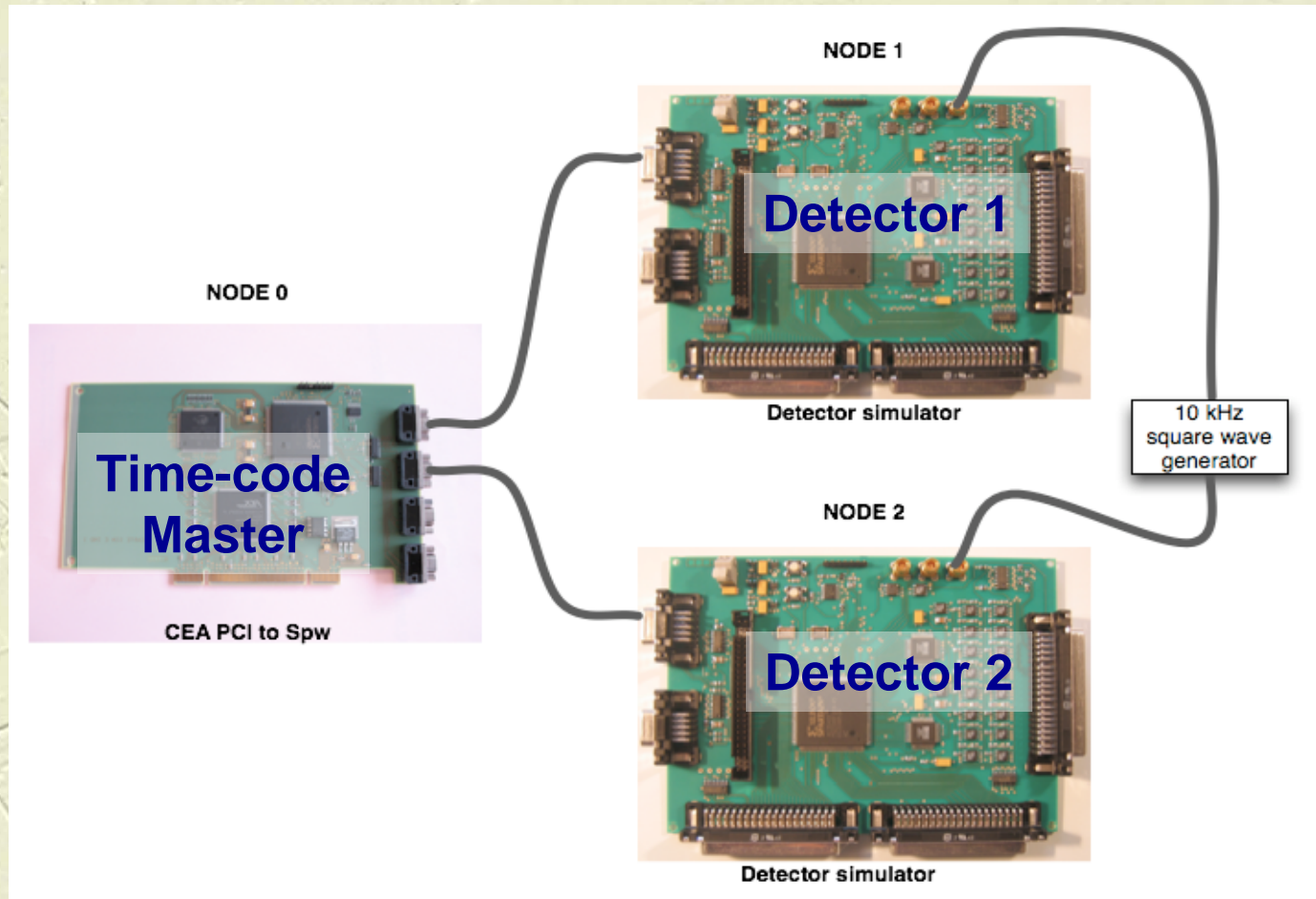
Irfu

cea

saclay
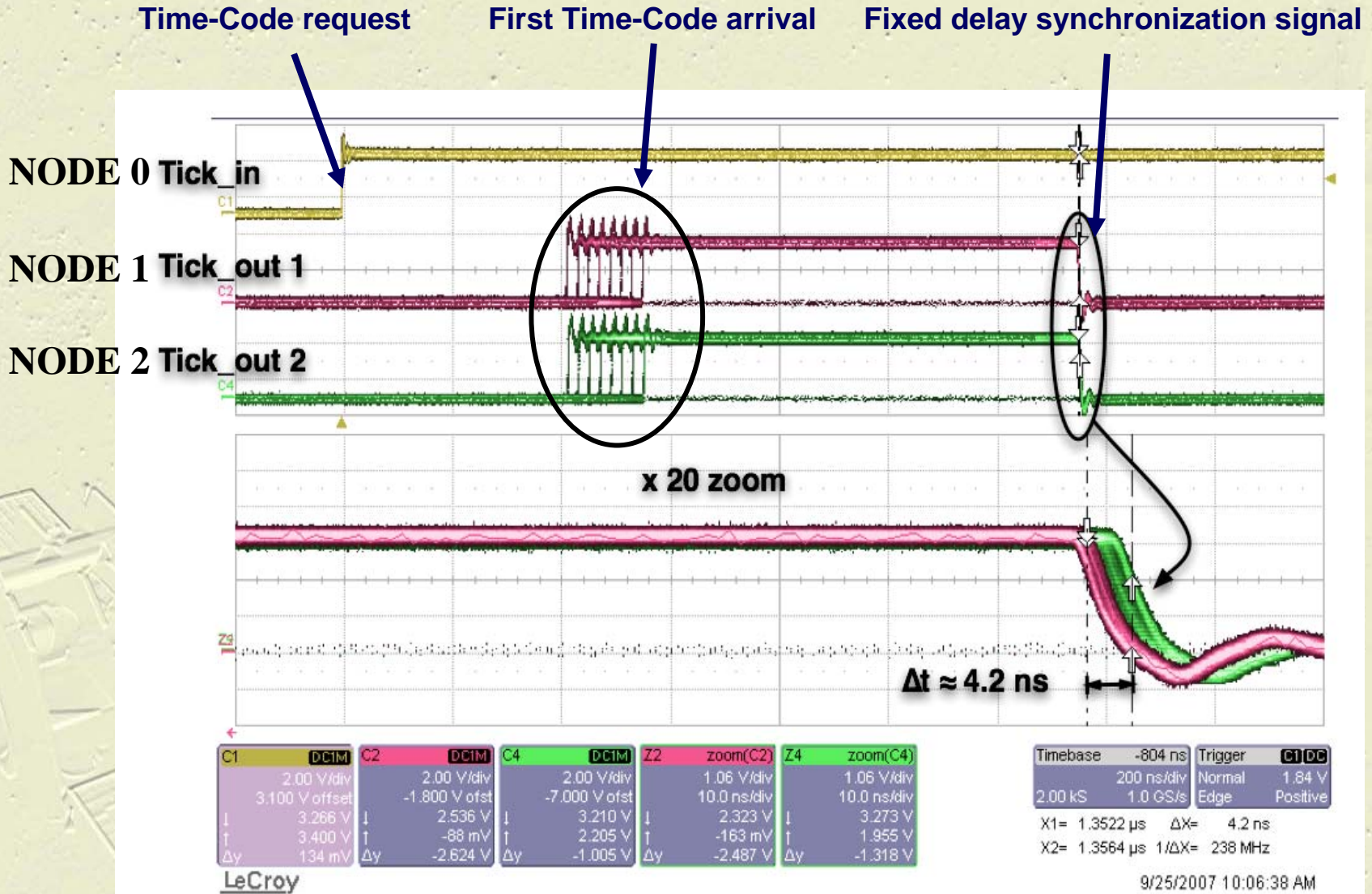
Simulation examples:

Experimental setup

➢ A PCI / SpaceWire board simulates the Time-Code Master while 2 detector acquisition boards simulate the destination nodes

Experimental result

Time-Code request

First Time-Code arrival

Fixed delay synchronization signal

NODE 0 Tick_in

NODE 1 Tick_out 1

Irfu

NODE 2 Tick_out 2

cea

saclay

x 20 zoom

Δt ≈ 4.2 ns

SpaceWire Time-Code improvement implementation

➢ Two new functions are added to the current SPACEWIRE codec:

- One for the time transmission (TIME_TX)
  - Get Time-Code transmission delay
  - Send successively 2 Time-Codes
- One for the time reception (TIME_RX)
  - Computes compensation delay
  - Generates sync signal after compensation delay

➢ Implementation is **low resource consuming**:

- In an ACTEL RTSX-SU72 FPGA:
  - Combinational cells: 62 of 4024 (1.5%)
  - Sequential cells: 42 of 2012 (2%)
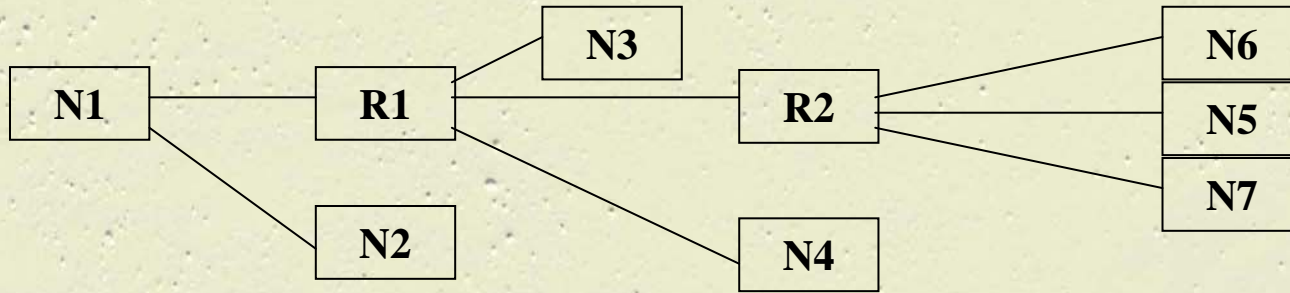
Network aspect

- For a highly accurate synchronisation through a SpaceWire Network
    - The same Time-Code distribution rules shall be followed
    - But a valid Time-Code is transmitted on the signal synchronization edge
    - So the delay between the time master tick-in generation and the node synchronization signal assertion dependant on the number links between them.
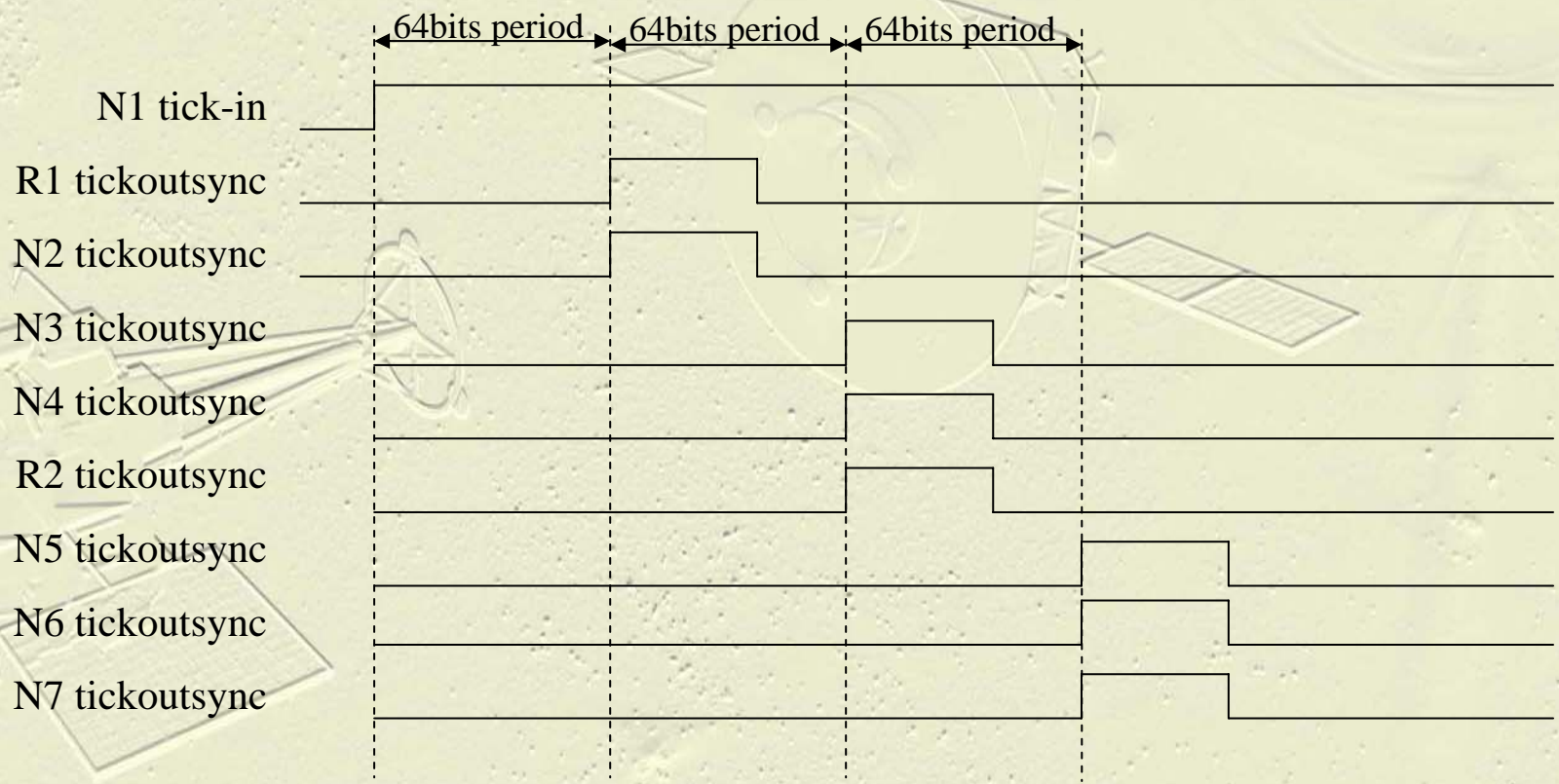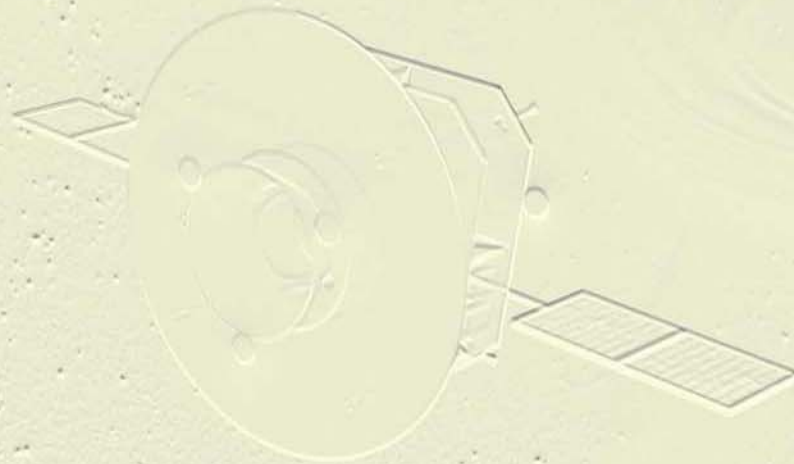
I r f u

cea

saclay

Network example
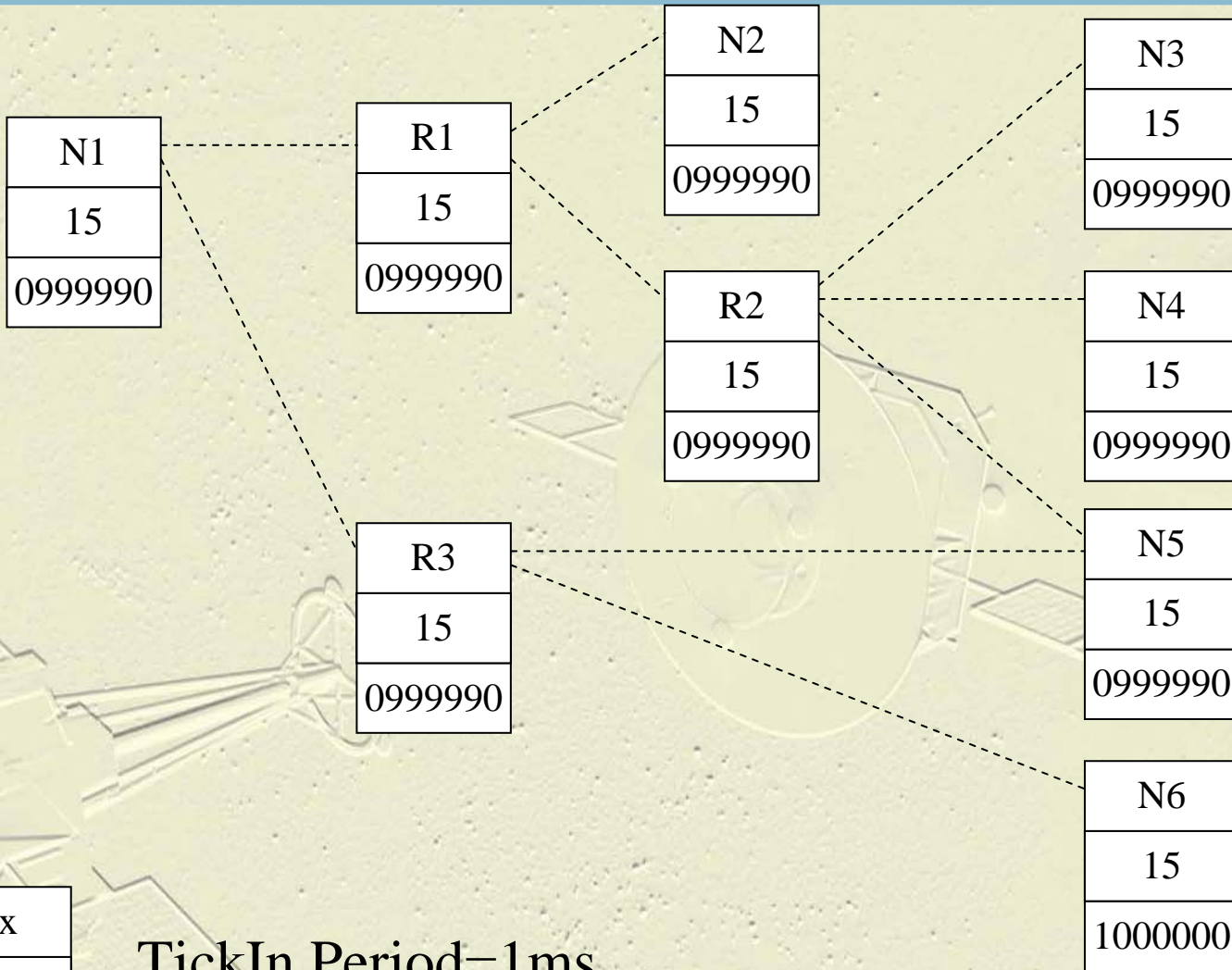
Questions & Comments

Irfu

cea

saclay

lrfu

cea

saclay

N2
15
0999990

N3
15
0999990

N1
15
0999990

R1
15
0999990

R2
15
0999990

N4
15
0999990

R3
15
0999990

N5
15
0999990

N6
15
1000000

Xx
TimeOut
SubTime
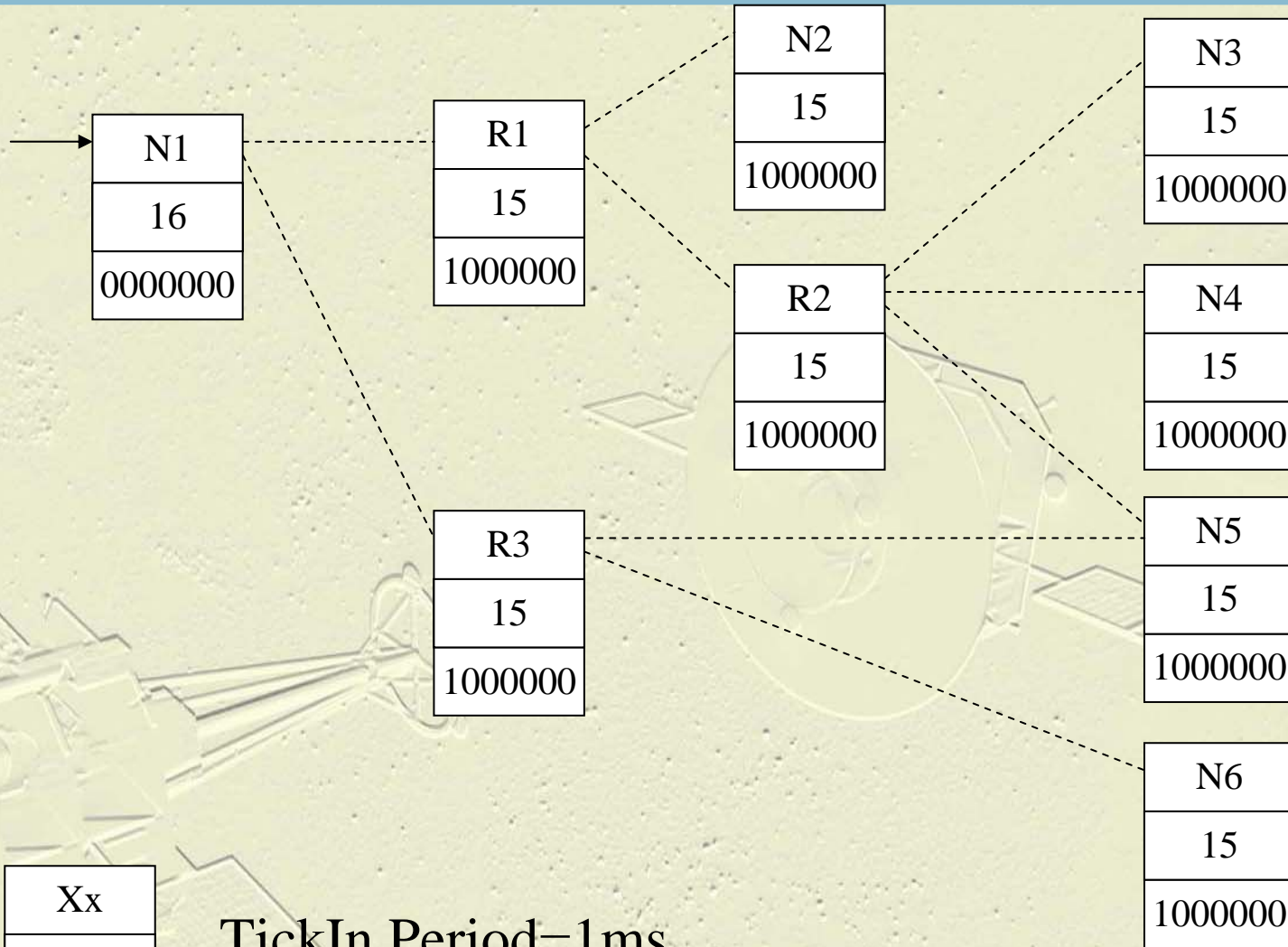
TickIn Period=1ms

Transmission Period=10ns / Links delay = 640ns

lrfu

cea
saclay

N1
16
0000000

R1
15
1000000

N2
15
1000000

N3
15
1000000

R2
15
1000000

N4
15
1000000

R3
15
1000000

N5
15
1000000

N6
15
1000000

Xx
TimeOut
SubTime

TickIn Period=1ms

Transmission Period=10ns / Links delay = 640ns

Irfu

cea

saclay

TickIn Period=1ms

Transmission Period=10ns / Links delay = 640ns

N2
16
0001280
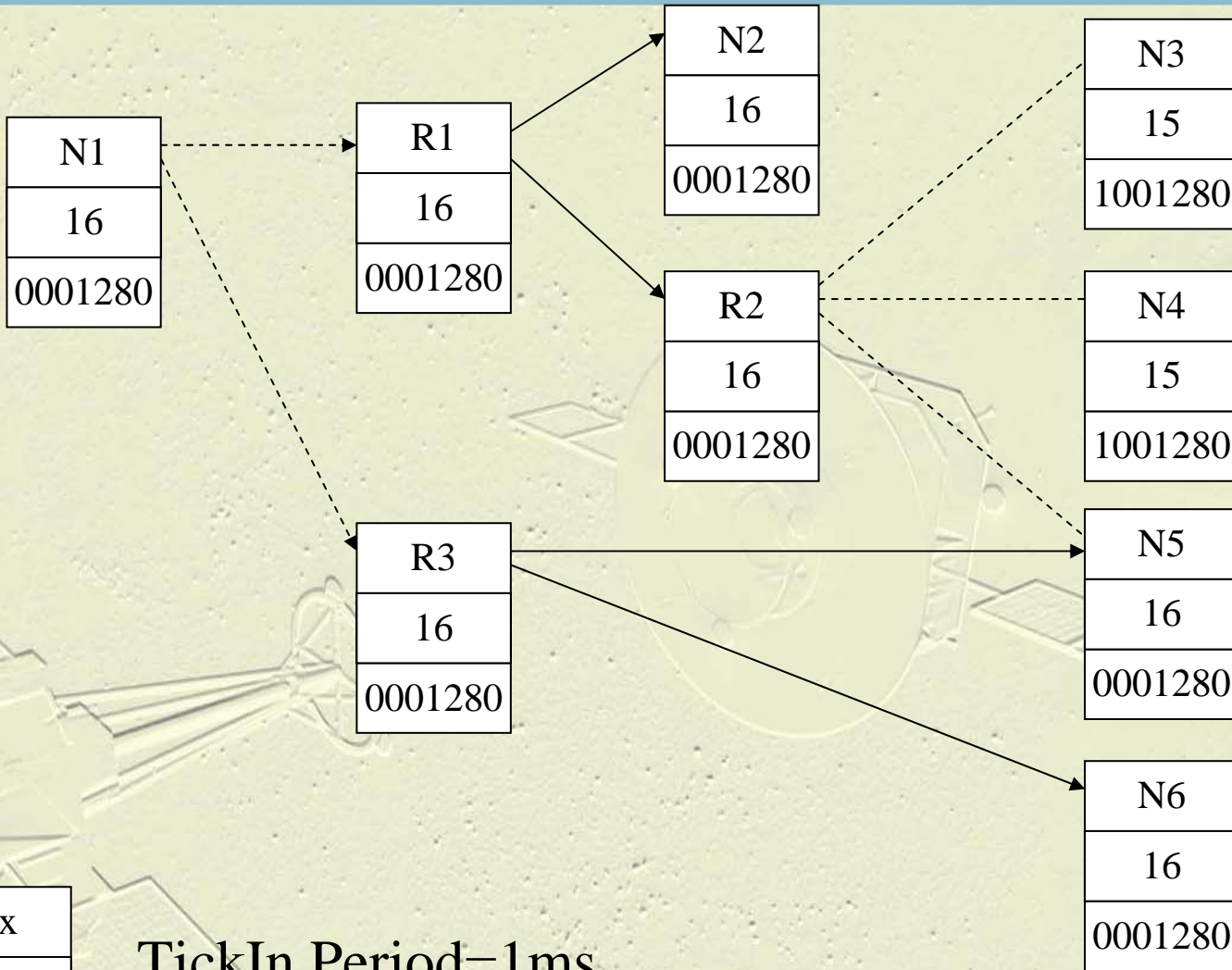
N3
15
1001280

N1
16
0001280
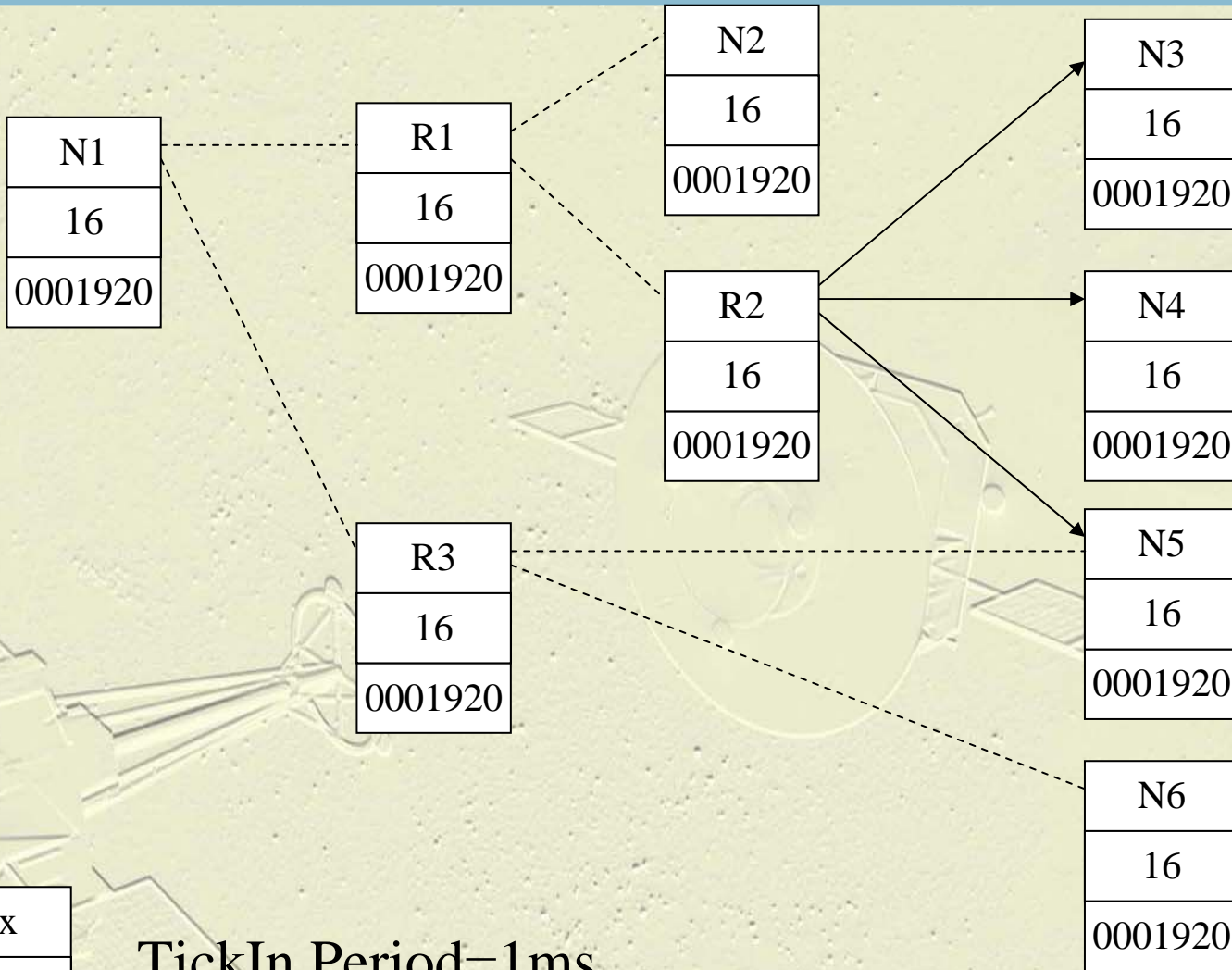
R1
16
0001280

R2
16
0001280

N4
15
1001280

R3
16
0001280

N5
16
0001280

N6
16
0001280

Xx
TimeOut
SubTime

TickIn Period=1ms

Transmission Period=10ns / Links delay = 640ns

TickIn Period=1ms

Transmission Period=10ns / Links delay = 640ns

N2
16
0001920

N3
16
0001920

N1
16
0001920

R1
16
0001920

R2
16
0001920

N4
16
0001920

R3
16
0001920

N5
16
0001920

N6
16
0001920

Xx
TimeOut
SubTime

TickIn Period=1ms

Transmission Period=10ns / Links delay = 640ns

I r f u

cea
saclay