A sensitivity analysis of two worst-case delay computation methods for SpaceWire networks

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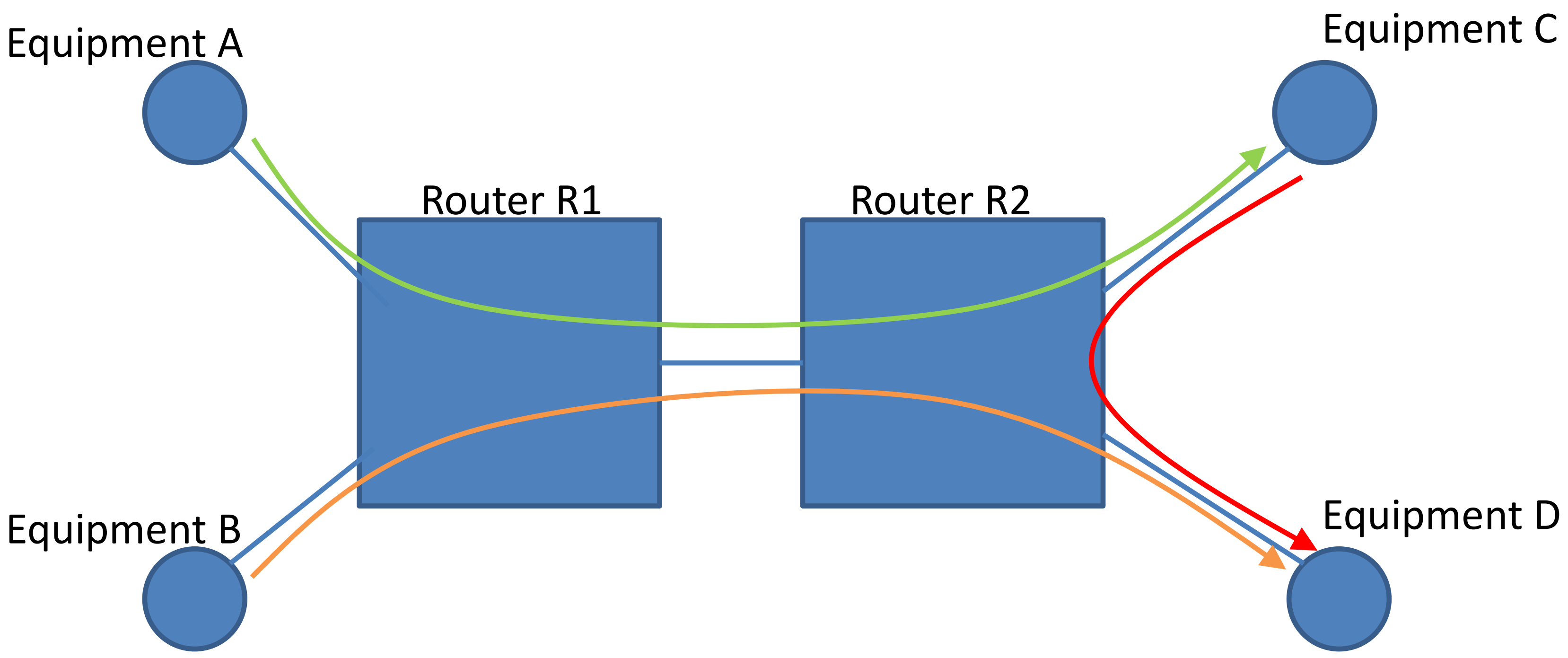
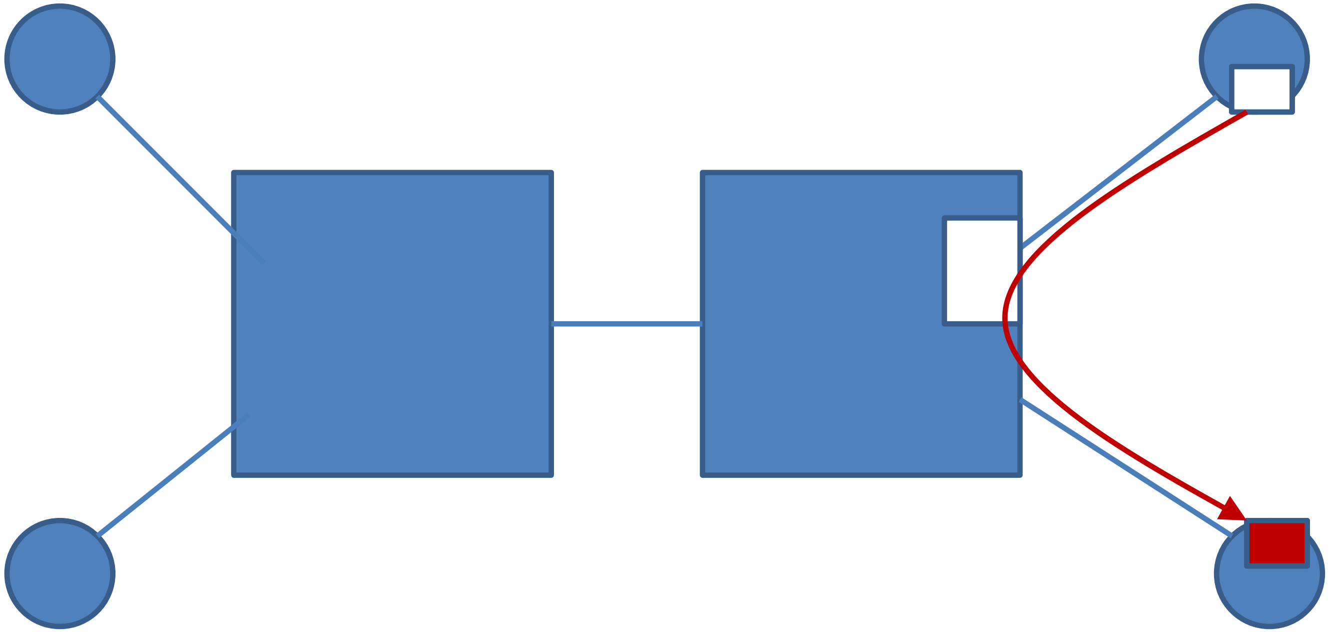
SpaceWire mechanisms in action

Illustrated with a single contention example…



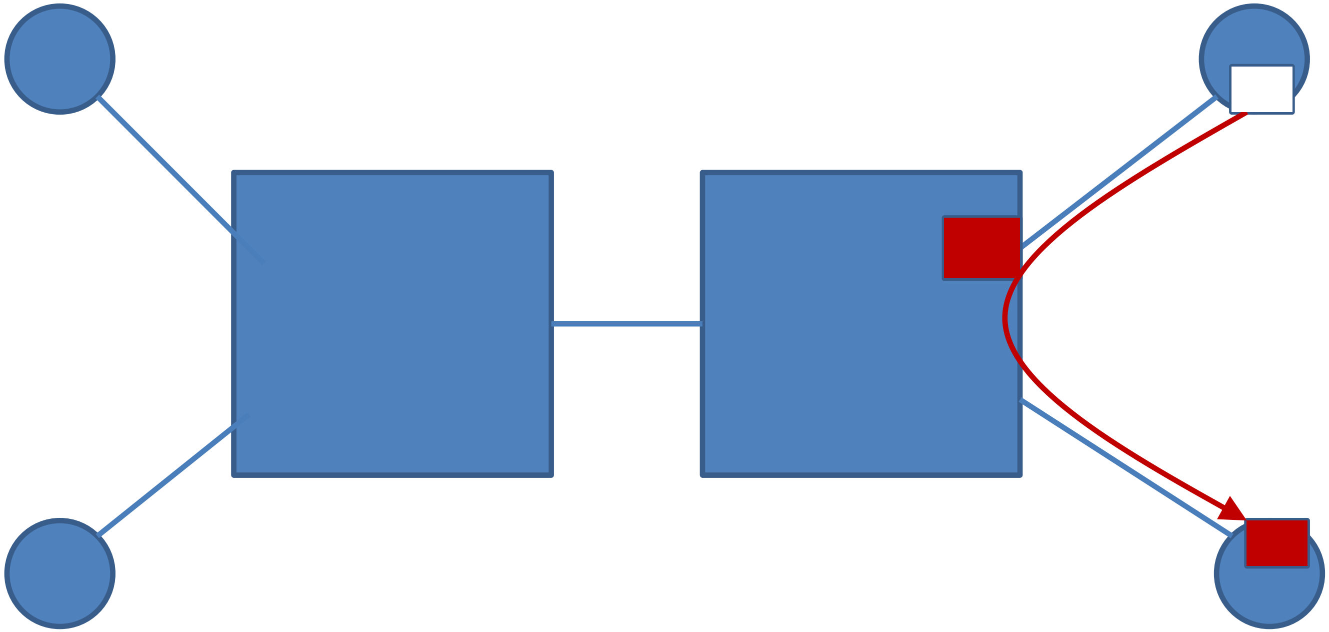
SpaceWire mechanisms in action

« On-the-fly » retransmission



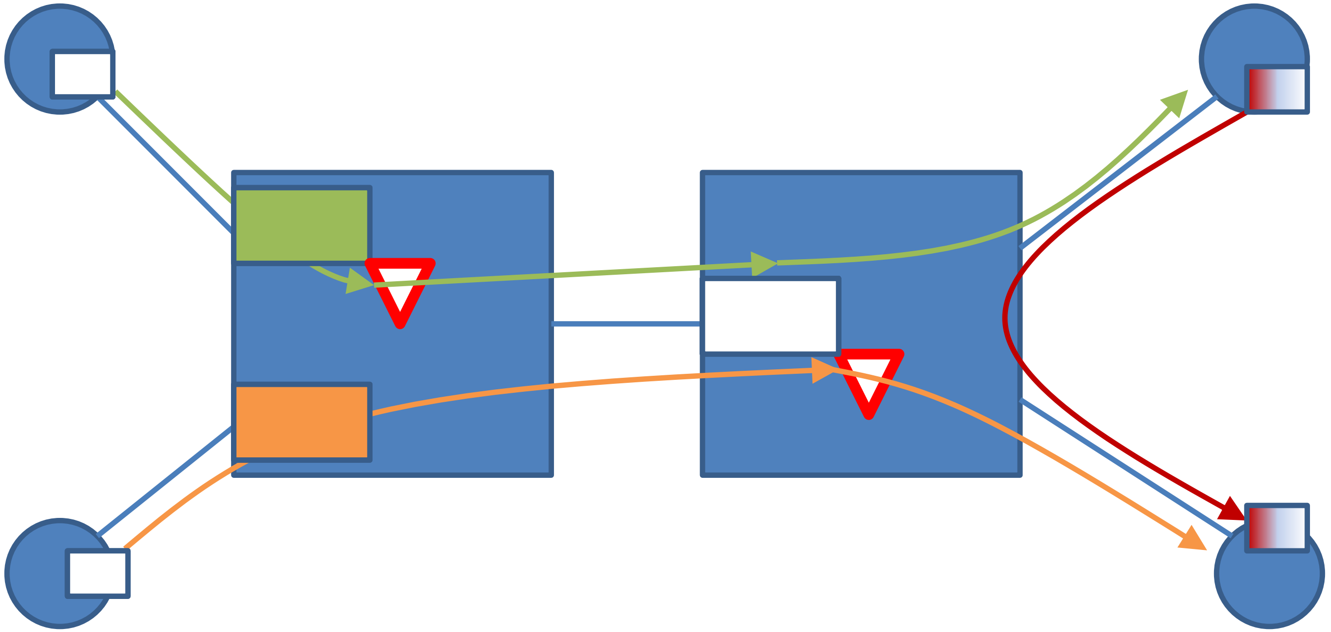
SpaceWire mechanisms in action

Local flow-control (per link)



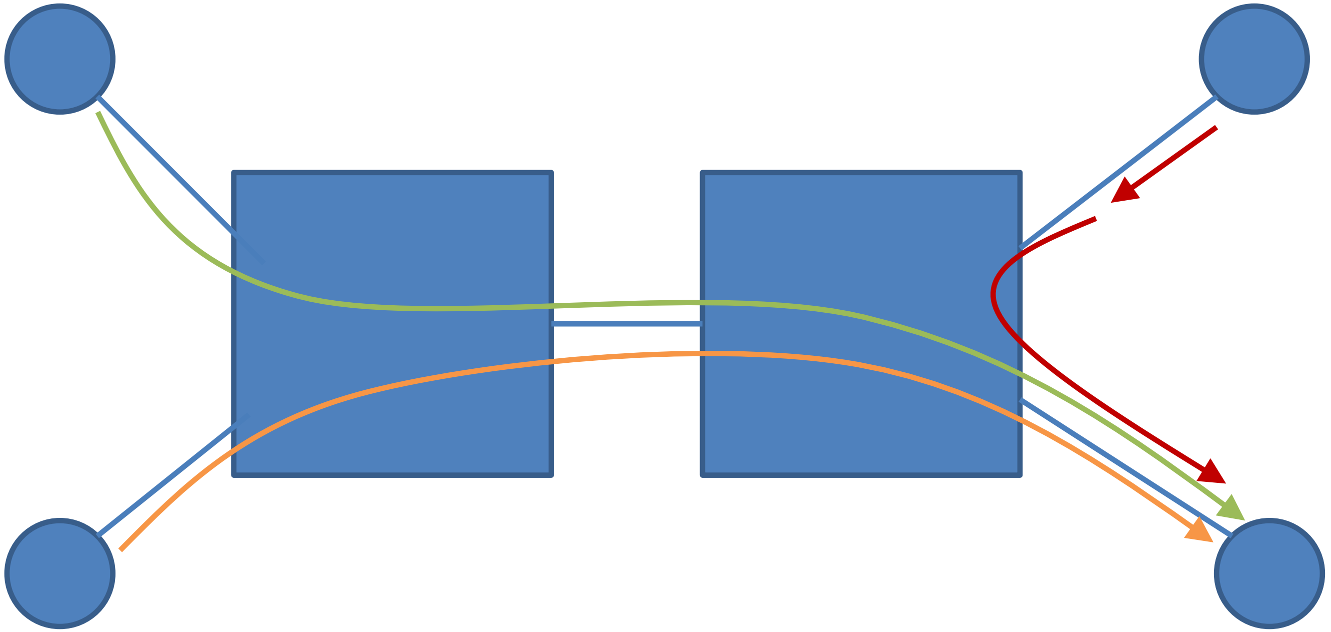
SpaceWire mechanisms in action

Wormhole routing



SpaceWire mechanisms in action

« Round-robin » election



Approaches for routed SpaceWire end-to-end delay analysis

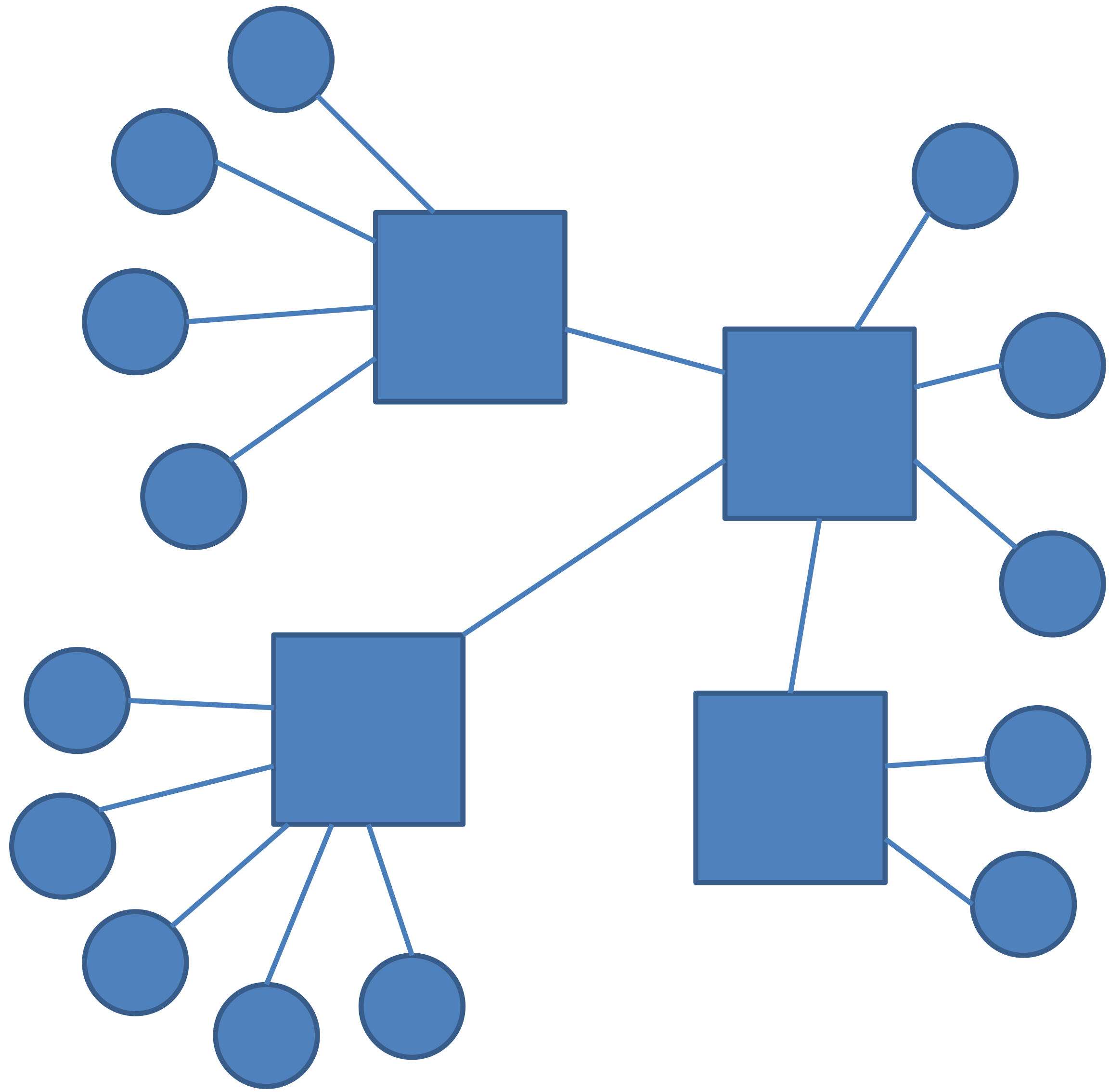
- Simulation
  - MOST simulator (OPNET-based)
    - developed by TAS (Thales Alenia Space)
    - sold to the ESA (European Space Agency)
    - 16 seconds simulated in ~ 1 hr
    - Cannot be presented as a proof that the observed worst-case will never be exceeded
- Model-checking
  - Model developed at TAS
    - cannot tackle the case study (combinatorial explosion)
- Calculation of latency bounds
  - Thomas Ferrandiz' thesis

Calculating latency bounds in routed SpaceWire networks

- Several methods developed during Thomas Ferrandiz’ thesis
  - First simple Recursive Calculus (DEDS’2011)
  - Enhanced Recursive Calculus (ECRTS 2010) : RC
  - Network Calculus method (ECRTS 2011) : NC
- Each method has strong and weak points
  - None is fully satisfying… stay tuned if you are looking for a new application domain…

Industrial Case Study

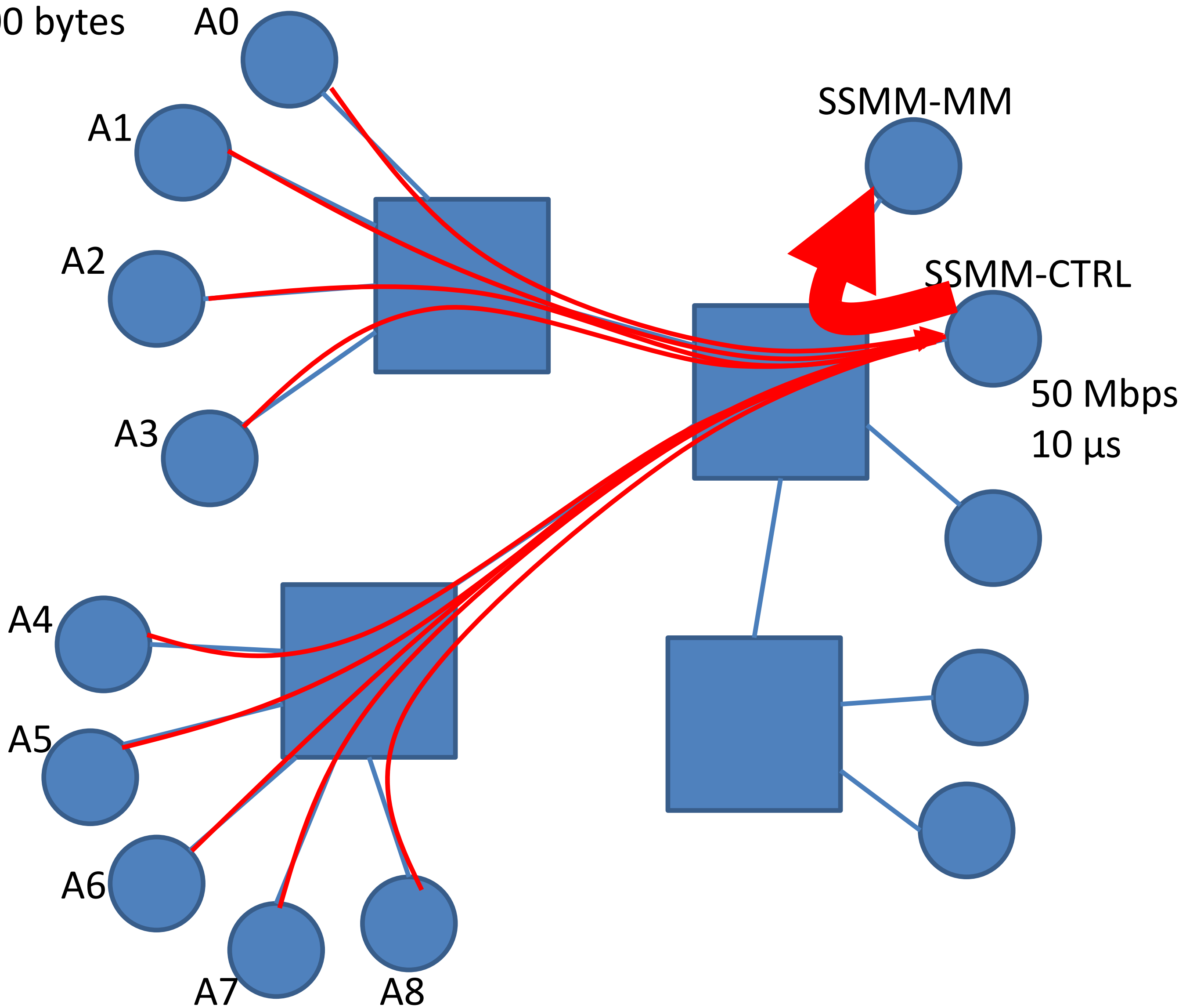
- A single SpaceWire network for both the scientific traffic, and the control (getting rid of 1553B)
  - Need to guarantee time constraints for the control
  - $\Rightarrow$ Calculate an upper bound
- Representative (for the next 20 years !) of the size of on-board networks in the largest satellites



Traffic flows

Scientific data packets : 4000 bytes
(fully independent sources)
⇒ Non time-critical data

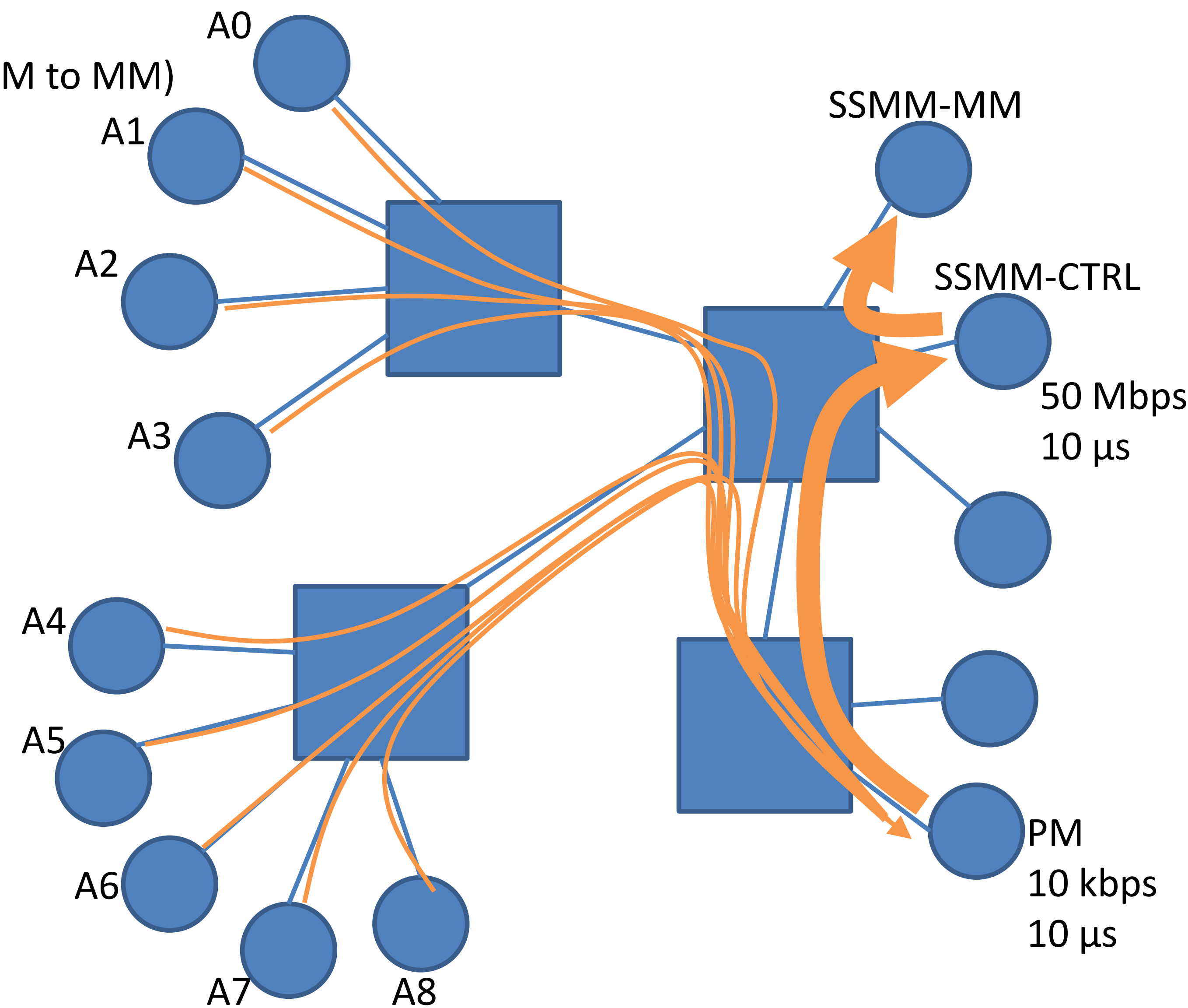
	Inter-arrival (ms)
A0	2.21
A1	26.4
A2	160.0
A3	3200.0
A4	7.5
A5	98.5
A6	400.0
A7	9697.0
A8	20000.0



Traffic flows

Housekeeping packets
20 bytes (100 bytes from PM to MM)
⇒ Time critical data

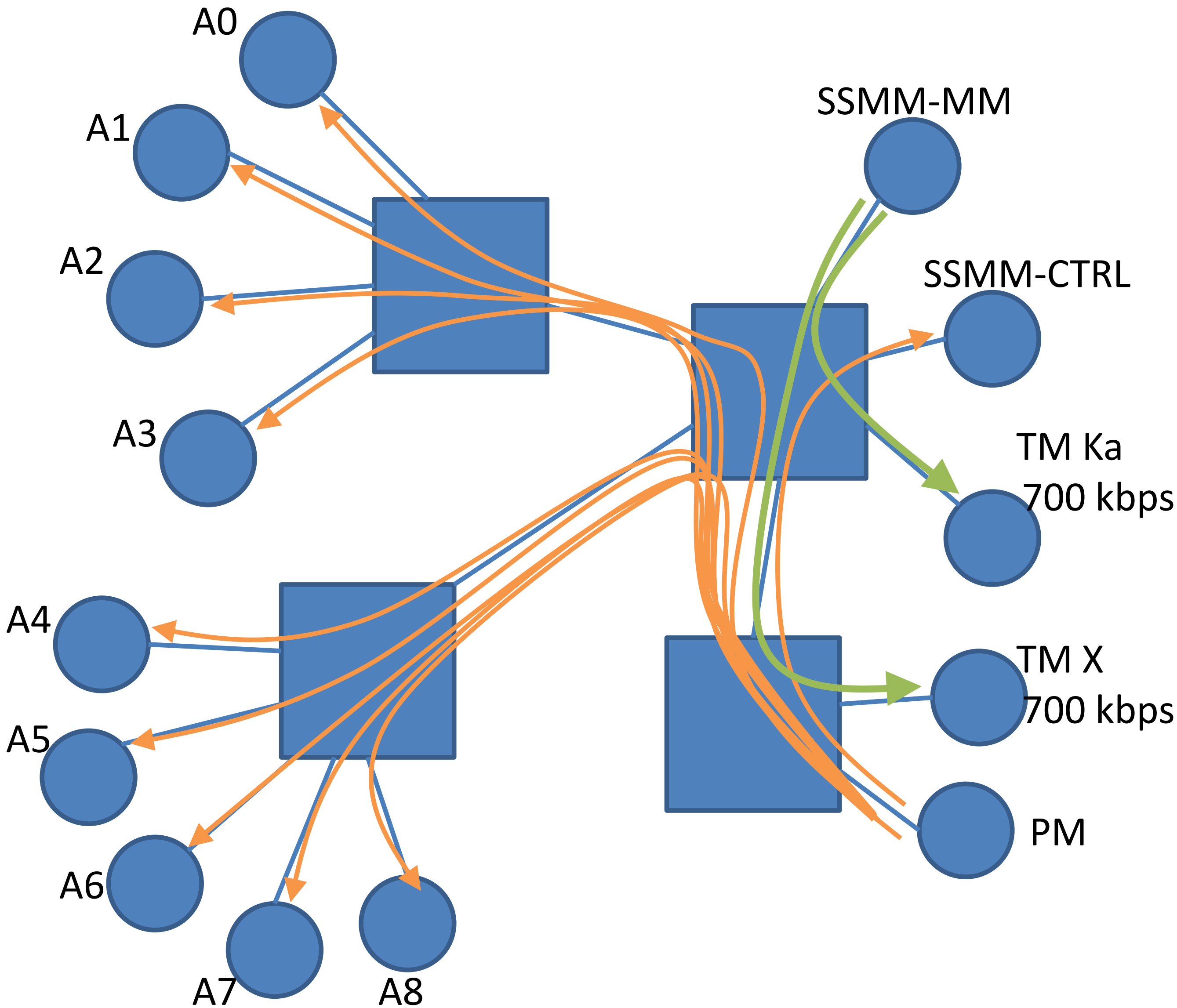
	Inter-arrival (ms)
A0	160.0
A1	53.3
A2	160.0
A3	5330.0
A4	320.0
A5	1330.0
A6	200.0
A7	8000.0
A8	16000.0
PM	80.0



Traffic flows

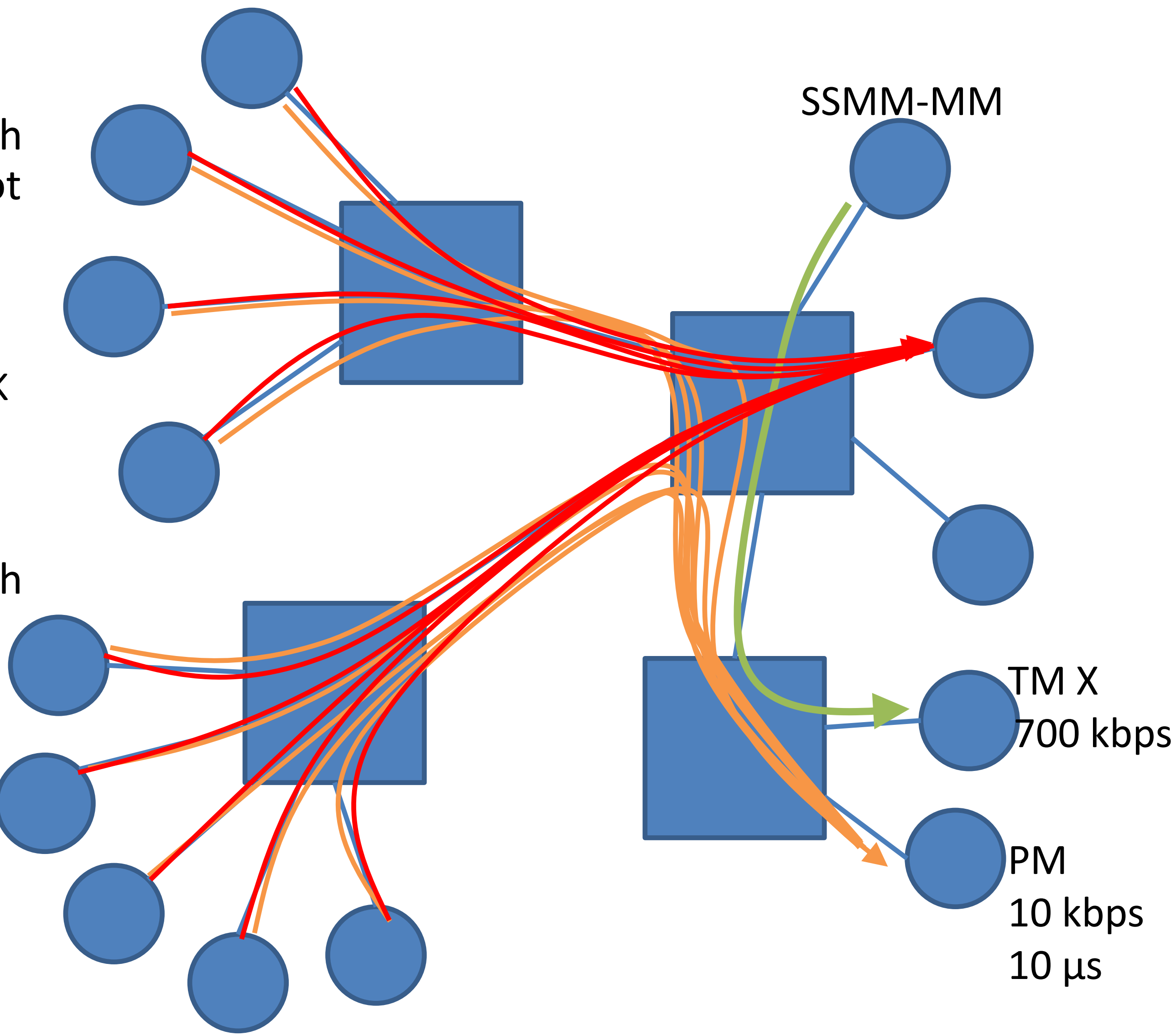
Command packets
1000 bytes
Period: 80 ms

Telemetry packets
4000 bytes
Period: 40 ms



Sensitivity analysis of RC and NC methods

1. Fragmentation of the large scientific packets :
   - Bounds calculated with RC are reduced but not in the same level as packet size reduction
     - (RC assumes that buffers are full of HK packets, which wait behind large TM X packets)
   - Bounds calculated with NC are much tighter than with RC and reduce with a larger factor along with packet size reduction
     - Most flows have a large period, so NC counts much less packets than RC



Sensitivity analysis of RC and NC methods

2. Influence of small service rate equipments
   - RC gives unusable over-estimated bounds
     - No “pay-burst-only-once” effect : multiplication of worst-case scenario of all crossed routers
     - Reduction of packet size actually increases some bounds
   - NC gives usable bounds, but…
     - The 20-bytes-long packets delay the 4000-byte-long scientific packets, whereas the opposite was expected!
     - In this situation reducing the scientific packet size doesn’t have a large impact
       - The bounds for the Command packets are better with RC than with NC: this comes from a preemptive model of the sharing of our “Wormhole section” by two conflicting flows

Sensitivity analysis of RC and NC methods

3. Impact of the size and period of the packets
   - RC gives period-independent bounds, best when the traffic is saturated with large packets
   - NC gives better or equal bounds (depending on the network size) when the traffic is far from being saturated
   - but NC gives more-pessimistic bounds when the traffic is saturated with large packets
   - When the traffic is saturated with a combination of small and large packets, NC becomes better again, but only because RC counts too many small packets
4. Impact of crossed flows and slow terminals
   - In a network with crossed flows, RC usually gives better bounds than NC, except when the network carries very small packets to a slow terminal
     - The pre-emptive model of the wormhole section sharing weights more than the gains due to taking the periods into account

Open problems

- Space Industrials were looking for a fast analysis technique that “gives approximately the same results as those obtained with MOST simulator”
  - Such a request is obviously arguable (rare events not captured by simulation)…
  - Many bounds obtained with our methods are compatible with the time constraints but others are still an order of magnitude higher than the worse latencies observed with the simulator
- The size of the network is much smaller than networks in civil aircrafts:
  - Is it possible to investigate exhaustive analysis techniques?
  - Still working on optimization of Model Checking, and plans to try SDD
  - Other analysis techniques ?