Integrating end-system frame scheduling for more accurate AFDX timing analysis

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Outline

Context: bounding AFDX communication delay

Opening the end-system box

Gain evaluation on a case study

Conclusion

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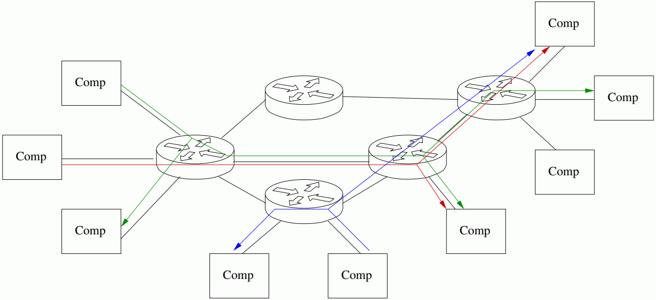
Context: AFDX backbone

Real-Time distributed systems:

- AFDX ≈ Ethernet technology for avionics
- ≈ hundred of computers
- ≈ 5–10 switches
- ≈ thousands of data flows



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Challenge: WCTT

WCTT

What is the worst-case network traversal time?

- Needed to ensure correct real-time behavior
- Used to dimension the system:
  if unsatisfied, change the system
- Worst case based on AFDX behaviour
  - Input flows (VL: virtual link) are constrained
    - Maximal frame size
    - Known static routing
    - Minimal time interval between two frames (BAG: Bandwidth Allocation Gap)
  - Network behaviour is known
    - Full duplex: direct access
    - Queue policy: FIFO, Static Priority

WCTT bounds

WCTT *bound*

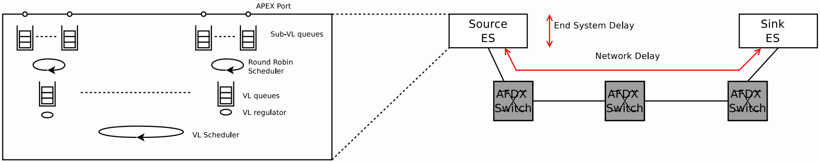
How to upper bound the WCTT ?

- The exact WCTT is unknown
- Several methods exist:
  - network calculus: used for A380, A350 [5, 4]
  - event model (Symtavision) [7, 12]
  - holistic scheduling (MAST) [6]
  - trajectorial-based approaches [1, 9, 8]
  - ad-hoc methods
- Accuracy of results:
  - NC pessimism ($|WCTTbound - realWCTT|$) $\leq 20\%$ on "typical" configurations

  $\Rightarrow$ not so much to gain

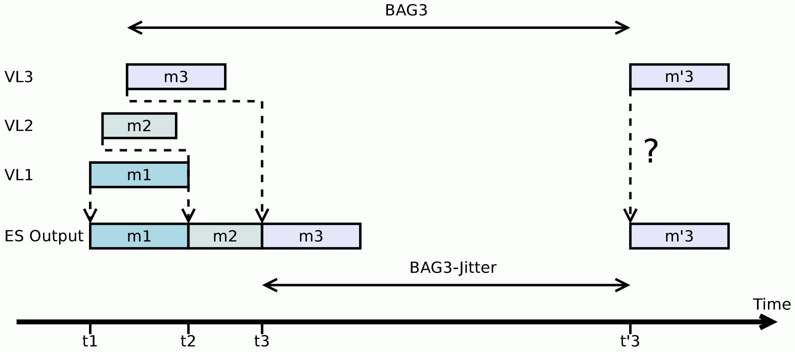
Outline

What is the AFDX end-system?



- End-System role
  - multiplex access to the output
  - guarantee BAG respect

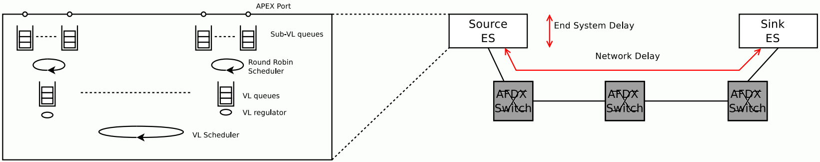
Why BAG guarantee is not trivial



Even if all VL are synchronous

- multiplexing introduced jitter
- jitter must be bounded
- the standard gives requirement on jitter ($\leq 500\mu s$)

Opening the black-box



More knowledge on the system

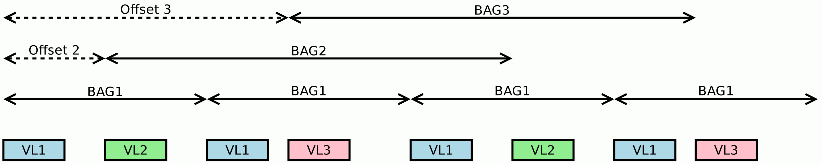
$\Rightarrow$ more accurate model

$\Rightarrow$ more accurate bounds

A periodic End-System

Assuming periodic output flows [11, 10]:

- VL i can send frames at $t_k^i = \phi_i + k \times \text{BAG}_i$
- $\approx$ local TDMA
- adequate choice of offset ϕ_i
- must synchronise applications and End-System or pay BAG as End-System Delay
- gain: decrease network delay up to 51%



Removing end-system

Assuming no End-System [2, 3]:

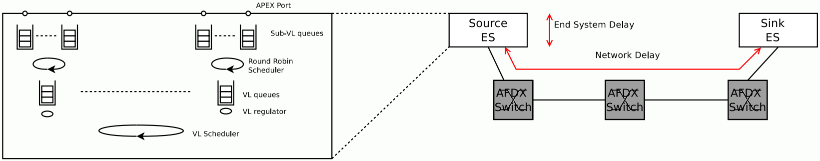
- consider task scheduling (static priority)
- theoretical model
- AER: Aquisition - Execution - Restitution model (frame send at end of execution)
- no respect of jitter bound
- (local) gain: linear with number of tasks

The Thales End-System

- An implementation of the standard
- Exact behaviour is confidential
  - respect the $500\mu s$ jitter
  - some flows can be "prioritised"

  $\Rightarrow$ end-system delay $\leq 1ms$
- The behaviour is a scheduler

$\Rightarrow$ use the "same" techniques as [2, 3]



Outline

A realistic AFDX network

Entities	Number
End Systems	104
Switches	8
Virtual Links	974
Latency constraints	6501

	VL destinations	BAG	Maximal Packet Size	Traversed Switches	Latency Constraint
minimum	1.0	2 ms	100 bytes	1	1.0 ms
average	6.6	60 ms	380 bytes	1.3	10.04 m
maximum	84.0	128 ms	1500 bytes	4	30.0 ms

Experiment

- Purely periodic
  Configure ES to have purely periodic behaviour
- All VLs in local high-priority class
  - minimise ES delay for all VL
  - no more respect of 1 ms local delay
  - create bursts
- VLs with BAG $\leq 8ms$ in local high-priority class
  - select some VLs
  - allow to "shape" the output

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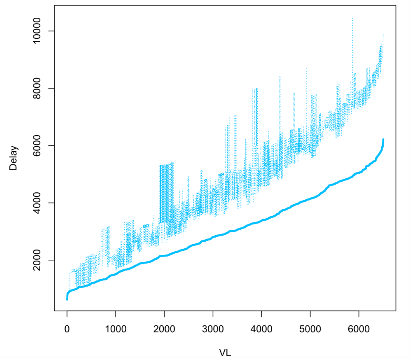
End-systems configuration	Average gain
Purely periodic	42%
All VLs in local high-priority class	26%
VLs with BAG $\leq$ 8ms in local high-priority class	38%

Plotting delais



Plotting, for each VL:

- WCTT bound with black-box End-systems
- WCTT bound with Thales End-System
- sorted by Thales-WCTT

Outline

Conclusion

- More information gives better bounds
  but often related to specific cases
- contribution:
  dramatic increase of bound accuracy

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