EADS INNOVATION WORKS

Modeling Aeronautic Networks for Internet Scenarios

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Outline

- Introduction to Communication Networks in Aeroplanes
- Goal of our Work
- Safety Criticality in the Aircraft Cabin
- Performance Bounds in Communication Networks
- DIMTOOL: A Platform for Determining WC Bounds
- State of the Switched Aircraft Cabin
- Conclusion

Communication networks in Airbus Aeroplanes

- Impression of the aircraft …
- Installation may look simple at system level, but …
- very complex at a/c level

Various Protocols like LVDS, RS-232, RS-485, CAN, Ethernet

Goal of our Work

Overall-goal in Aernonautics:
Safe weight, reduce kerosine, reduce complexity

Can we employ Internet Technology in the Aircraft Cabin ?

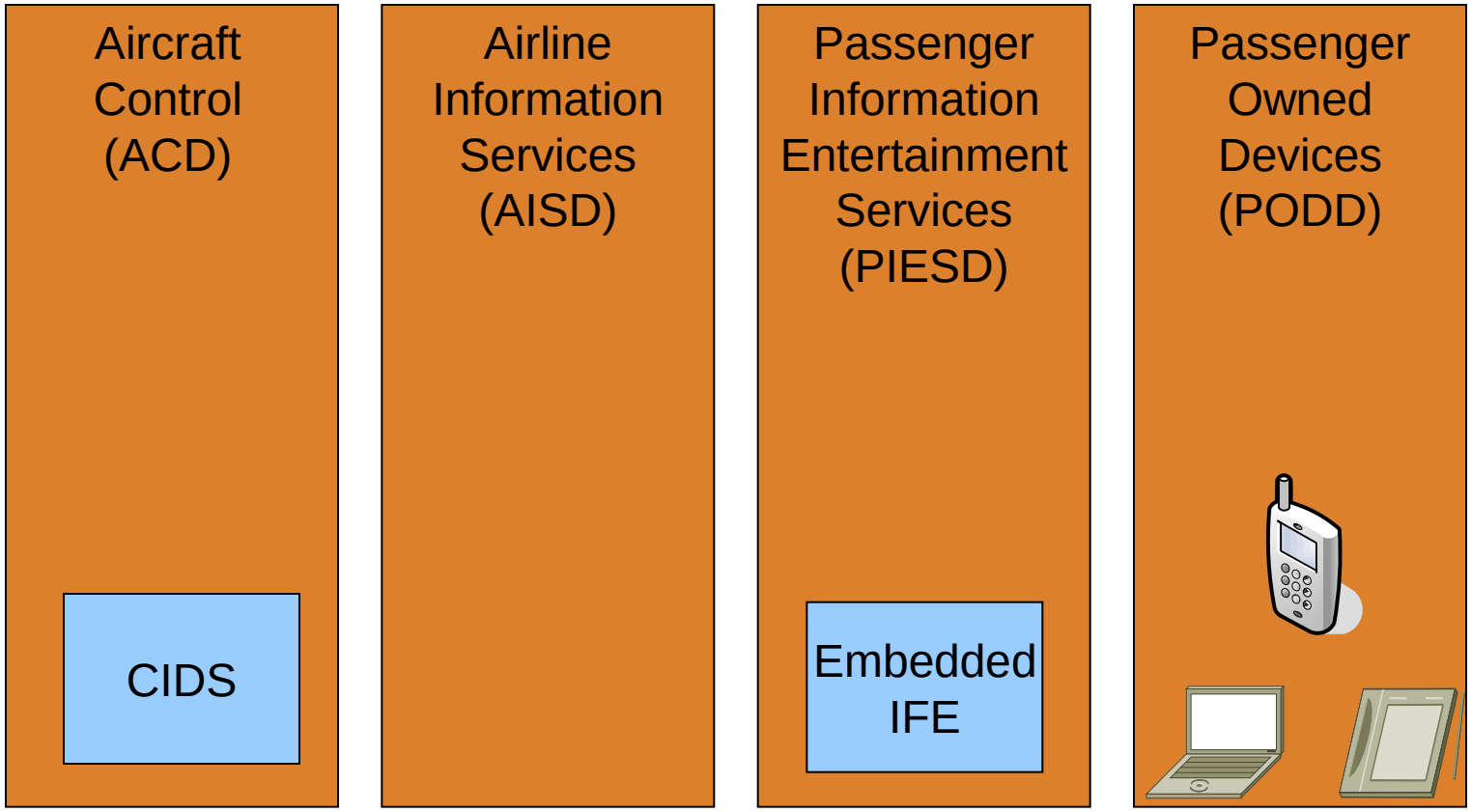
- Still cover safety related funtions
- Video, Games, Internet Surfing
- Passenger Owned Mobile Device, Laptop, Mobile
- Medical Care from ground by videostream
- Cabin Logbook sends information to ground, accessible by Website

Can we reduce number of networks ?

What does it mean for

Certification, System Integration, Deployment ?

Domains in the Aircraft [ARINC664P5]



Safety in Aeronautics

Expressed in terms of Design Assurance Level [DO254], [ARP4754A]

DAL	Classification	DAL Definitions	Failure Requirement [failures / hour]
Level A	Catastrophic	Catastrophic failure condition for the aircraft	$p < 10^{-9}$
Level B	Hazardous / Severe-Major	Hazardous / severe-major failure condition for the aircraft	$p < 10^{-7}$
Level C	Major	Major failure condition for the aircraft	$p < 10^{-5}$
Level D	Minor	Minor failure condition for the aircraft	-
Level E	No Effect	No effect on aircraft operational capability or flight crew workload	-

- Cabin Core Functions are „usually“ DAL-C
- Cabin Entertainment (IFE) is DAL-E
- Extensive use of redundancy in networks covering safety relevant functions
- Failure value is determined by Fault Tree Analysis
- Determinism must be presented in those networks

$\Rightarrow$ Necessity to determine the worst case

Network Latencies – Primer

Propagation Delay

- stable and almost negligible
- speed of light

Processing Delay

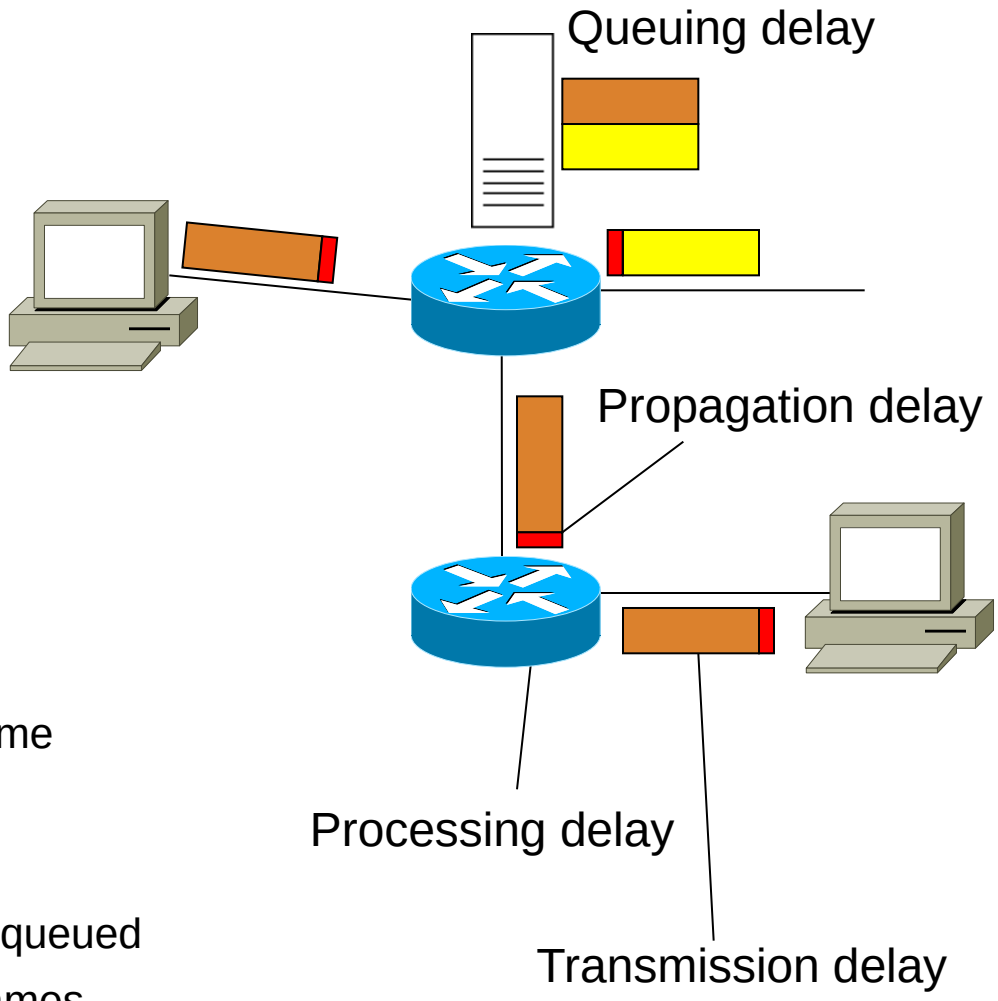
- Hardware dependent
- relatively stable

Transmission Delay

- Time it takes to transmit the whole frame

Queuing Delay

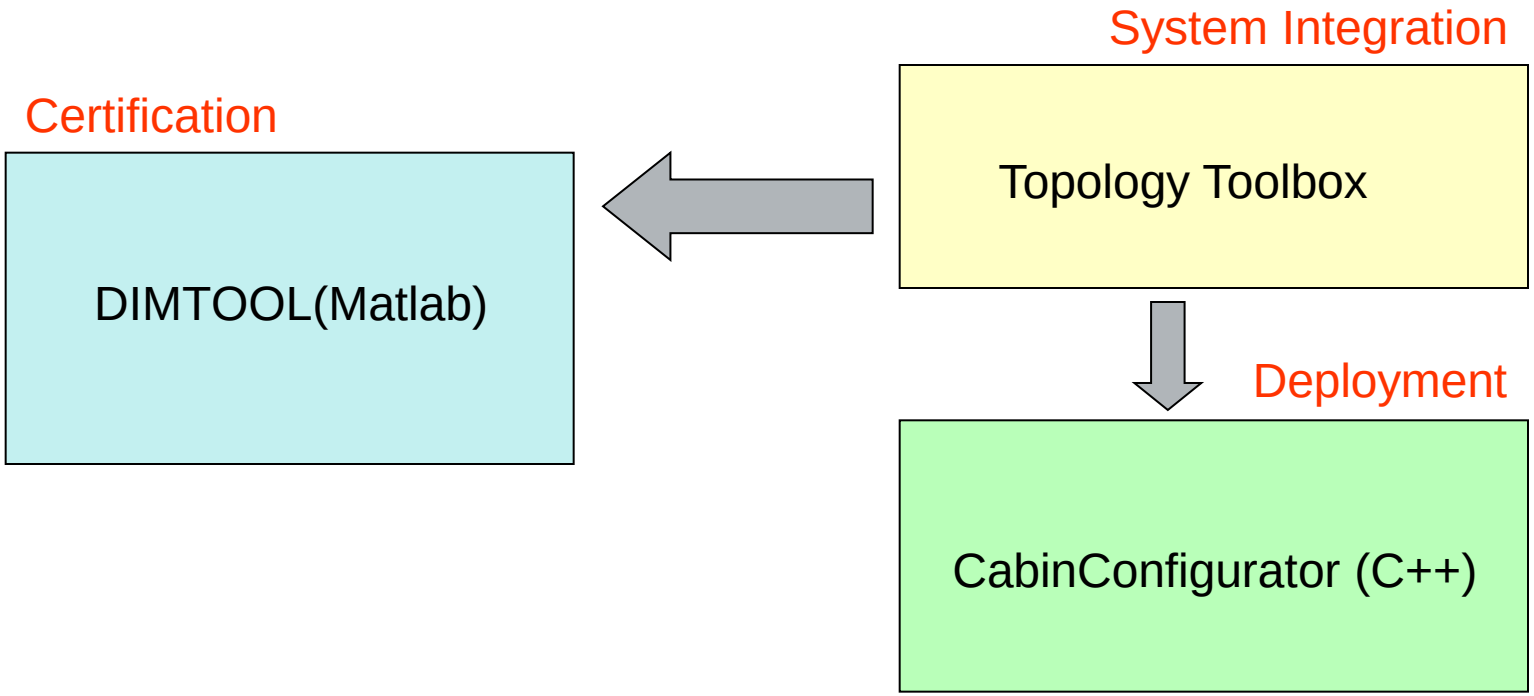
- If output port is busy, frames must be queued
- Sum of transmission delay of other frames, that have to be served before



Primer: Performance Bounds in Communication Networks

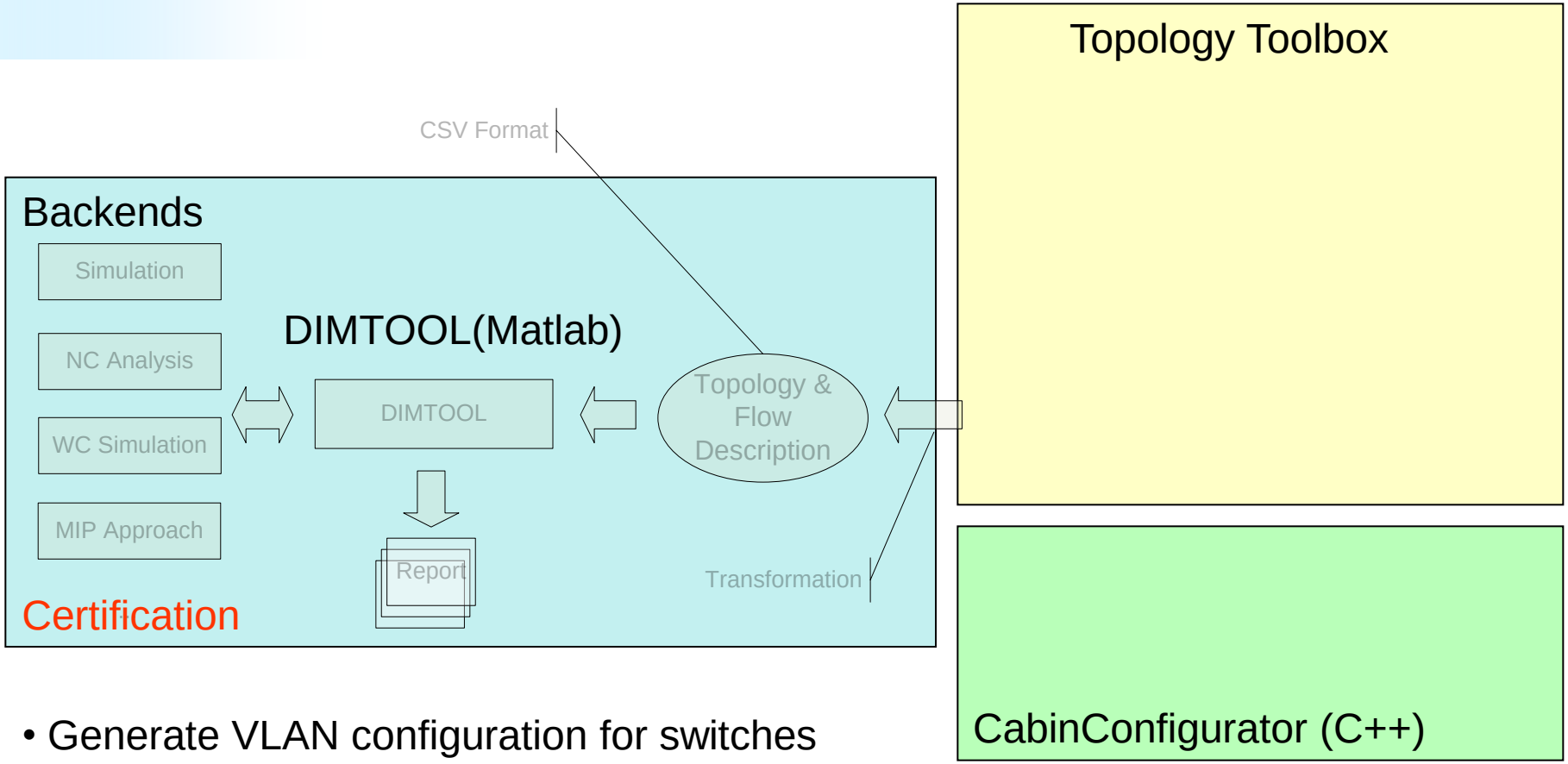
- Network Simulation with Monte Carlo Methods
  - ns-2, ns-3, OPNET, OMNET++
  - Simulation does not necessarily enforce worst case
- Network Calculus
  - (min, +)-algebra
  - Commutativity of convolution does not map reality
  - Fluid flow model
- Queuing Theory
  - Not only common in communication networks
  - Based on Stochastical Model
  - Fluid flow model
- Model Checking, Timed Automaton
  - Exact model, but problem of state explosion
  - Current models capture fixed sized packets

Toolchain DIMTOOL – Worst Case Estimation (I)



- Generate VLAN configuration for switches
- Extracting topology and flow information and forward to DIMTOOL
- DIMTOOL generates reports according to simulation, NC & worst case scheduling analysis

Toolchain DIMTOOL – Worst Case Estimation (II)



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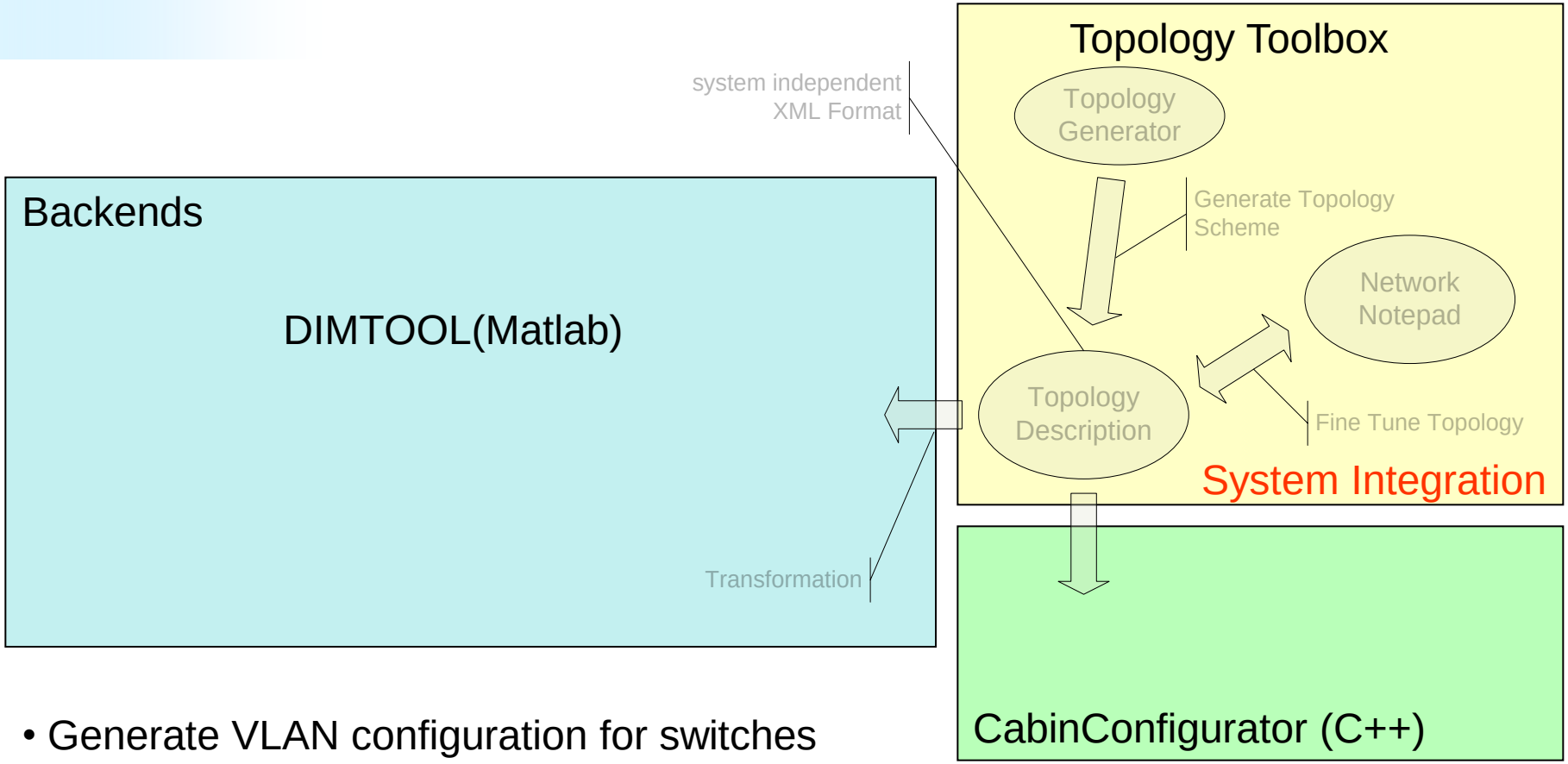
Toolchain DIMTOOL – Worst Case Estimation (III)



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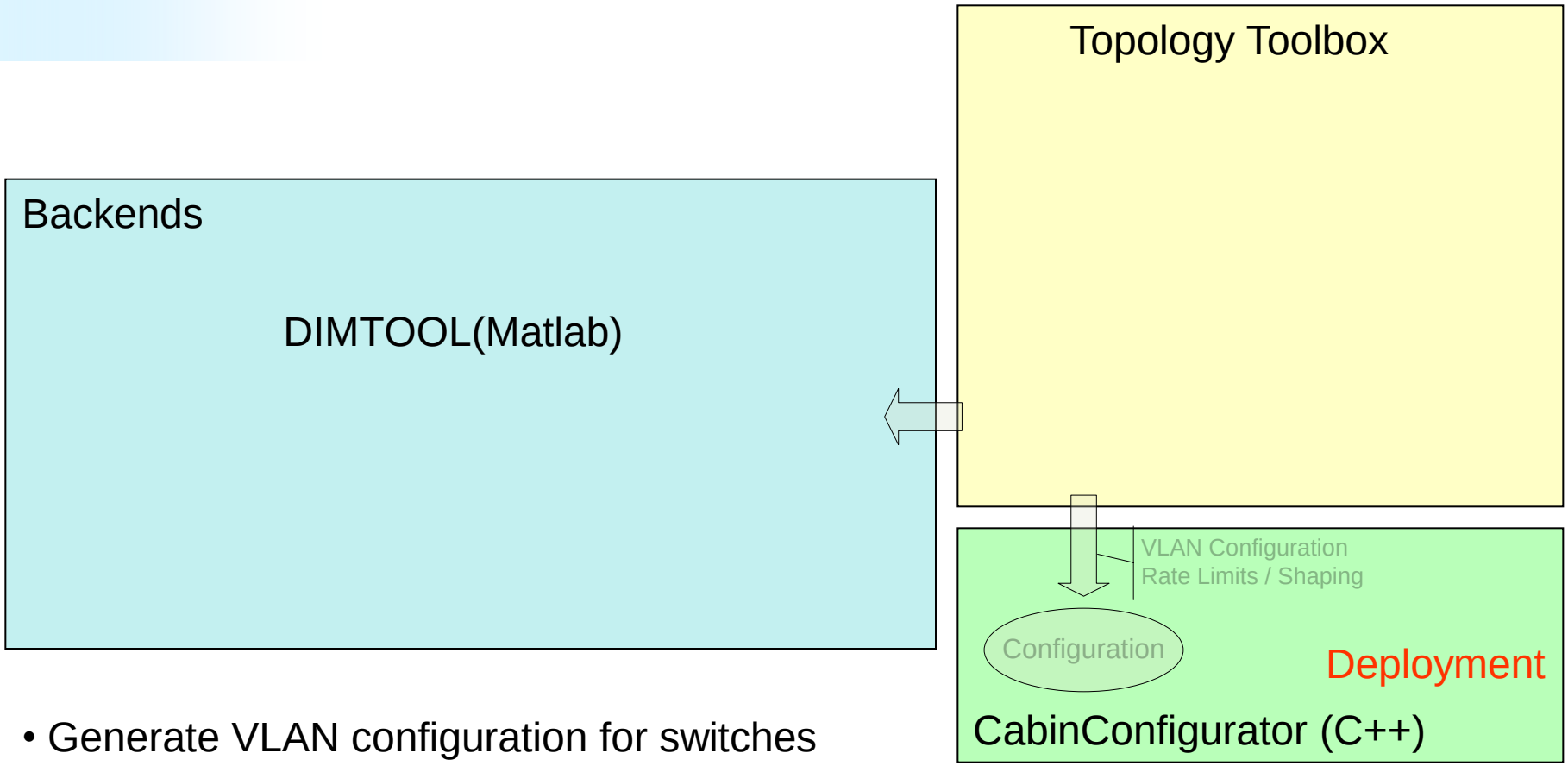

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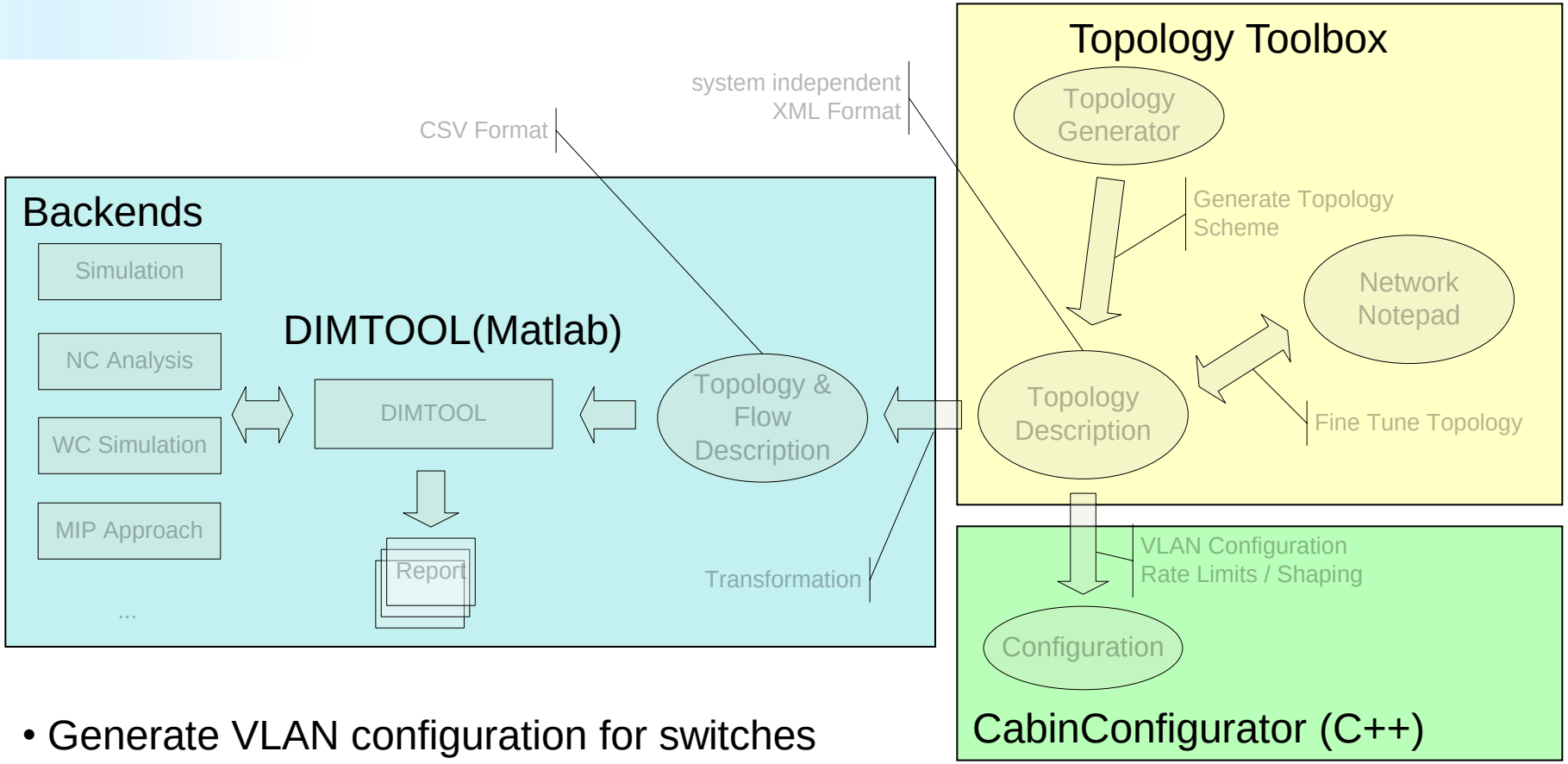

- Generate VLAN configuration for switches
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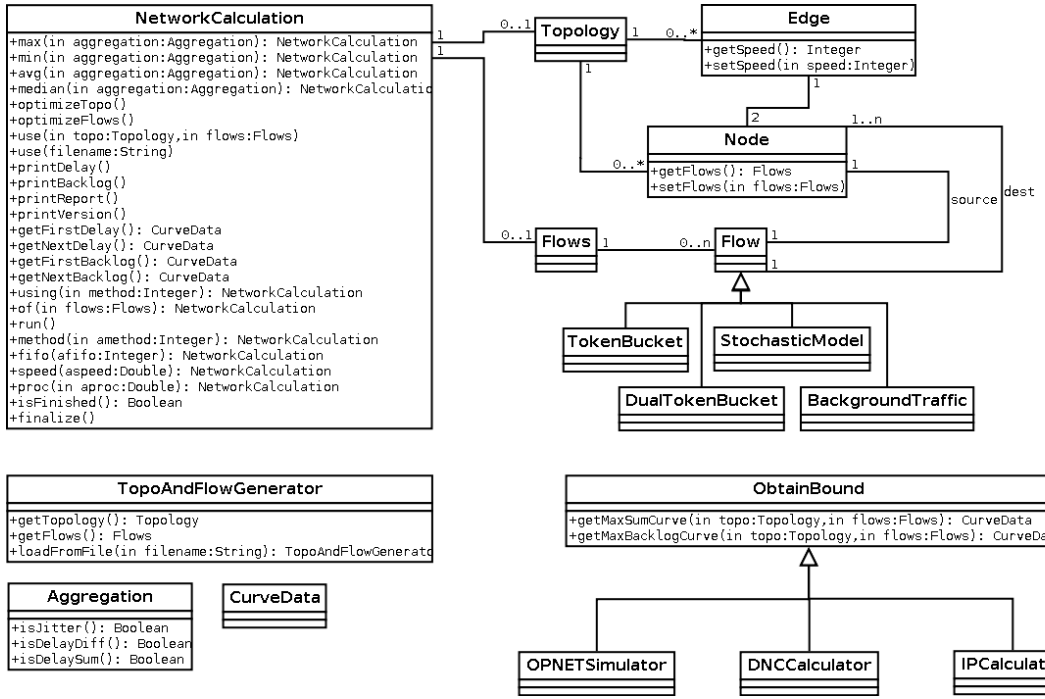
DIMTOOL – Architecture

- Simple, CSV Based Topology Description
- Converters for OPNET, OMNET, BRITE Topologies
- Converter for Camfigurator (Airbus Tool)
- Topology Generator for
  A30x, A350, A380
- Clean UML Description



DIMTOOL – Backends

Currently, the following backends are available

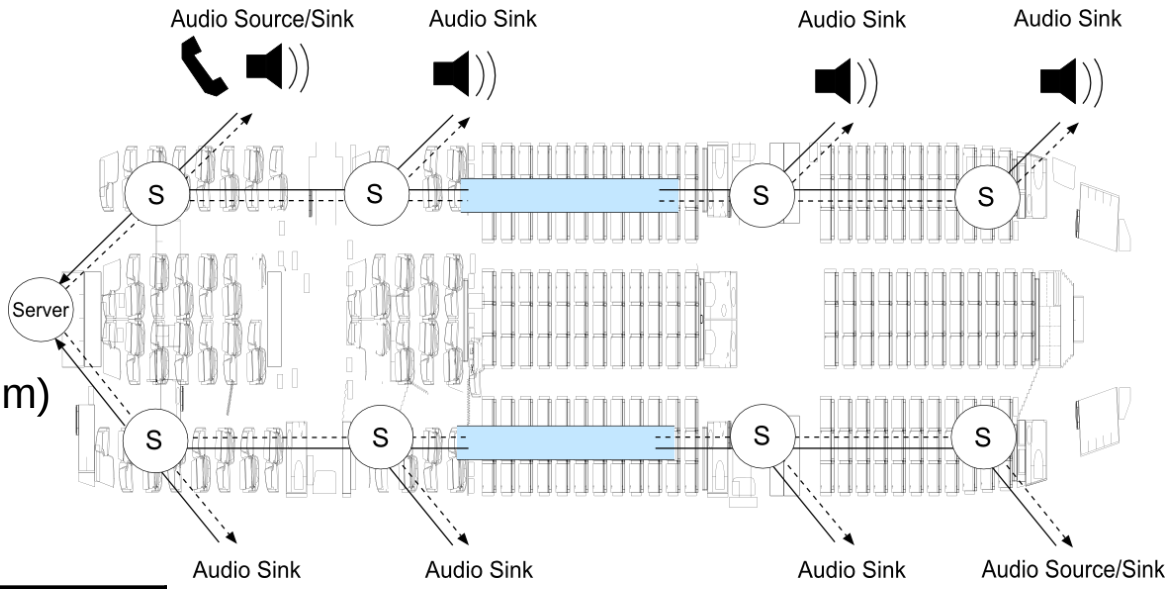
- Network Calculus Backend with DISCO network analyzer
- Network Simulation Backend with OPNET network simulator
- Worse Case Simulation Backend, OPNET
- Analytical / Modelchecking Backend

Future Work will address

- Stochastic Network Calculus backend
- Analytical Model for TCP

Application: Topology of Full Switched Aircraft Cabin

- Switched topologies for
  - A380
  - A350
  - A30x
- Mind store-and-forward delay (compared to TDMA bus system)



A380 Configuration, Number of Devices

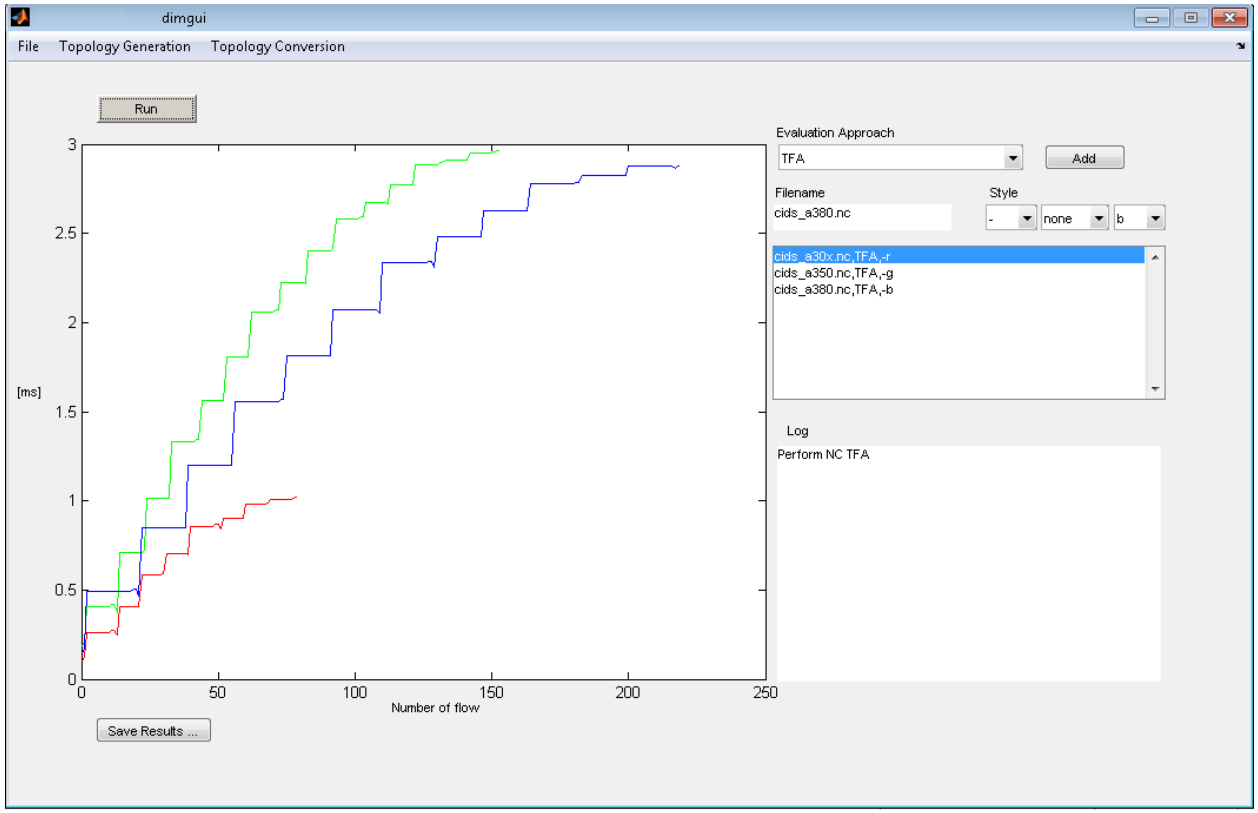
Device	Number	Description
PSU	190	Service Unit
IBU	1512	Light Scenario
Handset	20	Cabin Interphone
FAP	20	Panel for Cabin Control
CVMS	25	Video Surveillance

⇒ Ease certification by simplification to one line

DIMTOOL Graphical User Interface

- Provide several Performance Evaluation Backends
- Topology creator for A380, A350, A30x
- Topology converter for different input formats, Camfigurator, Network Notepad, OPNET
- Results shall be employable in certification

⇒ Deliver performance reports



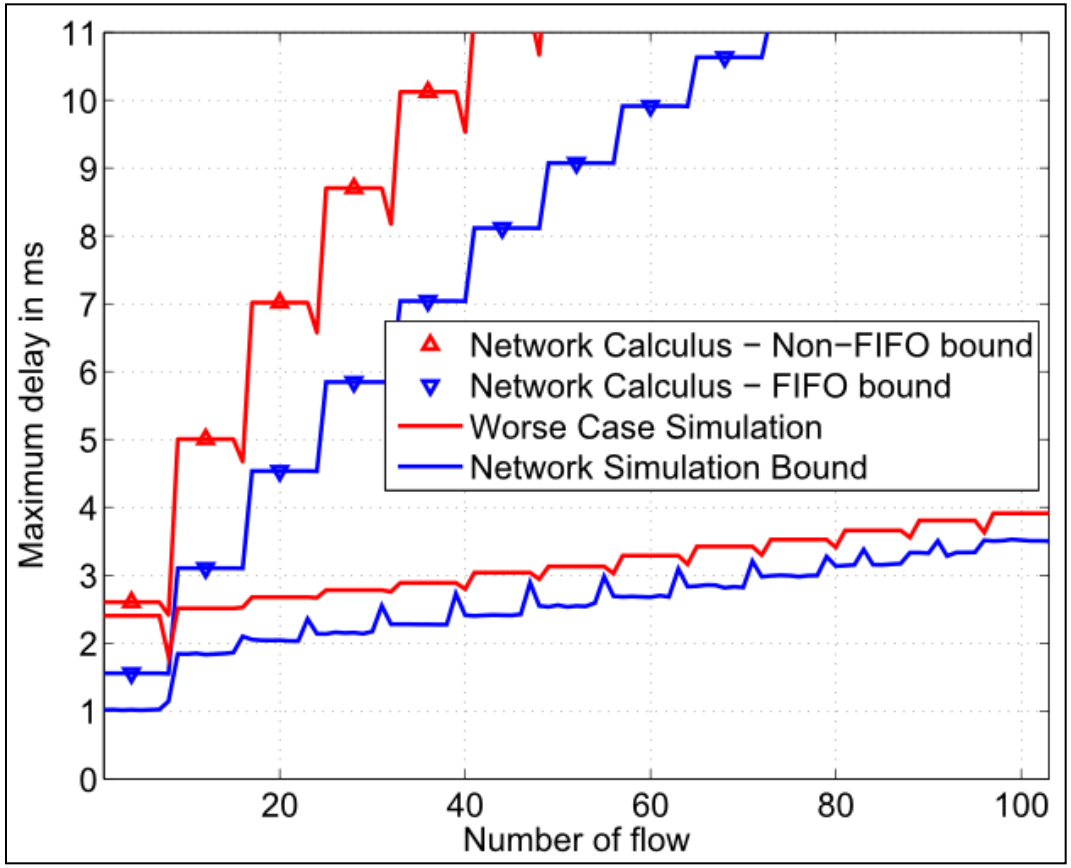
DIMTOOL – Results of Aircraft Cabin, 100MBit/s

- DIMTOOL Results for Upstream
- Worse Case Simulation shifts latency towards analytical bounds

⇒High level requirements of safety relevant cabin functions fulfilled

⇒ Readiness for multiple domains in same network

⇒ Providing infrastructure for Wireless Accesspoints, Radio Base Stations



Heidinger, E.; Burger, S.; Schneele S., Klein, A. & Carle, G., DIMTOOL: A Platform for Determining Worst Case Latencies in Switched Queuing Networks, ValueTools 2012, accepted

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Conclusions

- Valuable tool for
  - System Integration
  - Deployment
  - Certification
- Rapid analysis of novel switched aircraft networks
- Also beneficial for other real-time system
(In-Car Network, Automation Industry)

Future Work

- Coupling with weight database
- Move towards stochastic network calculus
- Address next generation AFDX networks

⇒also TCP flows shall be analyzed here

⇒ Network Calculus Models for TCP