Verification and Validation of a Fault-Tolerant Architectural Abstraction

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Motivation

- Fault tolerance at the architectural level
  - idealised fault tolerant architectural element
    - exception handling
- Fault tolerance doesn't come for free
  - increase in complexity
    - e.g., exception propagation
- Improve confidence
  - verification by model checking architectural configurations
  - validation by generation of test cases
- How the abstraction is implemented is not the topic of this paper

Outline

- Motivation
- Exception handling and software fault tolerance
- Idealised fault tolerant architectural element
- Rigorous development approach
- Conclusions
- Future work

Architectural Exception Handling

An architectural solution based on **exception handling**

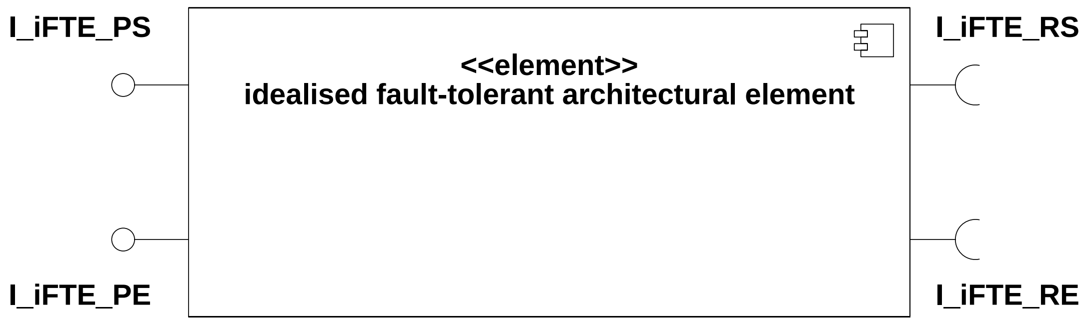
- components need to collaborate for handling certain failure scenarios
- configurations that allow the propagation of exceptions
  - controlled error propagation

Exception handling is not “the” solution, there are other alternatives

- it might be perceived as undesirable, but it’s reality
- depends on the failure assumptions and costs

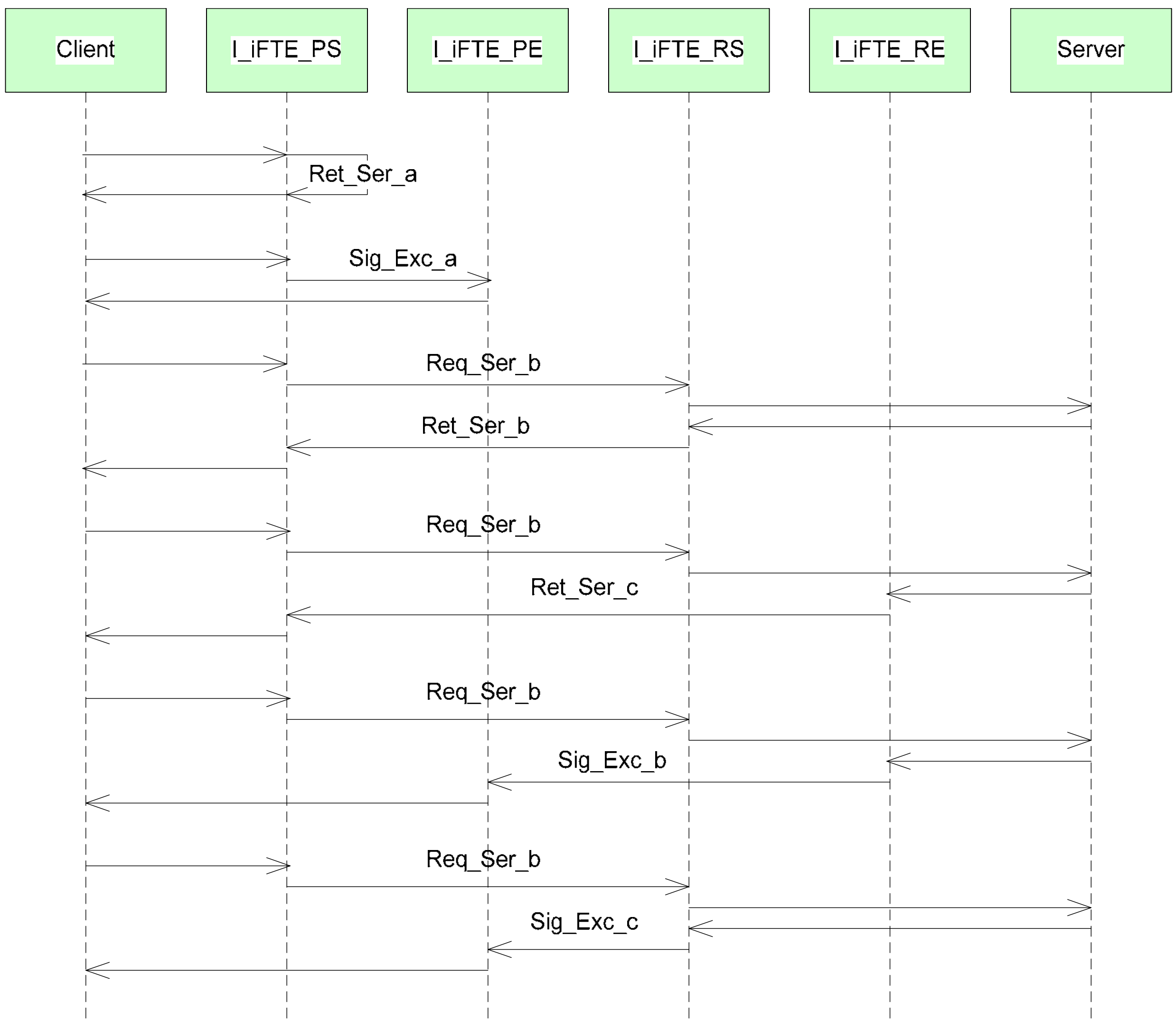
iFTE: Architectural Abstraction

- Idealised fault tolerant architectural element (iFTE)




```
system ifte_abstraction
  features
    I_iFTE_PS_i: in event data port  Service;
    I_iFTE_PS_o: out event data port  Service;
    I_iFTE_PE_o: out event data port  Exception;
    I_iFTE_RS_i: in event data port  Service;
    I_iFTE_RS_o: out event data port  Service;
    I_iFTE_RE_i: in event data port  Exception;
  flows
    Ret_Ser_a: flow path I_iFTE_PS_i -> I_iFTE_PS_o;
    Sig_Exc_a: flow path I_iFTE_PS_i -> I_iFTE_PE_o;
    Req_Ser_b: flow path I_iFTE_PS_i -> I_iFTE_RS_o;
    Ret_Ser_b: flow path I_iFTE_RS_i -> I_iFTE_PS_o;
    Sig_Exc_b: flow path I_iFTE_RS_i -> I_iFTE_PE_o;
    Ret_Ser_c: flow path I_iFTE_RE_i -> I_iFTE_PS_o;
    Sig_Exc_c: flow path I_iFTE_RE_i -> I_iFTE_PE_o;
end ifte_abstraction;
```

iFTE: Behavioural Scenarios

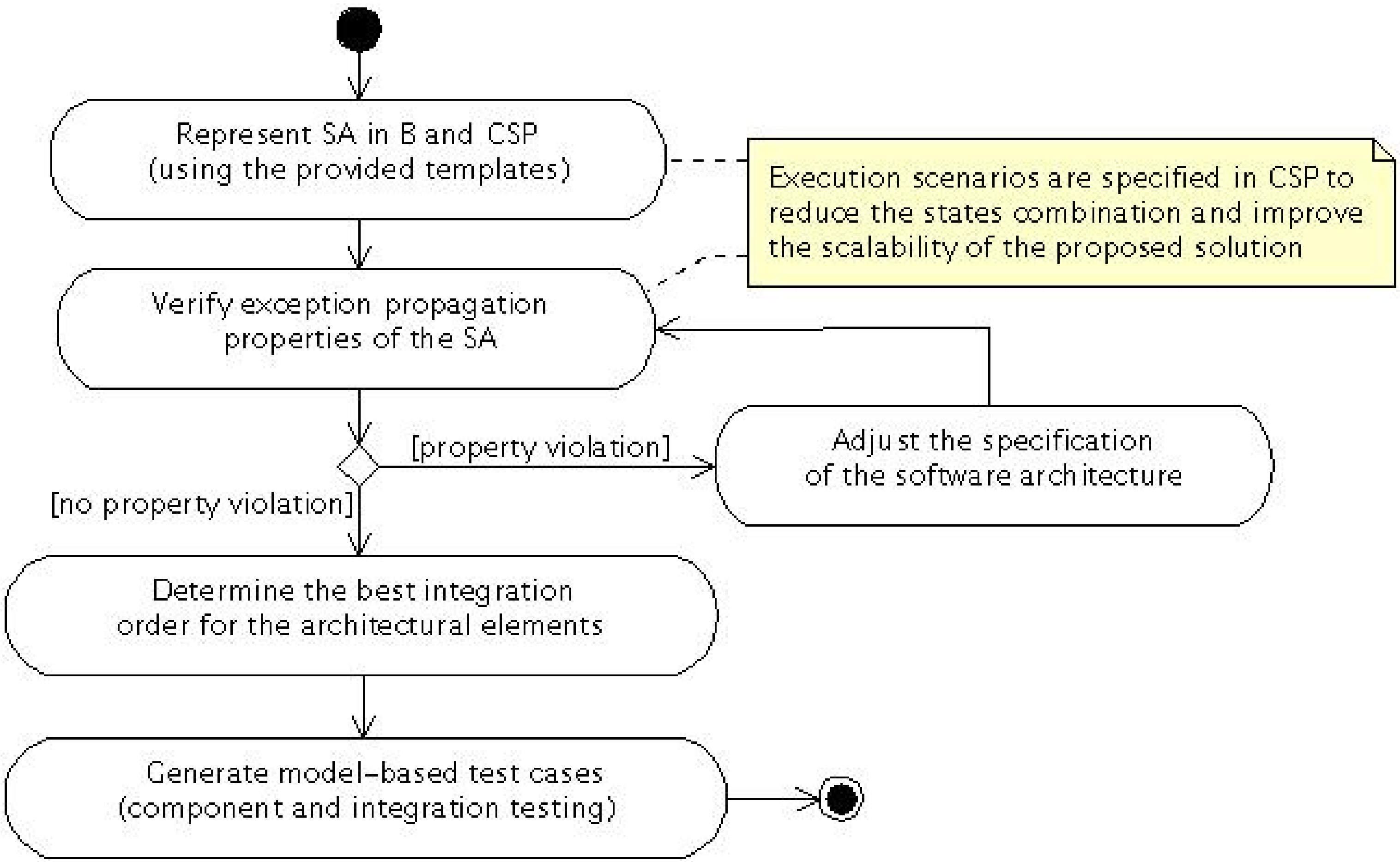


A Rigorous Development Approach

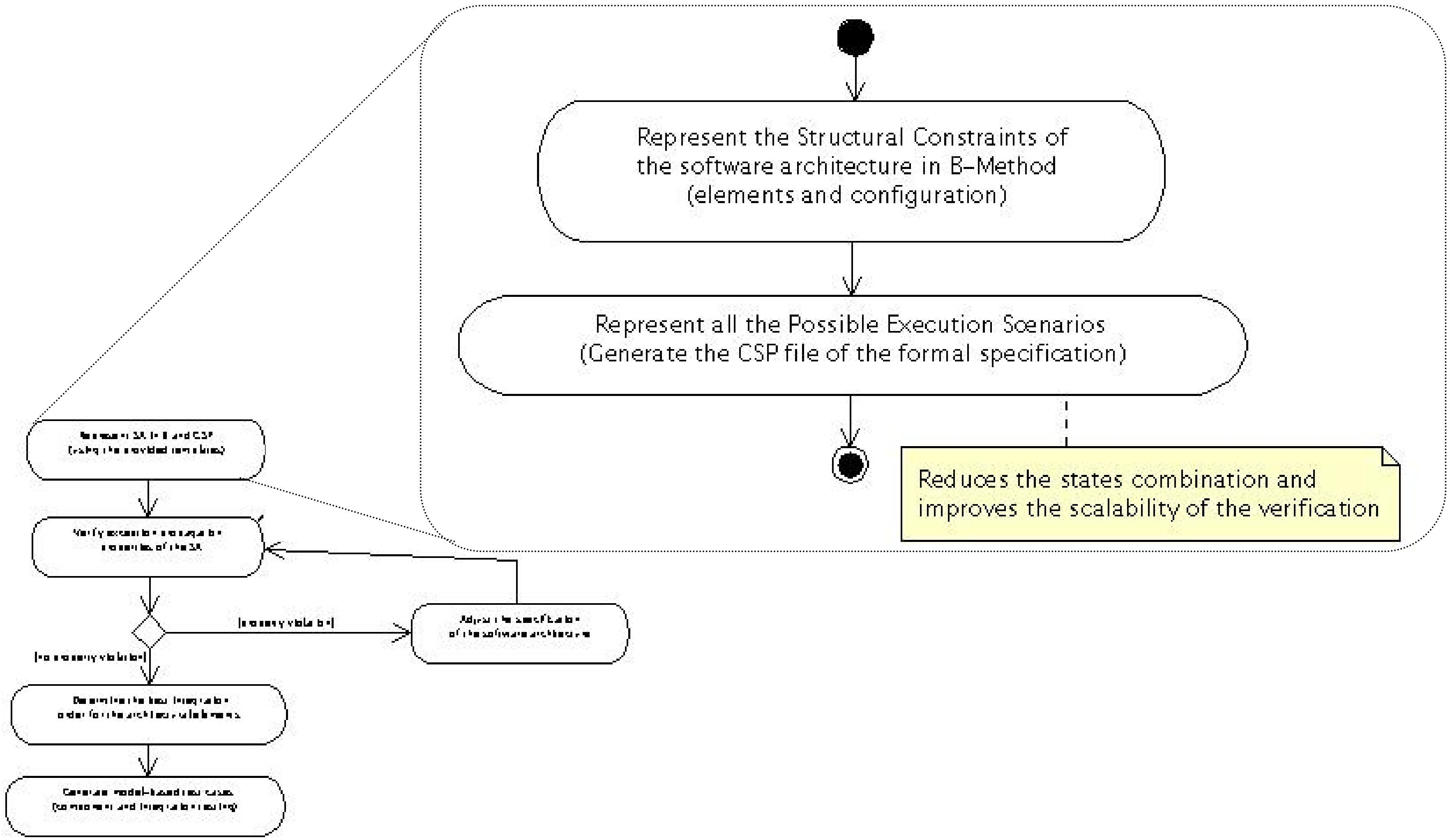
The main objectives of the approach

- Provide support for analysing exception propagation at the architectural level
- Analyse application-specific details about the exception propagation
- Define a scalable solution with support for automatic verification
- Define an approach for generating testing cases

A Rigorous Development Approach



A Rigorous Development Approach



Architecture Representation

- For each service of an iFTE
  - Provided interfaces
  - Required interfaces
  - Provided exceptions
  - Required exceptions
  - Maskable exceptions
- For the software architecture
  - The architectural configuration

Architecture Representation

B-Method

- Type representation
  - different contexts for each type of exceptions
- Easiness to represent relations between types
  - architectural configuration, exception conversions, etc.

CSP

- Easiness to represent complex ordered events
  - execution scenarios, complex architectural propagation rules

Architecture Verification

The ProB model checker is used to check for both

- Violations of structural (architectural configuration) constraints
- Extended architectural descriptions are used to analyse exception flow properties

Users can specify their own properties for a specific exception handling model

Violations result in error messages and counter-examples

Architecture Verification

Some architectural properties that are verified

- Absence of deadlock
- Explicit declaration of external exceptions (component interfaces)
- All the required exceptions are handled
- Only maskable exceptions can be masked

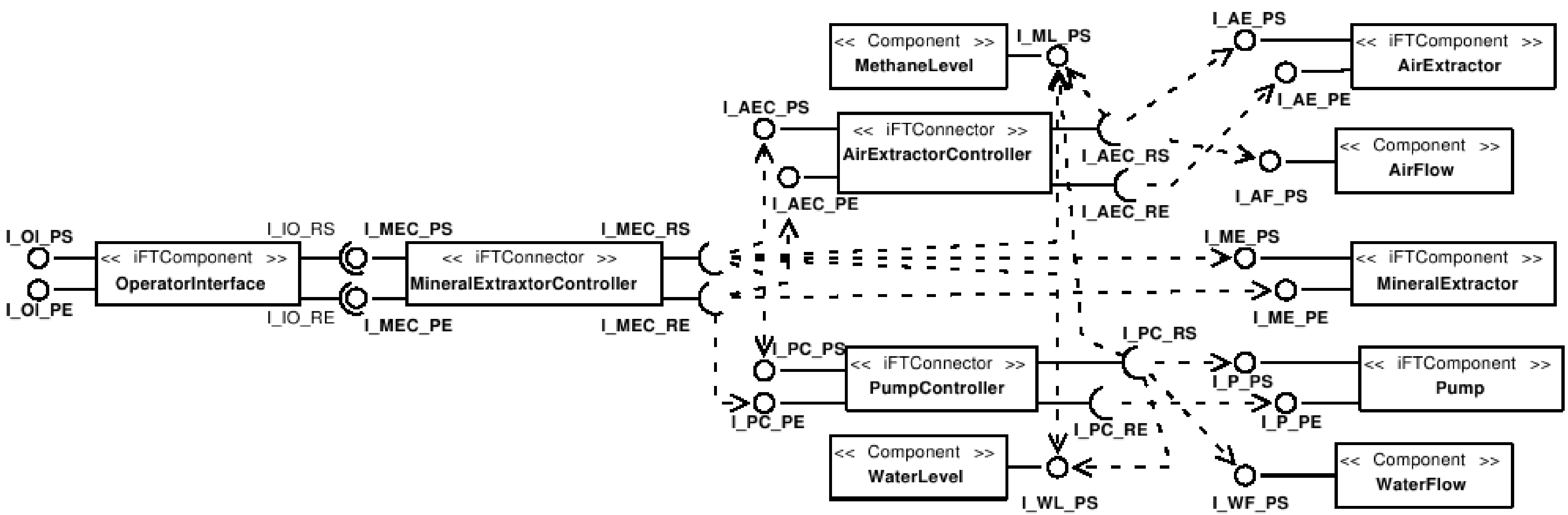
Integration Order

- Integration order tries to minimise dependencies among architectural elements
- Reduce the integration test effort for constructing stubs
- Provides a way for reasoning about the coupling among architectural elements (dependency matrix)

Generation of Test Cases

- The only input is the formal model (B + CSP) of the software architecture
- A graph is created for representing the interaction among architectural elements
- Test cases are identified based on the paths of the interaction graph
- Stubs are specified by analysing the arrows departing from the required interfaces nodes

An Application Example: A Mining Control System



- 7 iFTE architectural elements: 4 comps. and 3 conns.
- 4 non-iFTE architectural components

Architecture Verification

Architecture configuration property

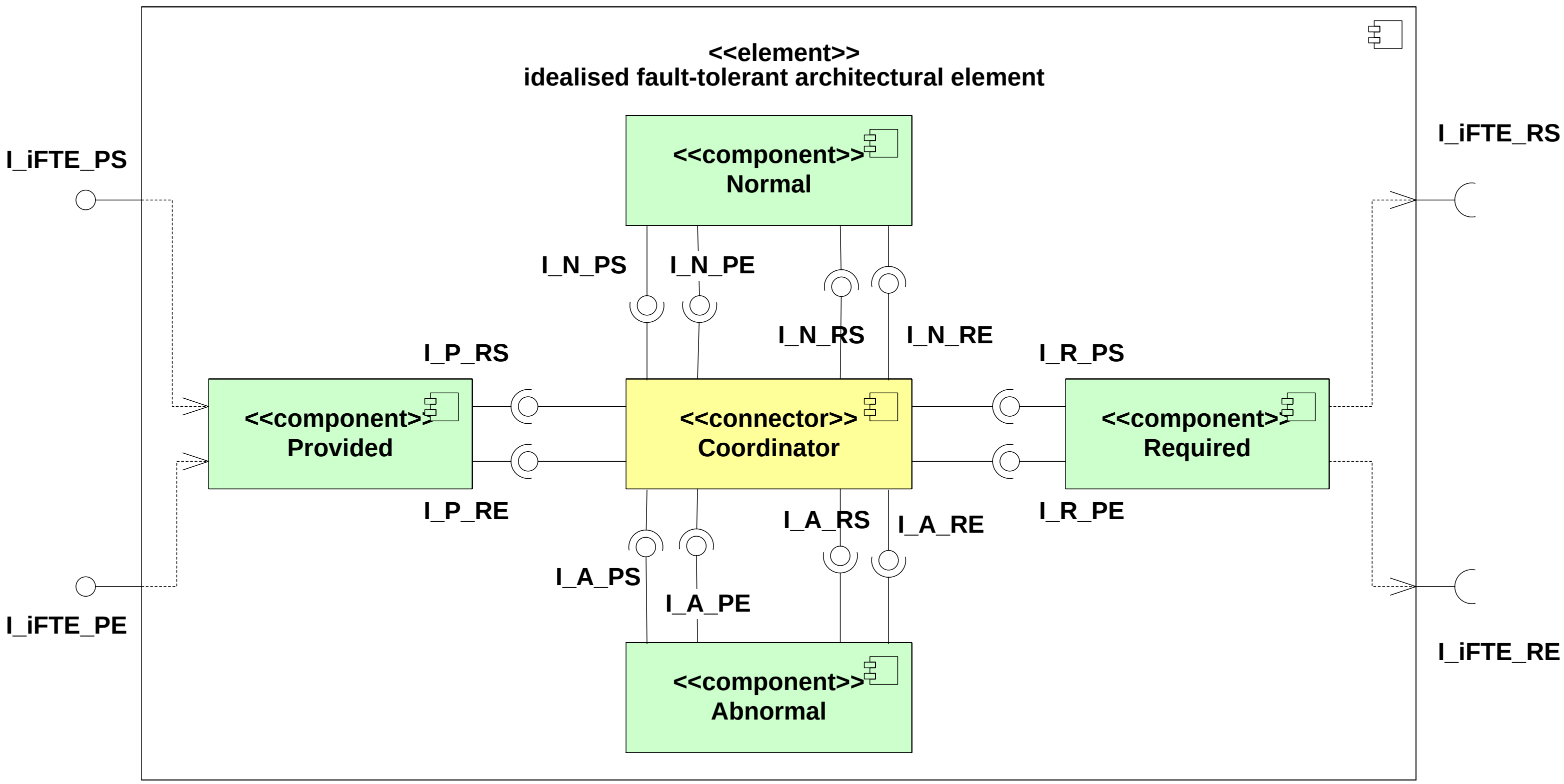
- every required service refers to a valid provided service of another component.

The following goal might never be satisfied:

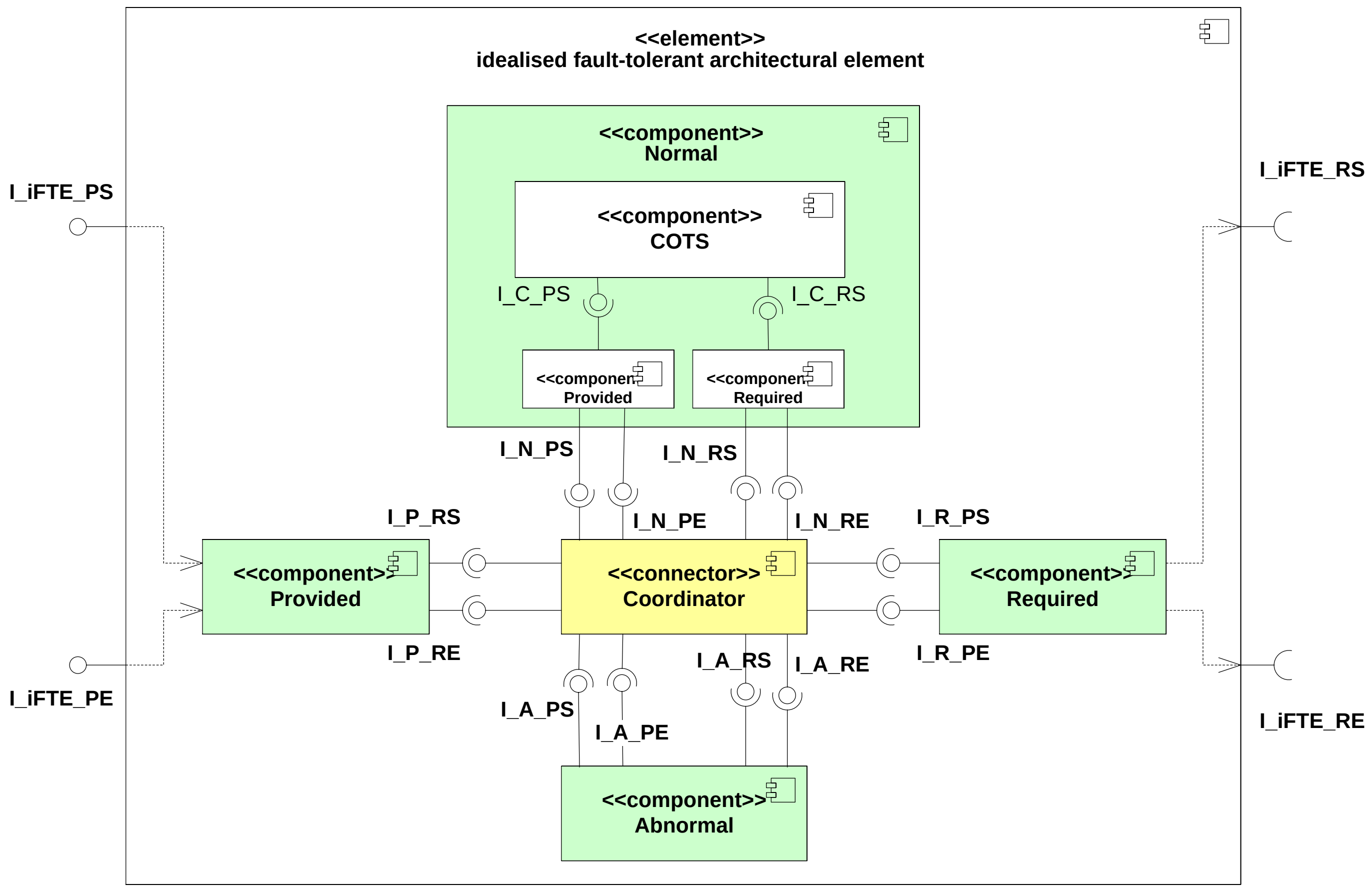
- $\exists$c1, c2 $\in$ **ArchitecturalElements**, t $\in$ **EventType**, s $\in$ **ArchitecturalServices**, e $\in$ **ArchitecturalExceptions** $\bullet$ (c1, c2, t, s, e) $\in$ sequenceHistory $\wedge$ c1 $\neq$ c2 $\wedge$ s $\notin$ providedArchService(c2)

iFTE Detailed Design

The architectural elements of an iFTE follow recursively the iFTE abstraction



iFTE Detailed Design



Conclusions

Fault tolerance at the architectural level

- error handling
  - since iFTE is application dependent, we need to obtain assurances when it is instantiated to a particular application
    - model checking specifications for exception propagation
      - ProB (B Method and CSP)
    - generation of testing cases for integration testing

Future Work

- Adapt the proposed approach to other architectural abstractions using other fault models, e.g., crash failures
- Improve the tool support for:
  - Generating the formal models from a UML component diagram (*UML2Formal*)
  - Additional information about the exceptional behaviour can be represented in XMI through meta tags