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Formal Modelling and Verification of an Asynchronous Extension of SOAP

Maurice ter Beek

FM&&T, ISTI–CNR, Pisa, Italy

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joint work with: Stefania Gnesi and Franco Mazzanti (FM&&T, ISTI–CNR)

Corrado Moiso (Telecom Italia)

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Outline

- Context: EU project Sensoria
- Why extend SOAP to aSOAP?
- Design and implementations of aSOAP
- Model checking with UMC and μ-UCTL
- Conclusions and future work

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Why aSOAP?

Current WS largely use SOAP on top of HTTP:

- blocks Clients between request and response
- request fails if no response within (limited) period of time

Next-generation telecom networks need asynchronous extension of SOAP for asynchronous interactions among distributed WS, to deal with:

- long-running computations
- temporary unavailability of WS consumer or WS provider

⇒ ongoing convergence of telecom & Internet worlds into a single application context requires modern WS to integrate telco features

aSOAP

An approach to handle asynchronous MEPs in the context of WS

Other approaches include ASAP, WSN, WS-Reliable Messaging and WS-Reliability by OASIS and Pubscribe by Apache:

- \+ ASAP can handle long-running computations
- – ASAP results returned as untyped XML “blobs”
- – no direct support for asynchronous two-way MEPs
- – no direct support for temporary Client/Server unavailability
- – all operate on application level

⇒ aSOAP allows asynchronous interaction on protocol level by extending SOAP

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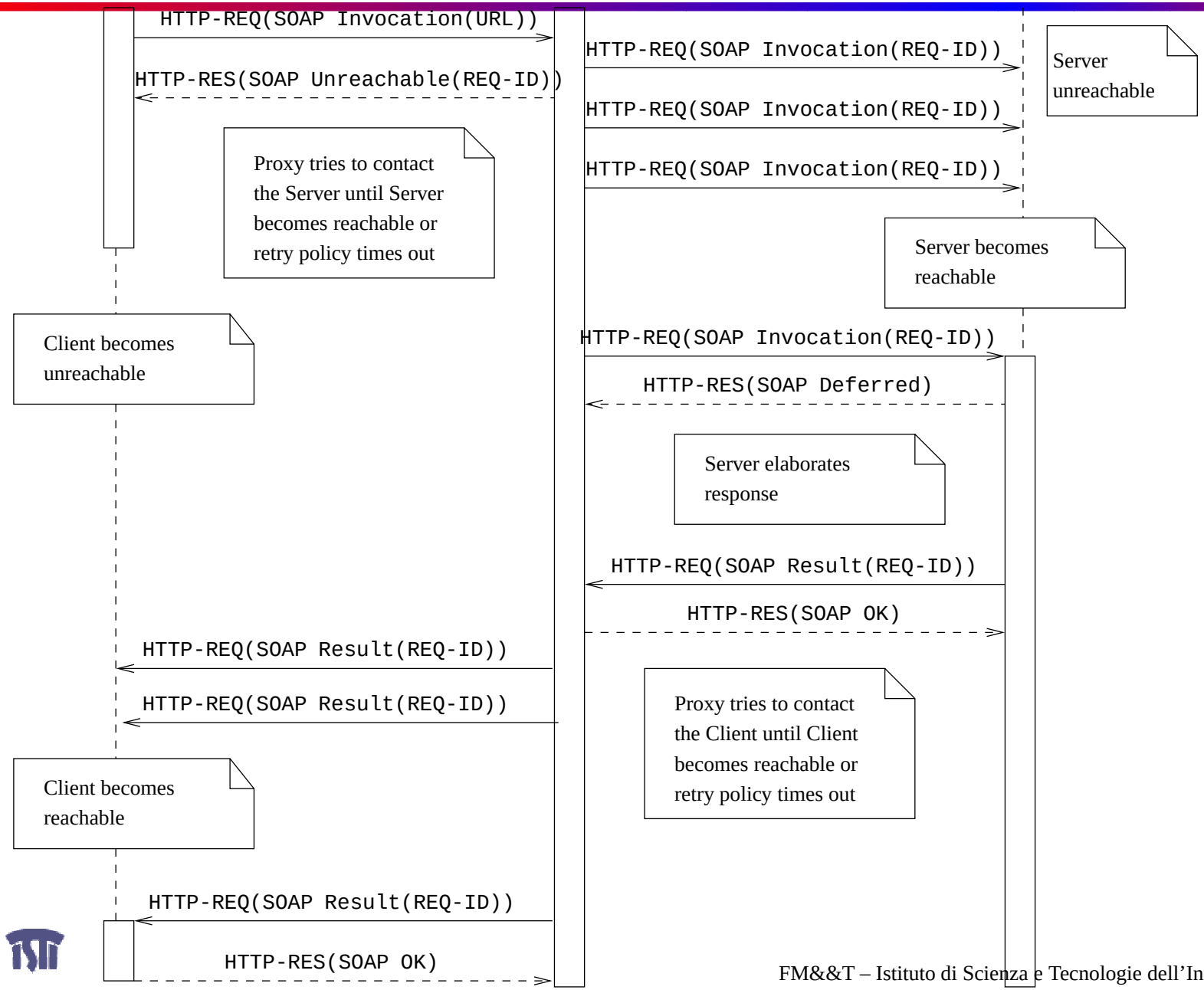
Assumptions

- Proxy is always reachable by both Client and Server whenever they have an active connection
- If Client is willing to accept an asynchronous response to SOAP `Invocation`, then it inserts the URL of the SOAP listener where it wants to receive the response in the SOAP header
- The URL in the header of SOAP `Invocation(URL)` is the address of a generic SOAP listener; the application level has a mechanism to receive SOAP messages at this URL
- Upon receiving an asynchronous SOAP `Invocation(URL)` from Client, Proxy generates `REQ-ID` to uniquely identify Client's SOAP `Invocation` in further communications

aSOAP scenario



Design and implementation

aSOAP is designed to have minimal impact on existing architectures:

- preserves backward compatibility with SOAP
- Client without asynchronous invocations need not be modified
- concentrates overhead resulting from extension in Proxy

aSOAP can be implemented by using SOAP v1.2:

- permits addition of SOAP headers (URL) to SOAP messages
- aSOAP headers can thus be SOAP v1.2 headers
- Proxy can be intermediary node processing aSOAP headers

Before implementation

We present a first step in the development of aSOAP:

- use formal methods to analyse an initial formalisation
- use conclusions to eventually arrive at a formal proposal

Methodology:

- specify aSOAP as a set of communicating UML state machines
- resulting semantics are doubly-labelled transition systems
- express behavioural properties in the action- and state-based temporal logic μ-UCTL
- verify with on-the-fly model checker UMC (developed by FM&&T, ISTI–CNR)

Model checking

Automatic technique to verify whether a (concurrent) system design satisfies its specifications

Very hard in standard ways (like testing) due to non-determinism and interleaving

+ exhaustive verification: takes into account all possible input combinations and states
– state-space explosion: risk of running out of memory

⇒ use a simplified model, still capturing core of system design, while abstracting from unnecessary details

Modelling choices

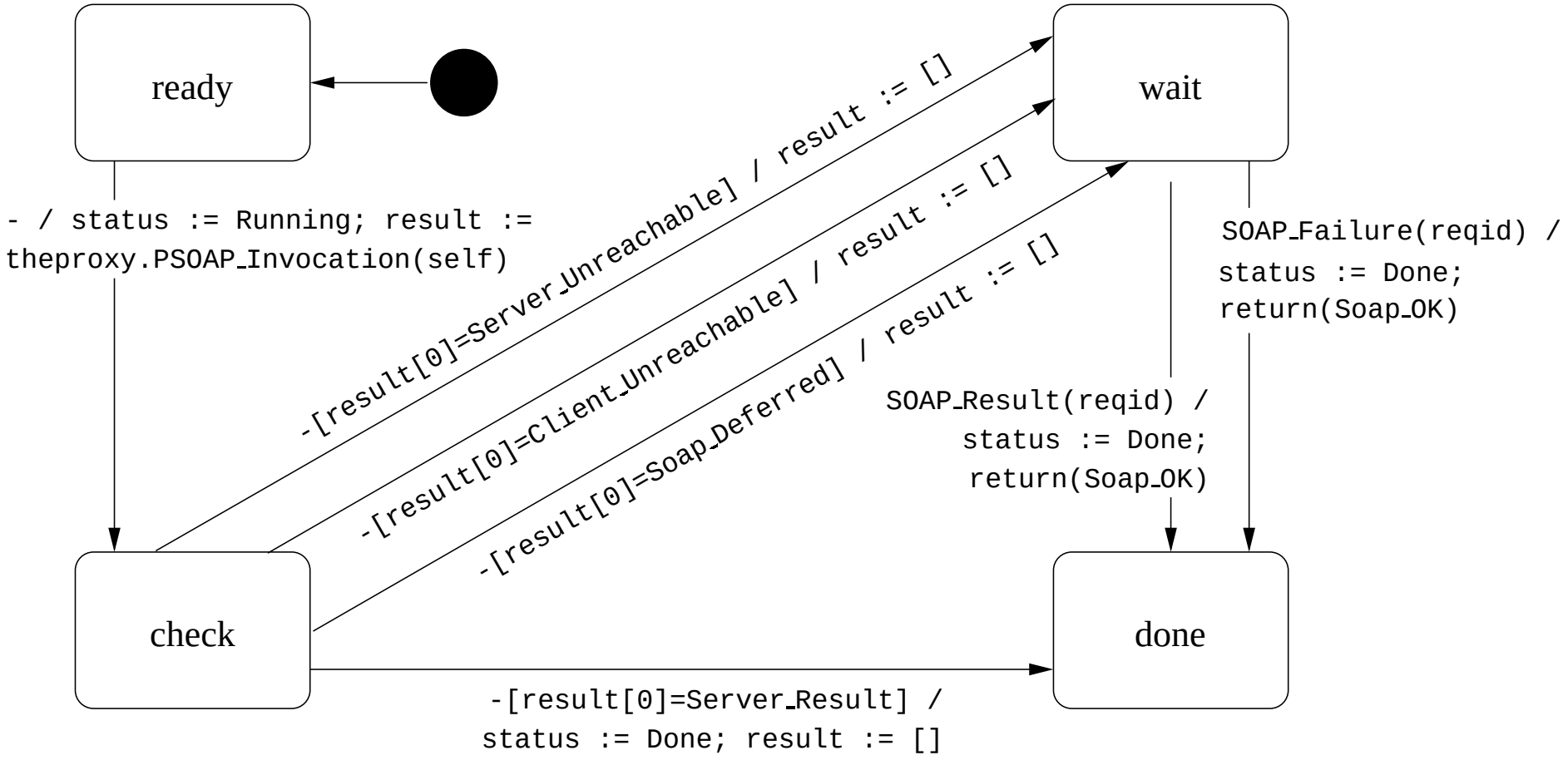
- Only asynchronous SOAP invocations: no backward compatibility
- URL in header of SOAP message is identified with Client: each Client is just a listener of asynchronous SOAP invocations
- System model: 1 Server (+ subthreads), 1 Proxy (+ subthreads) and fixed (configurable) # Clients
- Proxy and Server may activate at most a fixed (configurable) # parallel subthreads
- Client or Server unreachable: Proxy attempts to contact them at most a fixed (configurable) # times
- Client issues a single SOAP invocation and then terminates

$\Rightarrow$ Future work: Client performs loop of SOAP invocations or issues several SOAP invocations before waiting for deferred SOAP results

Excerpt from Client specification

```
Class Client is
Operations:
 SOAP_Result(requid:Tokens):Tokens; SOAP_Failure(requid:Tokens):Tokens;
Vars:
 status: Tokens := Inactive; theproxy: Proxy; result: Tokens[] := [];
State top = ready, check, wait, done
Transitions:
 ready -> check // Proxy always reachable
 { - / status := Running; result := theproxy.PSOAP_Invocation(self) }
 check -> wait // Server initially unreachable
 { -[result[0]=Server_Unreachable] / result := []; } // await results
 check -> wait // Connection with Proxy lost
 { -[result[0]=Client_Unreachable] / result := []; } // await results
 check -> done // Immediate result from Server
 { -[result[0]=Soap_Result] / status := Done; result := []; }
 wait -> done // Issued invocation to Proxy
 { SOAP_Result(requid) / status := Done; // await results from Proxy to
   return Soap_OK; }                     // complete listener execution
 ...
end Client;
```

Statechart specification of Client



State-space complexity

Clients	attempts	P subthreads	S subthreads	states
1	1	1	1	151
1	2	1	1	319
1	1	2	1	151
1	2	2	1	319
1	1	2	2	151
1	2	2	2	319
2	1	1	1	3701
2	2	1	1	8321
2	1	2	1	23953
2	2	2	1	97699
2	1	2	2	87569
2	2	2	2	393907
3	1	1	1	67099
3	2	1	1	151414
...	...	...	...	$>$ 500000

Initial UMC verifications

Property: *all system executions eventually reach a configuration in which all Clients are in status* `Done`

In μ-UCTL:

```
AF ((C1.status=Done) and (C2.status=Done))
```

$\Rightarrow$ False: Server's response need not reach Client

Not surprising, possible scenario: Client's SOAP invocation is deferred by Server, but its subsequent final SOAP result never reaches Client (because Client is unreachable for a sufficiently long time for Proxy to cancel the SOAP invocation)

Client and Server always reachable?

Property: *for all paths without communication failures the system will eventually reach a configuration in which all Clients are in status* `Done`

In μ-UCTL's minimal fixed point structure:

```
min Z :
 ( ((C1.status=Done) and (C2.status=Done))
 or((PT1.result=Client_Unreachable)
   or (PT1.result=Server_Unreachable)
   or (PT2.result=Client_Unreachable)
   or (PT2.result=Server_Unreachable))
 or(not FINAL and [true] Z) )
```

$\Rightarrow$ True: UMC analysed 34735 states

Unexpected result

Property: *if Client receives* `SOAP_Result(ReqId)` *operation call, then it received* `[Soap_Deferred,ReqId]` *response to its previous* `SOAP_Invocation`

In μ-UCTL:

```
AG [C1.SOAP_Result(*,ReqId)]
                    (C1.result=[Soap_Deferred,ReqId])
```

$\Rightarrow$ Formula should obviously be false, but unfortunately it is true

Possible reason: Proxy finds Client unreachable and is unable to notify Client of deferred Server response + `REQ-ID` (this of course does not prevent request to proceed as usual, until eventually the deferred result is produced by Server, but `REQ-ID` will mean nothing to Client)

$\Rightarrow$ Future work: gravity of this particularity and a way to avoid it

Conclusions and future work

- Ongoing work: applying academic experience with formal modelling and verification to an industrial case study
- ISTI–CNR & Telecom Italia: partners in EU project Sensoria on Software Engineering for Service-Oriented Overlay Computers
- Goal: use formal methods in design phase of aSOAP to arrive at a formal proposal of which we can guarantee certain properties
- Future work: use UMC for quite bigger specifications and more intriguing properties