Ensuring Faultless Communication Behaviour in an E-Commerce Cloud Application

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Abstract. The scale and complexity of Web Services raises the challenge of controlling their interaction. The goal of this work is to ensure that processes in a Cloud are correctly interacting according to a specification of their communication behaviour. To accomplish this goal, we employ session types to analyse the global and local communication patterns. Session types represents "formal blueprints" of how communicating participants should behave and offers a concise view of the message flows.

This work confirms the feasibility of application of session types on business protocols used by an e-commerce Cloud provider and developed in Session-Java, an extension of Java implementing Session-Based programming. Furthermore, we highlight the importance of this approach for services replicated across multiple Cloud providers each of which must correctly cooperate.

1 Introduction

The need for distributed highly available services presents challenges for application development. It is necessary for applications to be integrated both within an enterprise, and between businesses. Service-Oriented Architectures (SOA) are widely accepted as a paradigm for integrating software applications within and across organizational boundaries. In this paradigm, independently deployed applications are exposed as Web Services which are then interconnected using a stack of standards.

It is challenging to managing service interactions that go beyond simple sequences of requests and responses or involve large numbers of participants (multi-party communication). One technique for describing collaboration between a collection of services is a choreography. Choreographies capture a global view of the interactions between participating services. However, a choreography does not specify how a global description can be executed.

The challenge of controlling interactions of participants motivated the design of Web Services Choreography Description Language (WS-CDL) [9]. The WS-CDL working group identified critical issues [3] including:

1. the need for tools to validate conformance to choreography specifications to ensure correct cooperation between Web Services;
2. design time validation and verification of choreographies to guarantee correctness of such properties like deadlock, livelock e.g. behaviour of participants conforms to the choreography interface.

The aforementioned challenges can be tackled by adopting a solid foundational model. Successful approaches based on session types [9,8] include: the Chor and Jolie programming languages of Carbone and Montesi [16,10] based on sessions and trace sets [19]; Session-Java [15], Scribble [14] and Session C [17] due to Honda and Yoshida; Sing# [4] that extends Spec# with choreogrphies; and UBF(B) [2] for Erlang.

In this paper, we present a case study where processes interactions are controlled using Sessions Types. The theory of Session Types ensures communication safety by verifying that session implementations of each engaged participant conform to the defined protocol specification. In our case study, we use Session-Java, an extension to Java language supporting session, to specify protocols used by a Cloud provider that involve iteration and higher order communication.

In Section 2 we provide an overview of SJ. In Section 3, we explain a refinements a protocols used by a Cloud provider, implemented using SJ. Finally, in Section 4, we highlight how session types can improve the design of inter-Cloud protocols.

2 Basics of Session-Java

We briefly outline how Session-Java is employed to correctly implement protocols. Firstly, the global protocol is specified using sequence diagrams. The global specification is projected to sessions types, which specify the protocol for each participant. The session is then implemented using operations on session sockets. Finally, the correctness of the protocol can be verified using session types.

L_1, L_2	tag	$T ::= T\,.\,T$	Sequencing
		$\mid$ `begin`	Session initiation
p	protocol name	$\mid\ !\langle M\rangle$	Message send
		$\mid\ ?(M)$	Message receive
$M ::= \mathit{Datatype} \mid T$	message	$\mid \{L_1 : T_1, \ldots, L_n : T_n\}$	Session branching
$S ::= p\,\{T\}$	session	$\mid [T]*$	Session iteration
		$\mid \mathtt{rec}\, L\, [T]$	Session recursion scope
		$\mid \#L$	Recursive jump
		$\mid @p$	Protocol reference

Fig. 1: SJ protocol specification using Session Types (T).

2.1 Protocol Specification

The body of a protocol defines a *session type*, according to the grammar in Figure 1. The session type specifies the actions that the participant in a session should perform. In SJ, the behaviour of an implementation of a session is monitored by the associated protocol, as enforced by the SJ compiler. The constructs in Figure 1 can describe a diverse range of complex interactions, including message passing, branching and iteration. Each session type construct has its dual construct, because a typical requirement is that two parties implement compatible protocols such that the specification of one party is dual to another party.

Higher Order Communication. SJ allows message types to themselves be session types. This is called higher-order communication and is supported by using subtyping [21]. Consider the dual constructs $!\langle ?(\text{int})\rangle$ and $?(?(\text{int}))$. These types specify sessions that expects to respectively send and receive a session of type $?(\text{int})$. Higher order communication is often referred to a session delegation. Figure 2 shows a basic delegation scenario.

In Figure 2, the left diagram represents the session configuration before the delegation is performed: the user is engaged in a session s of type $!\langle\text{int}\rangle$ with the Cloud, while the Cloud is also involved in a session s' with SaaS of type $!\langle ?(\text{int})\rangle$. So, instead of accepting the integer from the user, Cloud delegates his role in s to SaaS. The diagram on the right of Figure 2 represents the session configuration after the delegation has been performed: the user now directly interact with SaaS for the session s. The delegation action corresponds to a higher-order send type for the session s' between Cloud and SaaS.

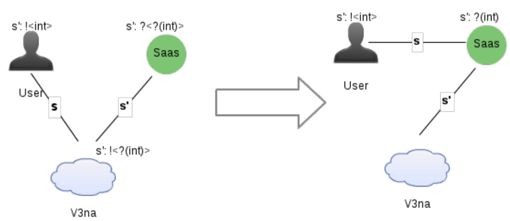

Fig. 2: Session delegation

Protocol Implementation using Session-Java. Session sockets represent the participants of a session connection. Each sockets implement the session code according to the specified session type. In SJ session sockets extend the abstract *SJSocket* class. The session is implemented within a session-try scope using specific session operations.

3 Case Study: Protocols for a Cloud

Our case study is an e-commerce Web portal called V3na that sells SaaS applications for business needs V3na[1] was developed in the Django framework — a high-level Web framework for Python. The persistence layer is based on MongoDB and Memcached.

[1] http://v3na.com. Cloud platform for optimizing your business performance. Source code available at https://github.com/Rustem/Master-thesis.

A major challenge was to automate the process of SaaS integration. In particular, V3na implements the following problems that can be addresses using sessions types:

- A SaaS user can connect to SaaS for trial period by simply clicking on the button;
- V3na provides one entry point to all of the user's applications.
- A subscription may be extended or frozen;
- The payment for use of a service can be confirmed confirmation;

In this section, we illustrate two refinement of the first scenario above.

3.1 A Simple Scenario with Branching

To begin, we specify a simple business protocol for SaaS connection. The protocol is informally specified as follows:

1. User begins a request session s with Cloud service (V3na) and sends the request "Connect SaaS" as JSON-encoded message.
2. V3na sends either:
   (a) FAIL, if user has no active session (not signed in on V3na).
   (b) OK, if user has logged in and request data has passed validation steps.
3. If OK is sent, the Cloud initiates a new session s' with SaaS and requests it for new user connection with message details in a JSON message.
4. Finally, the SaaS responds to the Cloud with connection status OK or FAIL and V3na sends this status to the user. Both sessions are then terminated.

Protocol 1.1: User

```
protocol p_uv {
  begin.
  !<JSONMsg>.
  ?{
    OK: ?(JSONMsg).?(int
         ),
    FAIL:
  }
}
```

Protocol 1.2: Cloud

```
p_vu {
  begin.?(JSONMsg).!{
    OK: !<JSONMsg>.!<int>,
    FAIL:
  }
protocol http_req_rep {
  !<JSONMsg>.
  ? (JSONMsg)
}
protocol p_vs {
  begin.@http_req_rep
}
```

Protocol 1.3: SaaS

```
protocol p_sv {
  begin.
  ?(JSONMsg).!<JSONMsg>
}
```

Fig. 3: Protocol specifications for Scenario 1

In Figure 3 we depict the protocol specifications for each participant (Cloud, SaaS or User). The protocols between User and Cloud and Cloud and SaaS are dual, i.e. the specification of interaction from one perspective is opposite from another. We implement this diagram in Session-Java, where the branching is implemented employing the `outbranch` and `inbranch` operations.

3.2 The Scenario extended with Iteration

We now introduce the iteration construct and demonstrate *session delegation*. The informal description of the scenario is as follows:

1. User begins a request session (s) with cloud service (V3na)
2. V3na asks User to login, so User provides V3na with login and password.
3. V3na receives User credentials and verifies them: If User is not authenticated and still has triesgo back to step 2, otherwise continue.
4. If User is not allowed to access V3na, the interaction between User and V3na continues on the DENY-branch, otherwise on the ACCESS-branch.
5. If next branch is ACCESS, User sends his connection request with details to V3na. V3na creates new session with SaaS (s') and delegates the remaining session s with User on the latter and sends last user request details. Session s' is terminated.
6. SaaS continues interaction with User according to session s. By steps of validation-verification, SaaS either responds User to proceed interaction by branch OK or FAIL. In both cases User receives from SaaS directly the reason and status of his request. Eventually, session s is terminated.

Protocol 1.1: User

```
protocol p_uv {
  begin.?[!<String>.!<String> ]*.
  ?{
   ACCESS: !<JSONMsg>.
   ?{
     OK: ?(JSONMsg), FAIL: ?(JSONMsg)
   },
  DENY: ?(String)
  }
}
```

Protocol 1.2: Cloud

```
private protocol p_vu {
  begin.
   ![ ?(String).?(String) // login
        password
     ]*.
  !{
    ACCESS: ?(JSONMsg).
    !{
      OK: !<JSONMsg>, FAIL: !<JSONMsg>
     },
      DENY: !<String>
   }
}
```

Fig. 4: User-Cloud interaction protocol specifications for Scenario 2

The protocol is specified in Figures 4 and 5. The protocol uses iterations specified using $![\ldots]*$ and $?[\ldots]*$ and higher order operations.

For session type $!\langle!\{\mathtt{OK}: !\langle \mathit{JSONMessage}\rangle, \mathtt{FAIL}: !\langle \mathit{JSONMessage}\rangle\}\rangle$, The first ! means that the Cloud is passing the high order message which describes the protocol that Saas should perform with the User. In the Saas-Cloud protocol, the protocol contains higher order messages by first defining them, then including them in the protocol. One protocol can be referenced from another using @ operator.

Interactions. Figure 6 depicts the protocols provided above using a sequence diagram. The language of the artifacts has already presented in the first scenario.

Protocol 1.1: Cloud

```
protocol p_vs {
  begin.
  !< !{
    OK: !<JSONMsg>,
    FAIL: !<JSONMsg>
  } >.!<JSONMsg>
}
```

Protocol 1.2: Cloud

```
protocol p_msg {
  !{
    OK: !<JSONMsg>,
    FAIL: !<JSONMsg>
  }
}

protocol p_sv {
  begin.?(@p_msg).?(JSONMsg)
}
```

Fig. 5: Cloud-SaaS interaction protocol specifications for Scenario 2

Implementation. Delegating the protocol is straightforward. Simply pass the socket to service using $s\_vs.send(user\_vu)$.

To receive a high order message type casting must take place in the case of a protocol, the type of protocol must be explicitly defined, using $v3na\_user\_socket = (@p\_msg)\ v3na\_sv.receive()$, where p_msg is a defined protocol. Thus we explicitly define the protocol to be delegated and then include it in the final protocol.

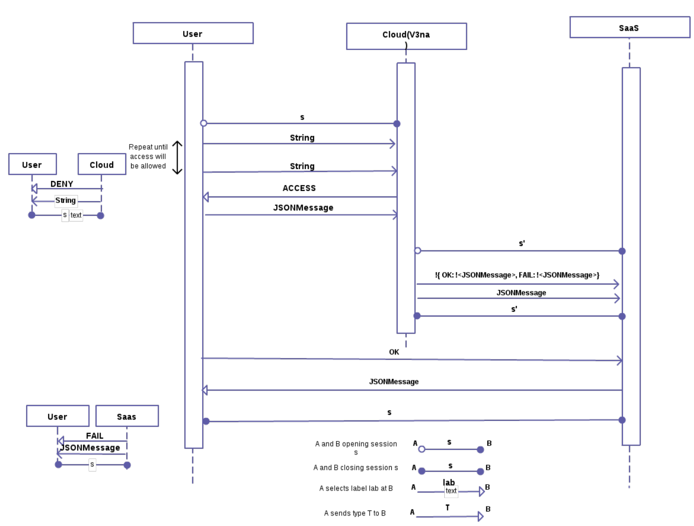

Fig. 6: Sequence diagram of interactions for Scenario # 2

4 Future Work: Inter-Cloud protocols and Session Types

In Cloud Computing there are considerable benefits if Services are hosted on more than one Cloud [1,7,6]. Benefits include geographic replication for highly available robust services, and a greater ability to circumnavigate legal and technical restrictions. Several visions have already proposed for inter-Cloud protocols in papers [20,12,11]. In [20], they emphasised the main components of general inter-networking architecture: (**a**) *Cloud Coordinator*, for bringing out Cloud services; (**b**) *Cloud Broker*, "for mediating between service consumers and Cloud coordinators"; (**c**) *Cloud Exchange* (e.g. Cloud Integrator), for collecting consumers' demands and locating Cloud providers.

We propose to employ multi-party session types [17] for type-safe conversations between Cloud providers and Cloud Integrators (many-to-many conversation). We start by specifying the interactions of an inter-Cloud protocol using a contract checker. We then extend implementations of protocols at the socket layer (e.g. SockJS), so that they check at runtime that each interaction is correct and, as a result, the whole communication is safe. Session types can improve the trust in protocols where each participant is developed and hosted by competing businesses.

5 Conclusion

Session-based programming has already proved itself in various fields, including parallel algorithms [18], event-driven programming [5] and multi-party conversations [13]. In this paper, our case study demonstrates the ability of session types to control interaction patterns between communicating processes in a Cloud. Participants are statically type-checked at compile time and dynamically type-checking at run-time to ensure that protocol are compatible. The highe level of abstraction of session types, implemented in SJ language, enabled effortless translation of business scenarios into protocols. We were able to refine our protocol from Scenario 1 to Scenario 2, due to support of higher-order message passing (session delegation). Further to scenarios presented here our case study covered a scenarios including payment and wallet recharging transactions, where we discovered the benefits of combining session delegation and threading provided by SJ. The session-programming approach is suited to correctly implementing inter-Cloud protocols, which is our future objective.

References

1. Michael Armbrust, Armando Fox, Rean Griffith, Anthony D Joseph, Randy Katz, Andy Konwinski, Gunho Lee, David Patterson, Ariel Rabkin, Ion Stoica, et al. A view of cloud computing. *Communications of the ACM*, 53(4):50–58, 2010.
2. Joe Armstrong. Getting Erlang to talk to the outside world. In *Proceedings of the 2002 ACM SIGPLAN workshop on Erlang*, pages 64–72. ACM, 2002.
3. Alistair Barros, Marlon Dumas, and Phillipa Oaks. A critical overview of the web services choreography description language. *BPTrends Newsletter*, 3:1–24, 2005.
4. Samik Basu, Tevfik Bultan, and Meriem Ouederni. Deciding choreography realizability. *ACM SIGPLAN Notices*, 47(1):191–202, 2012.

5. Andi Bejleri, Raymond Hu, and Nobuko Yoshida. Session-based programming for parallel algorithms. 2010.
6. David Bernstein, Erik Ludvigson, Krishna Sankar, Steve Diamond, and Monique Morrow. Blueprint for the intercloud-protocols and formats for cloud computing interoperability. In *ICIW'09.*, pages 328–336. IEEE, 2009.
7. Rajkumar Buyya, Chee Shin Yeo, Srikumar Venugopal, James Broberg, and Ivona Brandic. Cloud computing and emerging it platforms: Vision, hype, and reality for delivering computing as the 5th utility. *Future Generation computer systems*, 25(6):599–616, 2009.
8. Marco Carbone, Kohei Honda, and Nobuko Yoshida. Structured communication-centred programming for Web services. In *Programming Languages and Systems*, pages 2–17. Springer, 2007.
9. Marco Carbone, Kohei Honda, Nobuko Yoshida, Robin Milner, Gary Brown, and Steve Ross-Talbot. A theoretical basis of communication-centred concurrent programming. WS-CDL working report, W3C, 2006.
10. Marco Carbone and Fabrizio Montesi. Deadlock-freedom-by-design: Multiparty asynchronous global programming. In *Proceedings of the 40th annual ACM SIGPLAN-SIGACT symposium on Principles of programming languages*, pages 263–274. ACM, 2013.
11. E. Cavalcante, F. Lopes, T. Batista, N. Cacho, F.C. Delicato, and P.F. Pires. Cloud integrator: Building value-added services on the Cloud. In *Network Cloud Computing and Applications (NCCA'11)*, pages 135–142, 2011.
12. Vij D. Bernstein. Using xmpp as a transport in intercloud protocols. In *In Proceedings of CloudComp 2010, the 2nd International Conference on Cloud Computing*, pages 973–982. CiteSeer.
13. Michael Emmanuel. Session-based web service programming for business protocols. Available at: http://www.doc.ic.ac.uk/~yoshida/CDL_USECASE/sj/report/report.pdf.
14. Kohei Honda, Aybek Mukhamedov, Gary Brown, Tzu-Chun Chen, and Nobuko Yoshida. Scribbling interactions with a formal foundation. In *Distributed Computing and Internet Technology*, pages 55–75. Springer, 2011.
15. Raymond Hu, Nobuko Yoshida, and Kohei Honda. Session-based distributed programming in java. In *ECOOP 2008*, pages 516–541. Springer, 2008.
16. Fabrizio Montesi and Marco Carbone. Chor — choreography programming language. http://www.chor-lang.org/.
17. Nicholas Ng, Nobuko Yoshida, and Kohei Honda. Multiparty Session C: Safe parallel programming with message optimisation. In *Objects, Models, Components, Patterns*, pages 202–218. Springer, 2012.
18. Nicholas Ng, Nobuko Yoshida, Olivier Pernet, Raymond Hu, and Yiannos Kryftis. Safe parallel programming with Session Java. In *COORDINATION*, pages 110–126, 2011.
19. Zongyan Qiu, Xiangpeng Zhao, Chao Cai, and Hongli Yang. Towards the theoretical foundation of choreography. In *Proceedings of the 16th international conference on World Wide Web*, pages 973–982. ACM, 2007.
20. Rajiv Ranjan Rajkumar Buyya and Rodrigo N. Calheiros. InterCloud: Utility-oriented federation of Cloud Computing environments for scaling of application services. In *Algorithms and architectures for parallel processing*, pages 13–31. Springer, 2010.
21. Malcolm Hole Simon Gay. Subtyping for session types in the pi calculus. *Journal Acta Informatica*, 42(2-3):191–225, 2005.