Defendable Security in Interaction Protocols

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(joint work with Matthijs Melissen and Henning Schnoor)

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Outline

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Introduction

- **Interaction protocols** are ubiquitous in IT systems
- As soon as two machines communicate, a protocol is required
- Goal of a protocol: set of outcomes that are preferred
  Outcomes = runs
- Protocol is correct wrt its goal iff the goal is achieved in all runs where a predefined subset of players follows the protocol

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- Too strong? What if the goal can be violated only by **irrational** actions of “adversaries”?
- Too weak? What if the goal can be achieved only through **irrational** actions of “defenders”?

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- Incentive-based correctness: correct iff the goal holds in all runs that execute **rational** strategies [Dodis and Rabin 2007]
- For this, we need an idea of: incentives of participants, rationality of choices given incentives

  $\rightsquigarrow$ Game-theoretic view

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  $\rightsquigarrow$ Game-theoretic view
- **What if the actual incentives are unknown?**
- Idea: assume that a subset of participants ("defenders") is in favor of the goal
- ...and check if the protocol is correct for every distribution of incentives consistent with the assumption

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Contribution of this paper:

1. We generalize the idea of Dodis and Rabin

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3. ...Plus some theorems :-)

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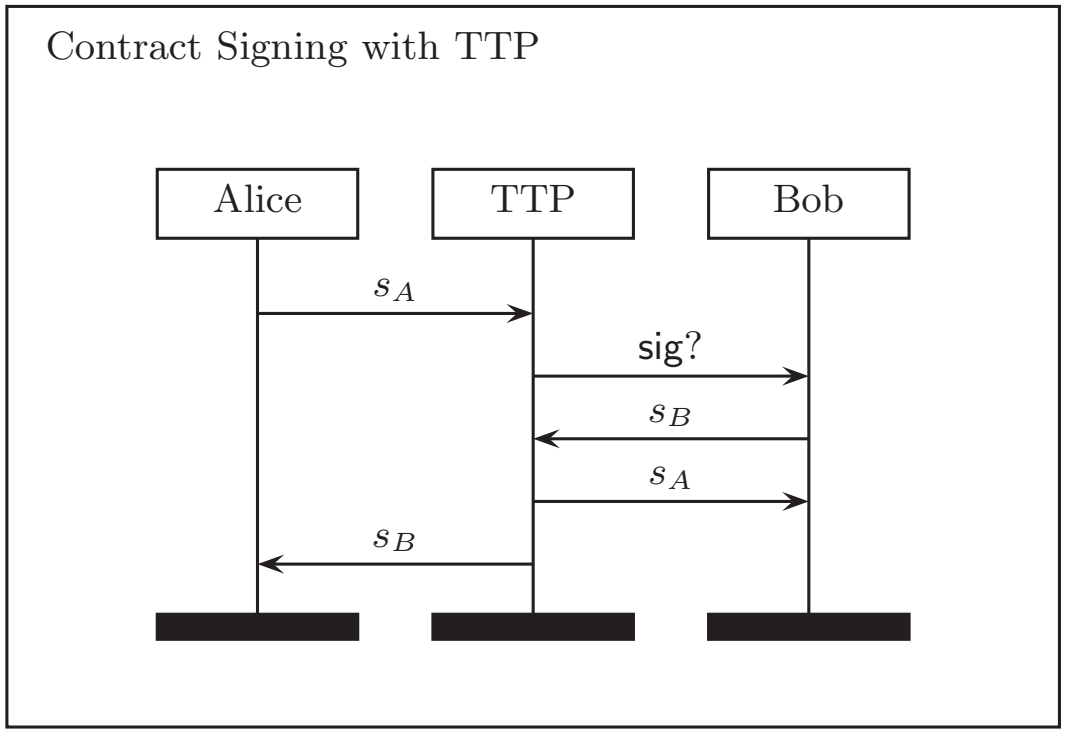
Security Protocols



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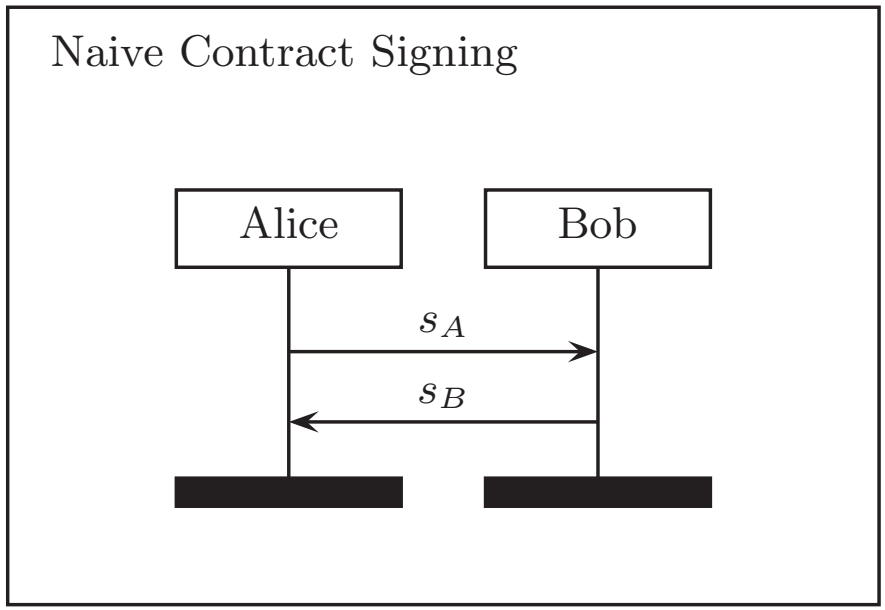
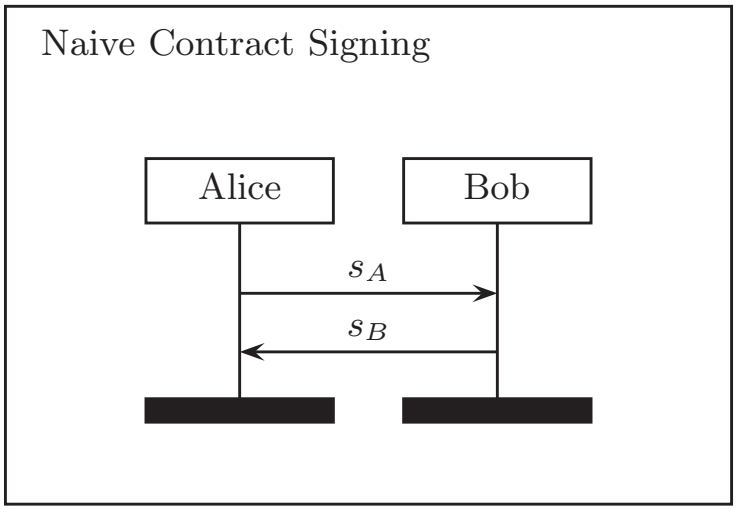


From Protocols to Games



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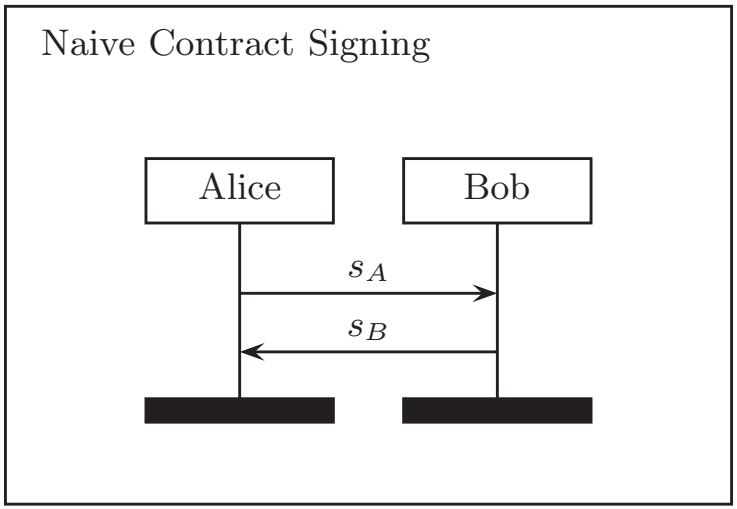

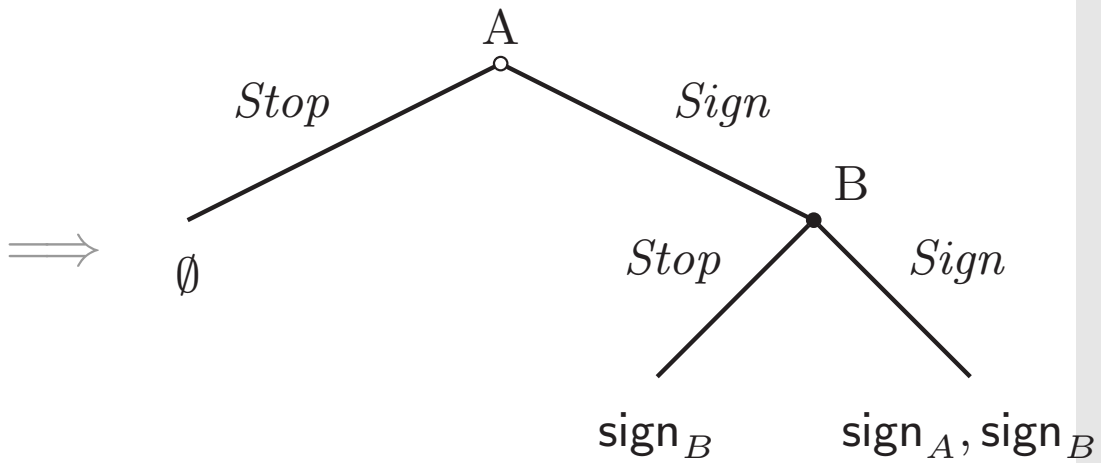

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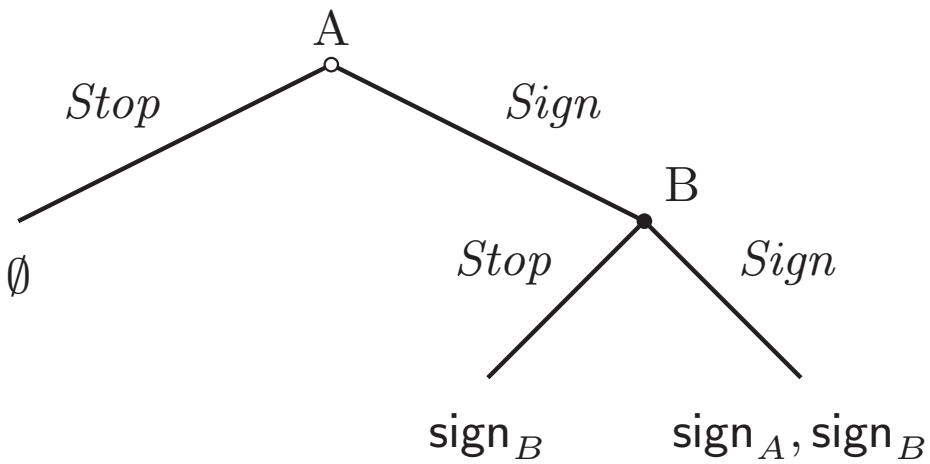

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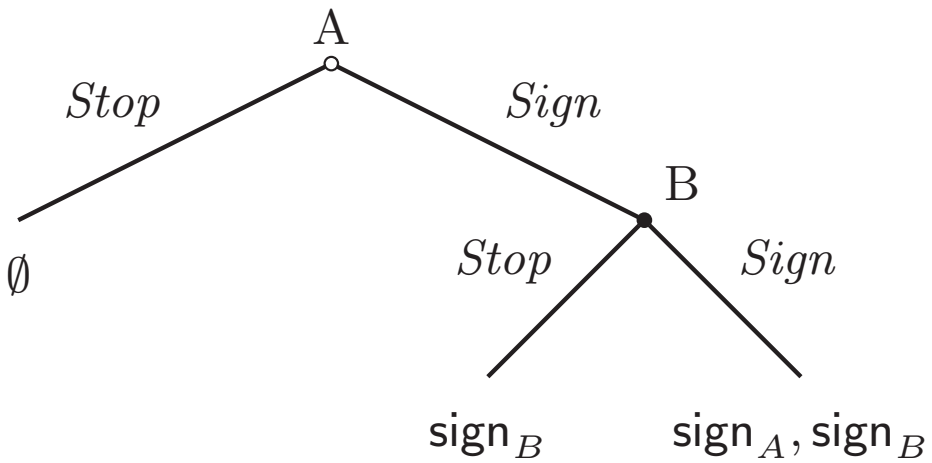

$\Longrightarrow$

$A \backslash B$	$Stop$	$Sign$
$Stop$	$\emptyset$	$\emptyset$
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Protocols as Games

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Incentive-Based Correctness

Definition

A protocol P with utility profile u is **correct** with respect to goal γ under solution concept SC iff:

$$\begin{cases} SC(P,u) \subseteq \gamma & \text{if } SC(P,u) \neq \emptyset \\ \gamma = \textit{all outcomes} & \text{otherwise.} \end{cases}$$

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Definition

A group of agents D **supports** goal γ in game (P, u) iff, for all $i \in D$, if $s \in \gamma$ and $s' \in \overline{\gamma}$ then $u_i(s) > u_i(s')$.

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Protocol P is **defended by agents** D with respect to goal γ and solution concept SC iff (P, u) is correct wrt γ, SC for all utility profiles u such that D support γ in (P, u).

Example: Fairness in Contract Signing

Is fairness defendable by Alice under Nash equilibrium?

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Fairness in contract signing is not defendable by Alice under NE

Example: Fairness in Contract Signing

Is fairness defendable by the grand coalition (Alice and Bob together)?

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Seems like it should be...

Defendability under Nash Equilibrium

Theorem

Let P be a finite protocol, and γ a nontrivial objective in P.

Then, γ **is defendable in P by the grand coalition under Nash equilibrium** *iff*

1. *the deviation closure of γ covers the whole payoff table, and*
2. *there is a strategy profile in γ that belongs to no strategic knots in γ.*

Defendability under Nash Equilibrium

Deviation closure:

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Defendability under Nash Equilibrium

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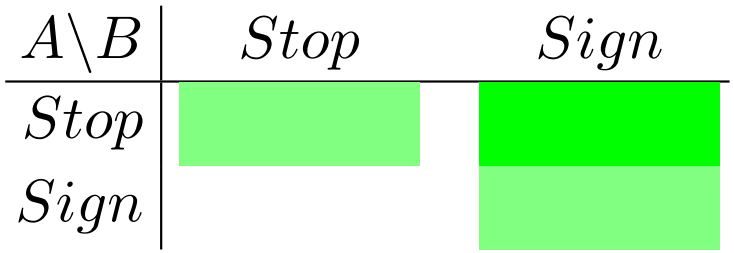

Defendability under Nash Equilibrium

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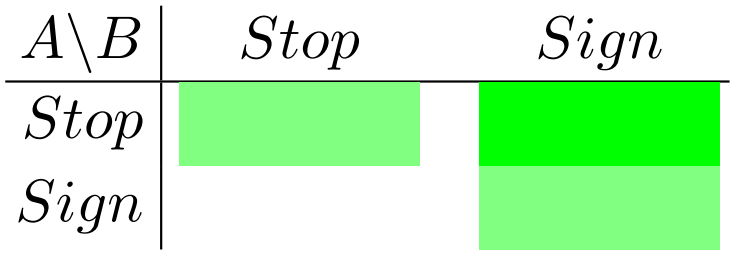
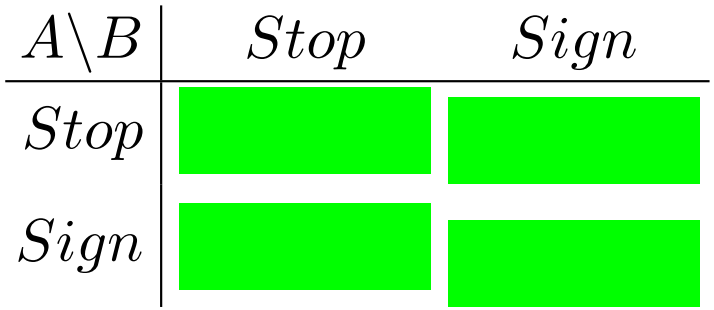


Strategic knot:



Defendability under Nash Equilibrium

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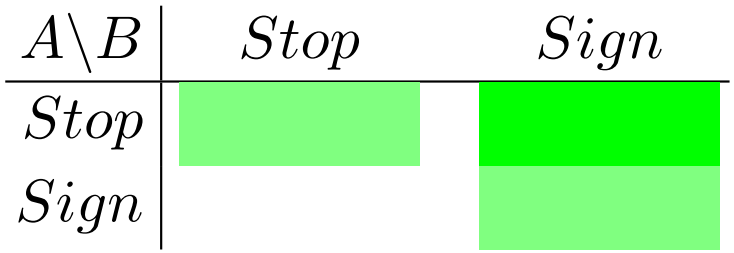

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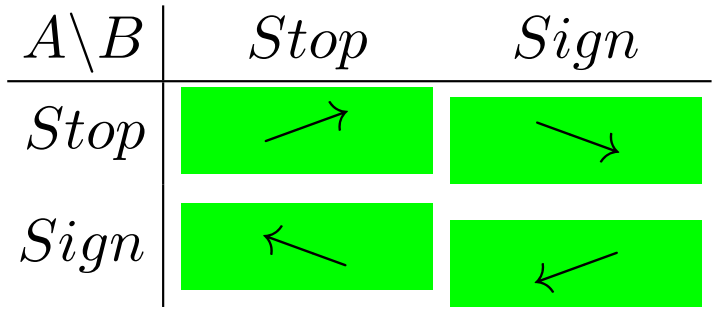

Defendability of Fairness in Contract Signing

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$Sign$		

Fairness in contract signing **is** defendable by Alice and Bob under Nash Equlibrium

Other Results

What else is in the paper:

- Characterization of defendability under Pareto-optimal Nash equilibrium
- Definition and characterization of defendability for mixed strategies
- Characterizations of defendability for non-injective games
- Complexity results for related decision problems
  Complexity between NP/co-NP and PSPACE
  $\rightsquigarrow$ Characterization results decrease the complexity!
- Analysis of the ASW contract signing protocol

Wojciech Jamroga, Matthijs Melissen and Henning Schnoor (2013), *Defendable Security in Interaction Protocols*. Proceedings of the 16th International Conference on Principles and Practice of Multi-Agent Systems (PRIMA 2013). LNCS vol. 8291, Springer.

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Conclusions

- A framework for analyzing interaction protocols, based on incentives and rationality of agents.
- Novel notion of **defendability**: the protocol is correct as long as a given subset of the participants (the "defenders") is in favor of the security property
- Formal results: characterizations of defendability, computational complexity

Thank you for your attention!