Decision-Making in Security Requirements Engineering with Constrained Goal Models

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Introduction

- The continuous growth of modern information systems renders their configuration a challenging process.
  - the number of interconnected goals they expected to satisfy;
  - the complexity of their architectures;
  - cyber-threats they must be able to protect against;
  - continuous changes in their operational environment.

Challenges

- The selection of appropriate **security configurations** taking into account:
  - the continuously evolving *threat landscape*
  - the *effects* of threats towards system goals
  - trade-offs between security and other *functional* and *non-functional* system goals

*"Thus, striking a balance between **effective risk management** and **functional system design** can be a challenging endeavour."*

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Research Approach

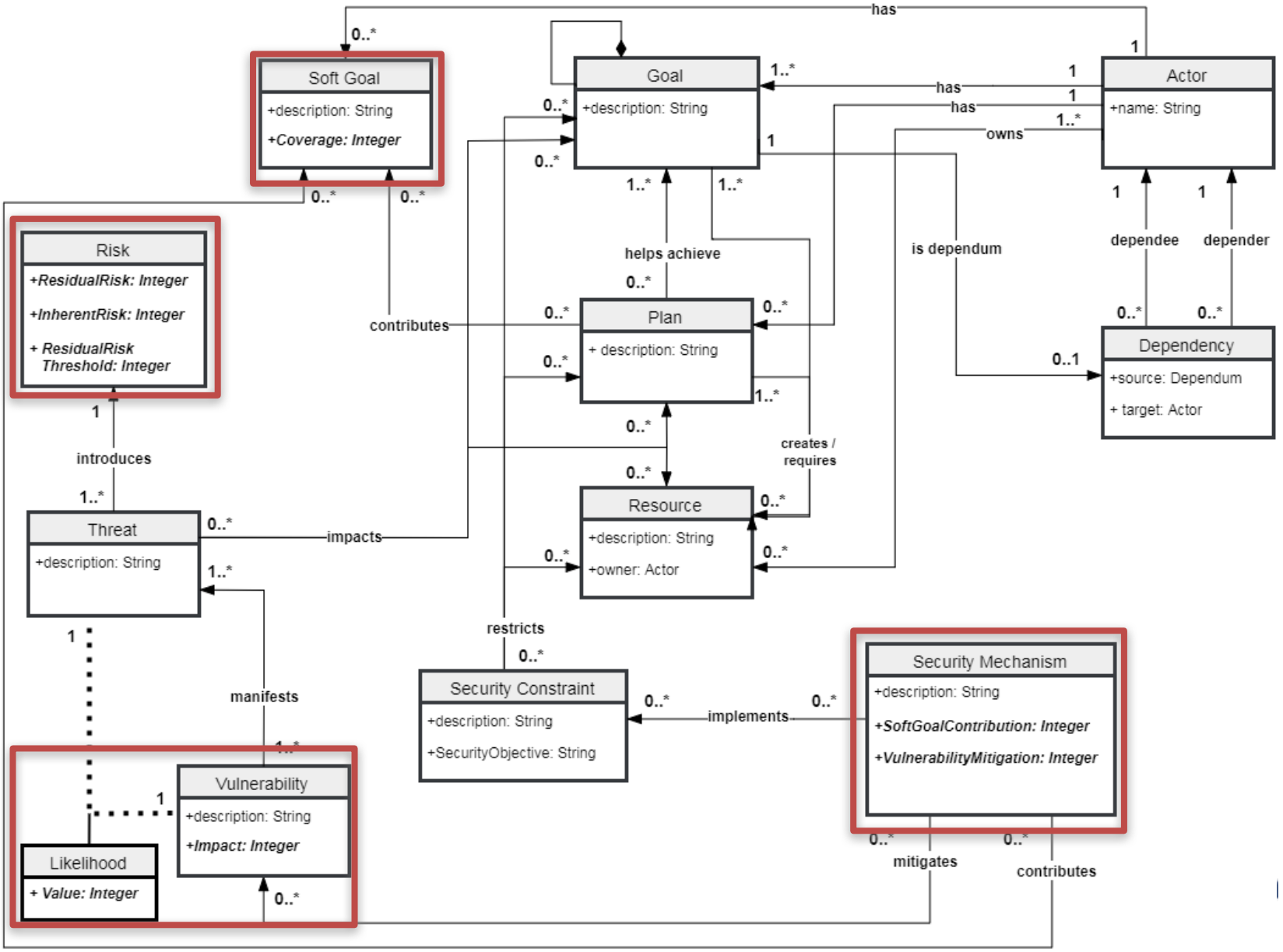
To overcome such challenges this work proposes:

- The extension of **Secure Tropos** in order to support *risk-aware decision-making* for the design of secure system configurations.
- A structured, **quantitative** approach towards the calculation of *risk related aspects* (impact, likelihood, mitigation)
- A framework that selects **optimal security configurations** with respect to the severity of threats and the priorities of other goals using *constraint goal models*.

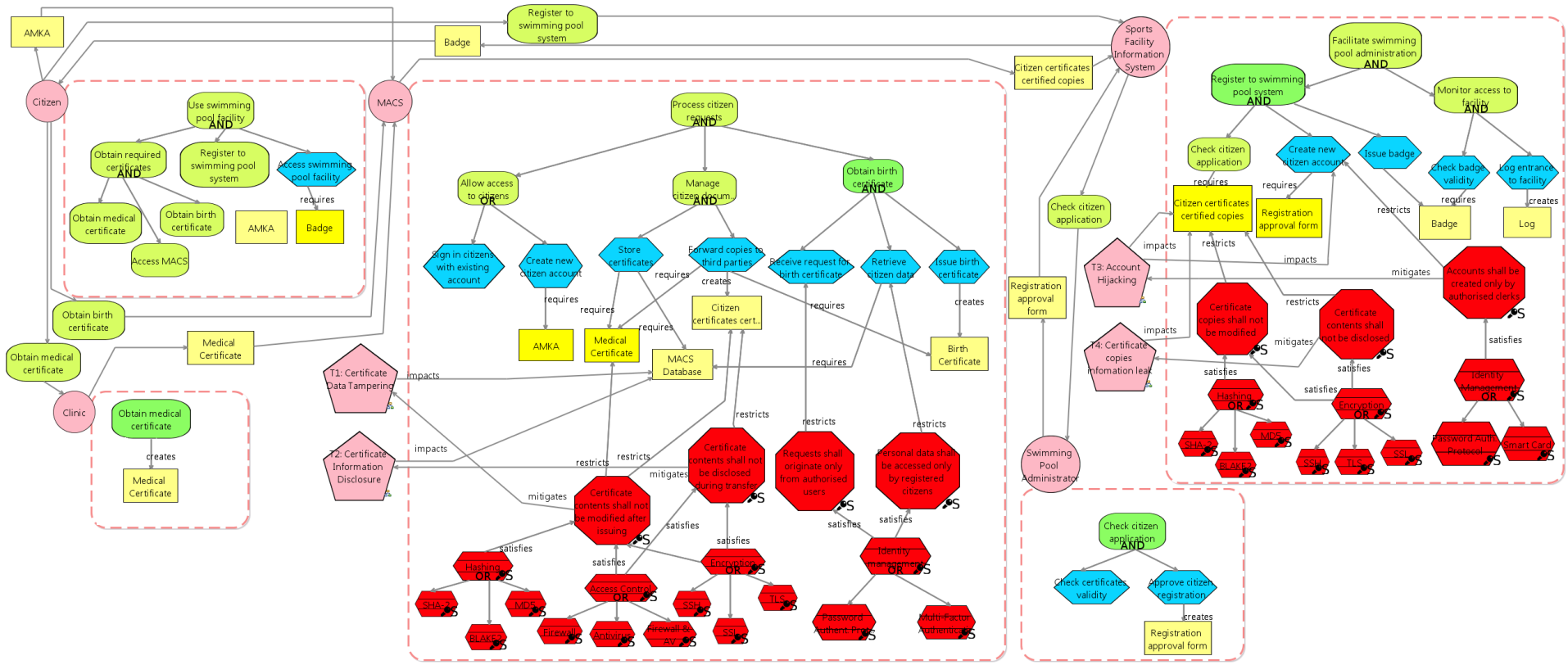
Secure Tropos – Baseline

- A security-oriented extension of Tropos methodology for the elicitation of *security requirements*.
- Standard goal-oriented requirements engineering concepts (e.g., *actors, goals, dependencies*)
- Security related concepts (e.g., *security constraints, threats, security mechanisms*).
- Supports a number of interrelated modelling views
  - *Security Requirements view* captures the goal decomposition of each system actor and the dependencies between them.
  - *Security Attacks view* decomposes each threat to identify its attack methods, the system vulnerabilities they exploit and the coverage provided by the security mechanisms.

Extending Secure Tropos



Security Analysis using Secure Tropos



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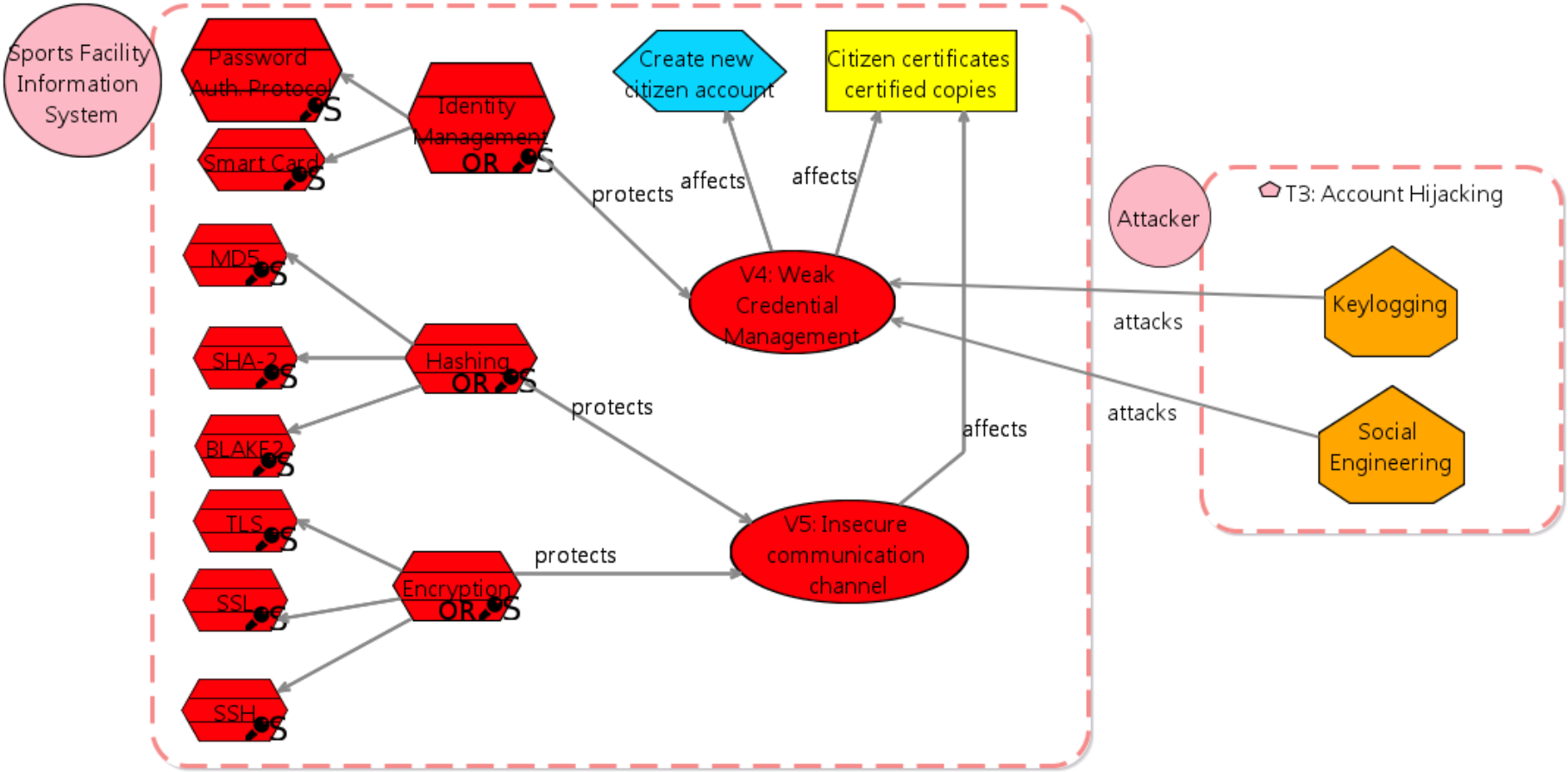
Security Analysis using Secure Tropos



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Risk Assessment 1/2

- **Step 2: Likelihood Estimation**
  - Assign a *Likelihood* value (L) for each threat that affects each vulnerability, using AHP (0≤ L ≤1).
- **Step 3: Impact Estimation**
  - For each vulnerability, estimate an *Impact* value (I) using AHP (0≤ I ≤1).

Therefore, the Inherent (initial) Risk of each Threat

Definit … od of a
vulnera … act, V,
where V … = 1) or
not (V … entified
vulnera … nt Risk
introdu …

Threat	Vulnerability	Impact	Likelihood	Inherent Risk
T1	V1	0.15	0.4	0.15
	V2	0.15	0.6	
T2	V2	0.15	0.25	0.2625
	V3	0.3	0.75	
T3	V4	0.25	1	0.25
T4	V5	0.15	1	0.15

(1)

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Risk Assessment 2/2

Mechanism Group	Security Mechanism	M_{V1}	M_{V2}	M_{V3}	M_{V4}	M_{V5}	Cost	Perf.
Encryption	SSH	0	0.6	0	0	0.6	30	30
	SSL	0	0.3	0	0	0.3	20	20
	TLS	0	0.8	0	0	0.8	40	20
Access Control	Firewall	0.3	0.6	0.4	0	0	50	60
	AntiVirus	0.5	0.3	0.3	0	0	40	70
	Firewall & Antivirus	0.7	0.8	0.7	0	0	90	80
Hashing	MD5	0.3	0	0	0	0.3	10	20
	SHA2	0.6	0	0	0	0.6	30	20
	BLAKE2	0.8	0	0	0	0.8	40	20
Ident. Management EMACS	Password	0.3	0	0	0	0	50	50
	Multi-Factor	0.7	0	0	0	0	60	80
Ident. Management SP IS	Password	0	0	0	0.3	0	50	50
	Smart Card	0	0	0.6	0	0	60	30

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Risk Minimisation

- **Step 5: Risk Minimisation**
  - *Using Constraint Goal Models and Satisfiability solvers identify the optimal Security Mechanism combinations that minimise the Residual Risk of each Threat and contribute towards the system's soft goals.*

Where, Residual Risk for each Threat is calculated as follows:

Definition 3. *Let R_R be the Residual Risk of a threat, then:*

$$R_R = R_I - R_M \overset{(1),(2)}{=} \sum_{i=1}^{n}[(L_i \times I_i \times V_i) \times (1 - \sum_{j=1}^{m} \frac{M_{ji}}{m})] \quad (3)$$

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Optimisation Scenarios

- Using the OptiMathSAT solver we can create optimisation scenarios where:
  - Each variable has a soft cap (min/max) or a specific hard cap limit (e.g., Residual Risk T1 < 25%)
  - Priorities can be assigned for the optimisation of variables (e.g., Residual Risk T1 > Cost > Residual Risk T2)

Variable \ Scenario	1	2	3	4	5	6
T1 Res. Risk ($R_{R_{(T1)}}$)	min	$min^{[1]}$	$min^{[3]}$	$min^{[2]}$	$< 25\%$	$< 50\%$
T2 Res. Risk ($R_{R_{(T2)}}$)	min	$min^{[2]}$	$min^{[4]}$	$min^{[3]}$	$< 25\%$	$< 50\%$
T3 Res. Risk ($R_{R_{(T3)}}$)	min	$min^{[3]}$	$min^{[5]}$	$min^{[4]}$	min	$< 75\%$
T4 Res. Risk ($R_{R_{(T4)}}$)	min	$min^{[4]}$	$min^{[6]}$	$min^{[5]}$	min	$< 50\%$
Added Cost Coverage	min	$min^{[5]}$	$min^{[1]}$	$min^{[6]}$	$min^{[1]}$	$min^{[1]}$
Performance Overhead Coverage	min	$min^{[6]}$	$min^{[2]}$	$min^{[1]}$	$min^{[2]}$	$min^{[2]}$

Optimisation Results

- Each scenario results in different set of selected Security Mechanisms, that satisfies its initial parameters

Scenario / Mechanism	1	2	3	4	5	6
Encryption	SSL	TLS	SSL	TLS	TLS	TLS
Access Control	Firewall	Firewall & AntiVirus	AntiVirus	Firewall	Firewall & AntiVirus	Firewall
Hashing	MD5	BLAKE2	MD5	BLAKE2	BLAKE2	MD5
Ident. Mgmt EMACS	Password	Multi-Factor Authent.	Password	Password	Multi-Factor Authent.	Password
Ident. Mgmt SP IS	Password	SmartCard	Password	SmartCard	Password	SmartCard

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Conclusions – Future Work

- Contributions of proposed framework
  - Extending Secure Tropos with Risk related concepts,
  - Support for quantitative risk assessment and trade-off analysis between security and other requirements.
  - Identification of optimal security configurations for a number of different scenarios
- Future Work
  - Exploring more advanced reasoners to support more complex optimisation scenarios
  - Support a more structured approach for Likelihood and Impact value estimation

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Thank you!

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