SREPPLine: Towards a Security Requirements Engineering Process for Software Product Lines

Daniel Mellado[1], Eduardo Fernández-Medina[2] and Mario Piattini[2]

[1] Ministry of Work and Social Affairs
Management Organism of Information Technologies of the Social Security
Software Development Centre of the National Social Security Institute, Madrid, Spain

[2] ALARCOS Research Group, Information Systems and Technologies Department
University of Castilla-La Mancha
Paseo de la Universidad 4, 13071 Ciudad Real, Spain

Abstract. Security related requirements are increasingly becoming a significant portion of the total set of requirements for many software systems. At the same time, nowadays many systems are developed based on the product line engineering paradigm. Within product lines, security requirements issues are extremely important because weakness in security can cause problems throughout the lifecycle of a line. The main contribution of this work is that of providing a standard-based process, which is an add-in of activities in the domain engineering as well as in application engineering processes. These processes deal with the security requirements from the early stages of product line lifecycle in a systematic and intuitive way especially adapted for product line based development. It is based on the use of the latest security requirements techniques, together with the integration of the Common Criteria (ISO/IEC 15408) into the product line lifecycle. Additionally, it deals with security artefacts reuse, by providing us with a Security Resources Repository. Moreover, it facilitates the conformance to the most relevant security standards with regard to the management of security requirements.

1 Introduction

Our society has become increasingly IT-based [31], depending as it does on a huge number of software systems which have a critical role and which manage critical and sensitive information, it is absolutely vital that Information Systems (IS) are properly assured from the very beginning [1, 22], due to the potential losses faced by organizations that put their trust in all these IS. Moreover, it is widely-accepted the principle which establishes that the building of security at the early stages of the development process is cost-effective and also brings about more robust designs [17].

Furthermore, nowadays, there is an increase in the demand as well in the complexity of the software needed. Thus, in order to obtain high-quality IS along with higher productivity, software product line (SPL) based development has become the

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most successful approach in the reuse field, because it can help us significantly reduce time-to-market as well as development costs [3, 4], by increasing the reuse of all types of artefacts, thanks to the combination of coarse-grained components with a top-down systematic approach where the software components are integrated into a high-level structure.

Due to the complexity and extensive nature of product line development, security and requirements engineering are much more important for a product line practice. Security is a cross-cutting concern in software intensive systems and should consequently be subject to careful requirements analysis and decision making, in addition the requirements for cost-effective product line development complicate this task. Therefore, the discipline known as Security Requirements Engineering is a very important part of the SPL development process for the achievement of secure SPL and applications, because it provides techniques, methods and standards for tackling this task in the development lifecycle. It also implies the use of repeatable and systematic procedures to ensure that the set of requirements obtained is complete, consistent, easy to understand and analysable by the different actors involved in the development of the system [18].

In the last few years, it has been a spectacular growing of security standards and security related proposals which have been developed to try to help develop security critical IS. Moreover, it has recently been developed SPL reference architectures for security and SPL requirements management approaches and tools, such as [14, 29]. Nevertheless, after analysing the previously performed comparative analyseses of several relevant proposals of IS security requirements, as those of [6, 23, 28, 30, 32],etc. in [24, 25], we conclude that those standards and proposals are neither specific enough for a systematic and intuitive treatment of SPL security requirements, nor make it easy the task of integrating security requirements engineering activities into the SPL based development. In addition, they did not provide intuitive, systematic and methodological support for the management of security requirements, with the aim of developing secure SPL and products that conform to the most relevant security standards with regard to the management of security requirements (such as mainly ISO/IEC 15408 [10] as well as ISO/IEC 27001 [12], ISO/IEC 17799 [11] or ISO/IEC 21827 [8]).

In this paper, as an evolution of our previous proposal SREP [25], we will present a Security Requirements Engineering Process for software Product Lines (SREP-PLine), which is a standard-based process that describes how to integrate security requirements into the software engineering process in a systematic and intuitive way, as well as a simple integration with the rest of requirements and the different phases/processes of the SPL development lifecycle. Additionally, this process will facilitate the fulfilment of the IEEE 830:1998 standard [7], and it will help develop IS which conform to the aforementioned security standards with regard to the management of security requirements, and without being necessary to perfectly know those standards; hence, reducing the participation of security experts to achieve it. In order to reach these goals, our approach is based on the reuse of security artefacts which are integrated in the variability model of the SPL, by providing a Security Resources Repository (SRR), together with the integration of the Common Criteria (CC) (ISO/IEC 15408) into the SPL lifecycle.

The rest of the paper is organized as follows: in section 2, we will summarize the main concepts of requirements engineering in software product lines. Then, in section 3, we will present an outline of our proposed security requirements engineering process for software product lines (SREPPLine). Later, in section 4, we will explain the security resources repository. Finally, in section 5, we will state our conclusions and future work.

2 A Summary of Product Line Requirements Engineering

A software product line is a set of software-intensive systems sharing a common, managed set of features[1] [15] that satisfy the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way [4].

The software product line engineering paradigm separates two processes: domain engineering and application engineering [27]. Domain engineering is the process of SPL engineering in which commonality and variability of the product line are defined and realised, and it is composed of five key sub-processes: product management, domain requirements engineering, domain design, domain realisation and domain testing. According to [27],the domain requirements engineering sub-process encompasses all activities for eliciting and documenting the common and variable requirements of the product line. Hence, domain requirements engineering differs from requirements engineering for single systems in the following subjects: commonality analysis; variability analysis and modelling; and it tries to anticipate prospective changes in requirements, such as laws, standards, technology changes and market needs for future applications. Application engineering is the process of SPL engineering in which the applications of the product line are built by reusing domain artefacts and exploiting the product line variability, and it is composed of the following sub-processes: application requirements engineering, application design, application realisation and application testing.

Product line requirements define the products and common and variable features of the products in the product line. Requirements common across the entire family, which constitute the product line requirements and an important core asset, should be managed separately from requirements that are particular to a subset of the products (or to a single product), which must be managed as well. Product line requirements engineering incorporates different requirements sources, such as stakeholders (domain experts, etc.), existing products or competitors' products, existing model domains or the SPL scope. The product line scope bounds the products included in the product line: product line requirements refine the scope by more precisely defining the characteristics of the products in the product line. The scope and product line requirements are tightly coupled and evolve together [4].

Finally, after analysing several relevant proposals of SPL requirements and some SPL requirement management tool, as those of [4, 14, 16, 27, 29], we argue that those proposals are neither specific enough for a systematic and intuitive treatment of SPL

[1] A feature is an end-user visible characteristic of a system.

security requirements, nor make it easy the task of integrating security requirements engineering activities into the SPL based development.

3 SREPPLine: a Security Requirements Engineering Process for Software Product Lines

The Security Requirements Engineering Process for software Product Lines (SREP-PLine) is an add-in of activities (that are decomposed into tasks which receive input artefacts and which generate output artefacts, with the participation of different roles) that are integrated into a SPL development process model of any organization providing it with a security requirements approach. The order in which they are performed depends on the particular process that is established in the organization. Hence the sub-process and its activities described in this paper can be combined with existing development methods such as the Unified Process or other development processes. In this paper we will describe the integration of our process into the SPL engineering framework proposed in [27].

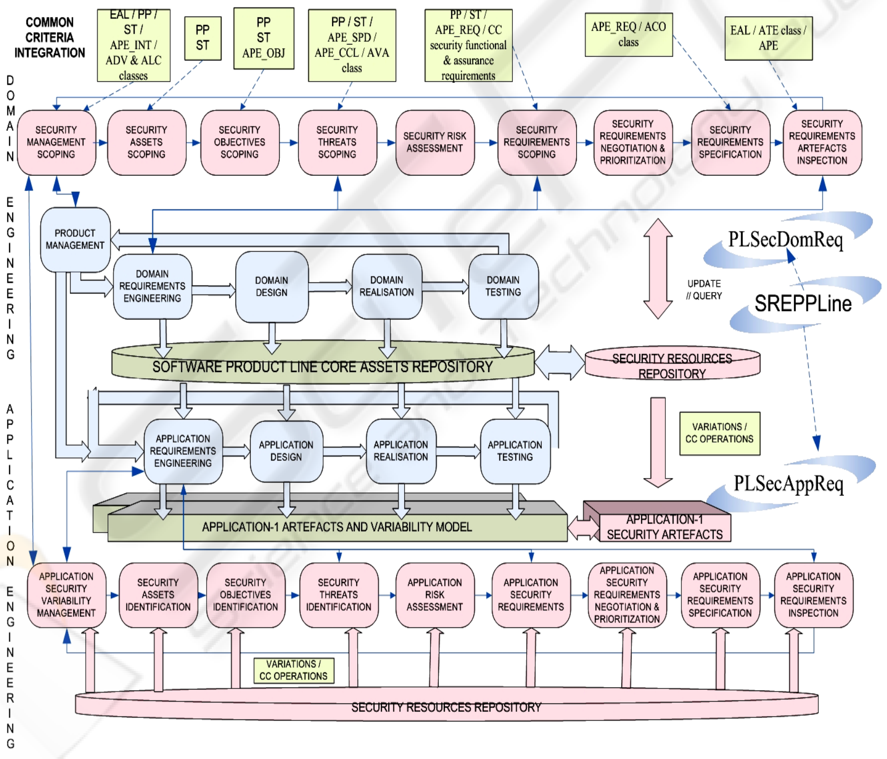

COMMON CRITERIA INTEGRATION
EAL / PP / ST / APE_INT / ADV & ALC classes
PP ST
PP ST APE_OBJ
PP / ST / APE_SPD / APE_CCL / AVA class
PP / ST / APE_REQ / CC security functional & assurance requirements
APE_REQ / ACO class
EAL / ATE class / APE
DOMAIN ENGINEERING
SECURITY MANAGEMENT SCOPING
SECURITY ASSETS SCOPING
SECURITY OBJECTIVES SCOPING
SECURITY THREATS SCOPING
SECURITY RISK ASSESSMENT
SECURITY REQUIREMENTS SCOPING
SECURITY REQUIREMENTS NEGOTIATION & PRIORITIZATION
SECURITY REQUIREMENTS SPECIFICATION
SECURITY REQUIREMENTS ARTEFACTS INSPECTION
PRODUCT MANAGEMENT
DOMAIN REQUIREMENTS ENGINEERING
DOMAIN DESIGN
DOMAIN REALISATION
DOMAIN TESTING
PLSecDomReq
UPDATE // QUERY
SREPPLine
SOFTWARE PRODUCT LINE CORE ASSETS REPOSITORY
SECURITY RESOURCES REPOSITORY
VARIATIONS / CC OPERATIONS
APPLICATION ENGINEERING
APPLICATION REQUIREMENTS ENGINEERING
APPLICATION DESIGN
APPLICATION REALISATION
APPLICATION TESTING
PLSecAppReq
APPLICATION-1 ARTEFACTS AND VARIABILITY MODEL
APPLICATION-1 SECURITY ARTEFACTS
APPLICATION SECURITY VARIABILITY MANAGEMENT
SECURITY ASSETS IDENTIFICATION
SECURITY OBJECTIVES IDENTIFICATION
SECURITY THREATS IDENTIFICATION
APPLICATION RISK ASSESSMENT
APPLICATION SECURITY REQUIREMENTS
APPLICATION SECURITY REQUIREMENTS NEGOTIATION & PRIORITIZATION
APPLICATION SECURITY REQUIREMENTS SPECIFICATION
APPLICATION SECURITY REQUIREMENTS INSPECTION
VARIATIONS / CC OPERATIONS
SECURITY RESOURCES REPOSITORY

Fig. 1 The Software Product Line Security Requirements Engineering Framework.

As it is shown in Fig. 1, SREPPLine is composed of two sub-processes with their respective activities: PLSecDomReq (Product Line Security Domain Requirements

Engineering sub-process) and PLSecAppReq (Product Line Security Application Requirements Engineering sub-process). These sub-processes cover the four basic phases of the requirements engineering according to [19]: requirements elicitation; requirements analysis and negotiation; requirements documentation; and requirements validation and verification. Therefore, at least, they have to be performed for each iteration of the Domain or Application Requirements Engineering Process of the SPL, respectively. However, in this paper due to space restrictions, we will outline the key activities and tasks that have to be part of PLSecDomReq and we will present a brief overview of PLSecAppReq (as an evolution of SREP [25]).

3.1 Product Line Security Domain Requirements Engineering Sub-process

The main goals of this sub-process (SP1) are the development of common and variable security requirements which conform to IEEE 830:1998 as well as their precise documentation in a Protection Profile[2](PP) similar document and the development of their common and variable related security artefacts following a CC similar format. The process model of this sub-process is shown in Fig. 2.

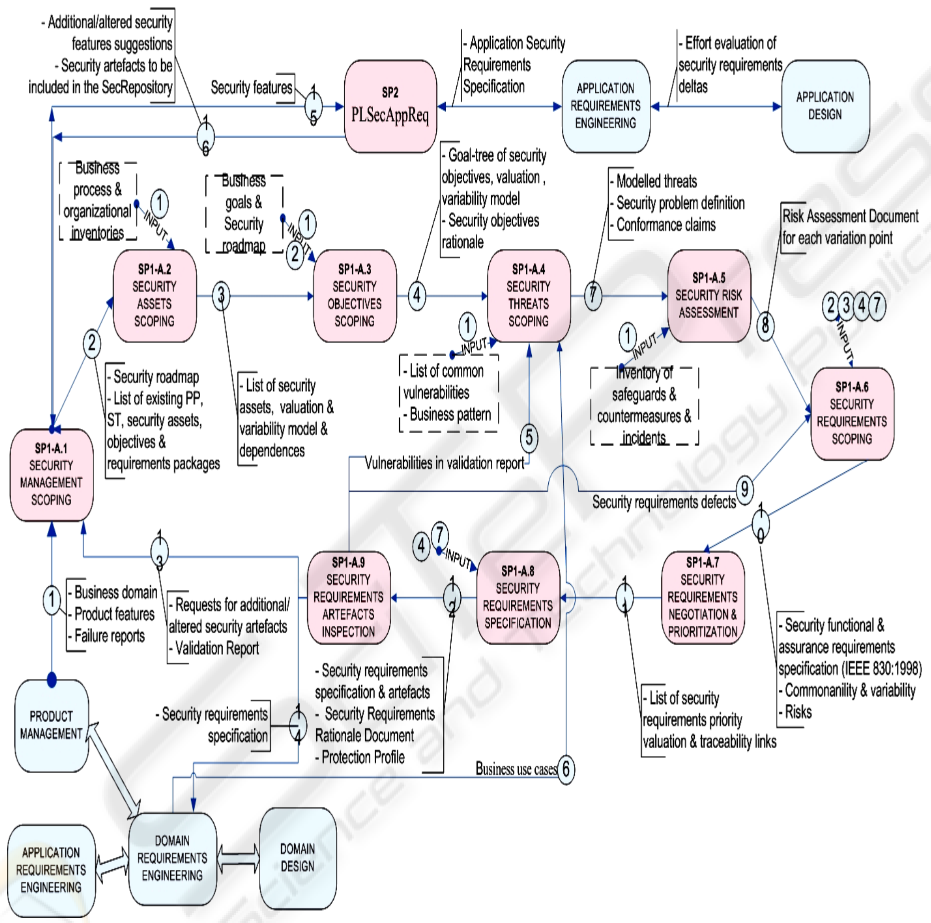
SP1 - Activity A1.1: Security Management Scoping. This activity comprises the following tasks: security resources repository improvement (up-to-date artefacts and links); identification of specific stakeholders; security definitions agreement; security environment identification (security policy, security standards, laws, constraints, security needs and security acceptance criteria as well as the evaluation assurance level (EAL) of the CC); identification of the relevant type of assets and security objectives; security cost impact and risk superficial estimations; and security features identification (commonalities and variability).

SP1 - Activity A1.2: Security Assets Scoping. This activity comprises the following tasks: security assets identification for each asset (or group of them) and for the environment; security assumptions; security asset scoping, which aims at identifying particular components to be developed for reuse, common and variable assets; identification of dependences between security assets; and valuation of security assets.

SP1 - Activity A1.3: Security Objectives Scoping. This activity comprises the following tasks: security objectives identification (commonality and variability analysis); security objectives modelling and specification (APE_OBJ CC class); security objectives valuation.

[2] The Common Criteria define a Protection Profile as an implementation independent statement of security requirements that is shown to address threats that exist in a specified environment

SP1 - Activity A1.4: Security Threats Scoping. This activity comprises the following tasks: identification of potential vulnerabilities in public domain sources; identification of the attack tree associated with the business pattern or SPL domain; identification of the misuse cases and threats for each security objective and asset (commonality and variability analysis), because each asset is targeted by threat/s that can prevent the security objective from being achieved; threats modelling and specification; validation of security objectives against threats and assets and their variability models.



- Additional/altered security features suggestions
- Security artefacts to be included in the SecRepository
Security features
SP2 PLSecAppReq
- Application Security Requirements Specification
APPLICATION REQUIREMENTS ENGINEERING
- Effort evaluation of security requirements deltas
APPLICATION DESIGN
Business process & organizational inventories
INPUT
Business goals & Security roadmap
INPUT
- Goal-tree of security objectives, valuation, variability model
- Security objectives rationale
- Modelled threats
- Security problem definition
- Conformance claims
Risk Assessment Document for each variation point
SP1-A.2 SECURITY ASSETS SCOPING
SP1-A.3 SECURITY OBJECTIVES SCOPING
SP1-A.4 SECURITY THREATS SCOPING
SP1-A.5 SECURITY RISK ASSESSMENT
SP1-A.6 SECURITY REQUIREMENTS SCOPING
INPUT
- Security roadmap
- List of existing PP, ST, security assets, objectives & requirements packages
- List of security assets, valuation & variability model & dependences
- List of common vulnerabilities
- Business pattern
INPUT
Inventory of safeguards & countermeasures & incidents
INPUT
SP1-A.1 SECURITY MANAGEMENT SCOPING
Vulnerabilities in validation report
Security requirements defects
SP1-A.9 SECURITY REQUIREMENTS ARTEFACTS INSPECTION
SP1-A.8 SECURITY REQUIREMENTS SPECIFICATION
SP1-A.7 SECURITY REQUIREMENTS NEGOTIATION & PRIORITIZATION
INPUT
- Business domain
- Product features
- Failure reports
- Requests for additional/ altered security artefacts
- Validation Report
- Security requirements specification & artefacts
- Security Requirements Rationale Document
- Protection Profile
- Security requirements specification
- List of security requirements priority valuation & traceability links
- Security functional & assurance requirements specification (IEEE 830:1998)
- Commonanility & variability
- Risks
Business use cases
PRODUCT MANAGEMENT
APPLICATION REQUIREMENTS ENGINEERING
DOMAIN REQUIREMENTS ENGINEERING
DOMAIN DESIGN

Fig. 2. Activity model of PLSecDomReq.

SP1 - Activity A1.5: Security Risks Assessment. This activity comprises the following tasks in order to achieve 100% risk acceptance: assessing whether the threats are relevant according to the security level specified by the security objectives; estimating the security risks based on the relevant threats, their likelihood and their potential negative impacts, depending on the variation points. To do so, the ISO/IEC 13335

(GMITS) [9], provides guidance on the use of the risk management process. In Spain it could be used MAGERIT [21], which conforms to ISO/IEC 13335.

SP1 - Activity A1.6: Security Requirements Scoping. This activity comprises the following tasks: security requirements elicitation, the suitable security requirements or the suitable package of security requirements that mitigate the threats at the necessary levels with regard to the risk assessment must be selected; identification of common security requirements according to the elicited requirements and through the previously performed risk analysis; defining variable requirements and variability dependencies; security requirements modelling; definition of CC operations (iteration, assignment, selection or refinement); definition of security test/metric and countermeasure for each security requirement. Thus, at the end of this activity and according to ISO/IEC 17799:2005 it must have been specified the functional, assurance, and organizational security requirements, along with the security requirements for the IT development and operational environment.

SP1 - Activity A1.7: Security Requirements Negotiation and Prioritization. This activity comprises the following tasks: interdependences with other functional and non-functional requirements and trade-offs in the security variability model and therefore in the orthogonal variability model; balancing the risk with the economical impact of implementing countermeasures.

SP1 - Activity A1.8: Security Requirements Specification. This activity comprises the following tasks: security requirements modelling and security requirements specification.

SP1 - Activity A1.9: Security Requirements Artefacts Inspection. This activity comprises the following tasks: i) it is verified whether the security requirements conform to CC (ISO/IEC 15408) and to IEEE 830-1998 standard, because according to this standard, a quality requirement has to be correct, unambiguous, complete, consistent, ranked for importance and/or stability, verifiable, modifiable, and traceable. ii) Furthermore, SREP proposes the use of the SSE-CMM (ISO/IEC 21827) in order to help in the evaluation of the product line security engineering process in the Domain Testing sub-process, with the help of the CC_SSE-CMM [20] approach. Thereby, we propose to evaluate the security of the SPL along with the product line security engineering process by using the CC assurance requirements and the SSE-CMM at the same time with the help of CC_SSE-CMM. iii) It will verify in the Domain Testing sub-process the fulfilment of the previously approved EAL and the CC evaluation.

3.2 Product Line Security Application Requirements Engineering Sub-process

PLSecAppReq (Product Line Security Application Requirements Engineering sub-process) activities in this sub-process (SP2) are similar to SREP [25] activities, except for some specific tasks and activities that are unique to security requirements engineering in SPL. The main goals of this sub-process are: elicitation and documentation of the security requirements and their related security artefacts; to make them conform to IEEE 830:1998, as well as to gather them in a Security Targets[3] (ST) similar document; at the same time to reuse, as much as possible, the security domain artefacts and requirements.

Due to space restrictions, we have enumerated in Fig. 1 the key activities of PLSecAppReq sub-process and below we will only describe the key differences between this sub-process and security requirements engineering for single systems (such as SREP):

- Requirements elicitation is based on the communication of the available commonality and variability of the SPL. Most of the requirements are not elicited anew, but are derived from the domain requirements.
- During security requirements elicitation, the differences between security application artefacts and security domain artefacts (sec-deltas) must be detected, evaluated with regard to the required adaptation effort, and suitably documented. If the required adaptation effort is early known, trade-off decisions concerning application security artefacts are possible not only to reduce the effort but also to increase the amount of domain artefacts.

4 The Security Resources Repository

SREPPLine proposes a Security Resources Repository (SRR), which facilitates the product line security requirements engineering by making it easier the development with security requirements reuse, which is an important concept in SPL because it helps us increase the security requirements quality for an improved use in subsequent projects [32]. Moreover, it helps manage in an easier way one of the most important factors of success in the development of a secure SPL: the management of commonalities and variability of the security requirements and their traceability links.

The security requirements can be obtained from security objectives or threats starting from the assets for a new SPL or for a new product of a SPL. Furthermore, the SRR uses the concept of package, understood as a homogeneous set of requirements that can be applied to different products of the SPL, and that are put together to satisfy the same security objectives as well as to mitigate the same threats, being a bigger and more effective reuse unit. The security domain requirements engineering as well as the security application requirements engineering sub-processes are supported by this repository.

Next, we will outline the most important and/or complex aspects of the metamodel shown in Fig. 3:

- ‘Domain Threat’ and ‘Domain Security Requirement’ (or CC Component) are described independently of particular products. They can be represented as different specifications, thanks to the elements ‘Threat Specification’ and ‘Security

[3] The Common Criteria define a Security Target as an implementation dependent statement of security needs for a specific identified product.

Requirement Specification'. They are included in the core assets of the SPL, together with the 'Security Objective', which are documented through a goal tree specified in XML in order to enable the explicit documentation of variability. Besides all of them support traceability links.

- 'Security Requirement Package' is a set of requirements that work together to satisfy the same security objectives and mitigate the same threats.
- The 'Security Requirement – Security Requirement' relationship allows an inclusive or exclusive trace between requirements, that is variability constraints. An exclusive trace between requirements means that they are mutually alternative, for example that they are in conflict or overlapping, whereas, an inclusive trace between requirements means that to satisfy one, other/other/s is/are needed to be satisfied. In addition, it is used to model the dependencies with other functional and non-functional requirements. Traces among requirements in the SPL infrastructure do automatically also exist in the products.

In addition, there could have been links further on to design level specifications, security test cases, countermeasures, etc., as well as traceability links with other artefacts ("artefacts dependencies"), through the relationship between a variant of the orthogonal variability model and the associated development artefact, because our proposed model process is based on the concept of the orthogonal variability model of Pohl et al. [27]. Thus, the SRR must be integrated into the SPL core assets repository to facilitate these traceability links between the variability model of the SPL and the different types of security artefacts and the other development artefacts.

Finally, we would like to point out the fact that using the CC, a large number of security requirements on the SPL itself and on the products development can be defined. Nevertheless, the CC neither provide us with methodological support, nor contain security evaluation criteria pertaining to administrative security measures not directly related to IS security measures. However, it is known that an important part of the security of an IS can be often achieved through administrative measures. Therefore, according to ISO/IEC 17799:2005, we propose to include legal, statutory, regulatory, and contractual requirements that the organization, its trading partners, contractors, and service providers have to satisfy, and their socio-cultural environment. After converting these requirements into software and system requirements format, these requirements along with the CC security requirements would be the initial subset of security requirements of a SPL, acting like horizontal security requirements patterns for the software product lines of the organization.

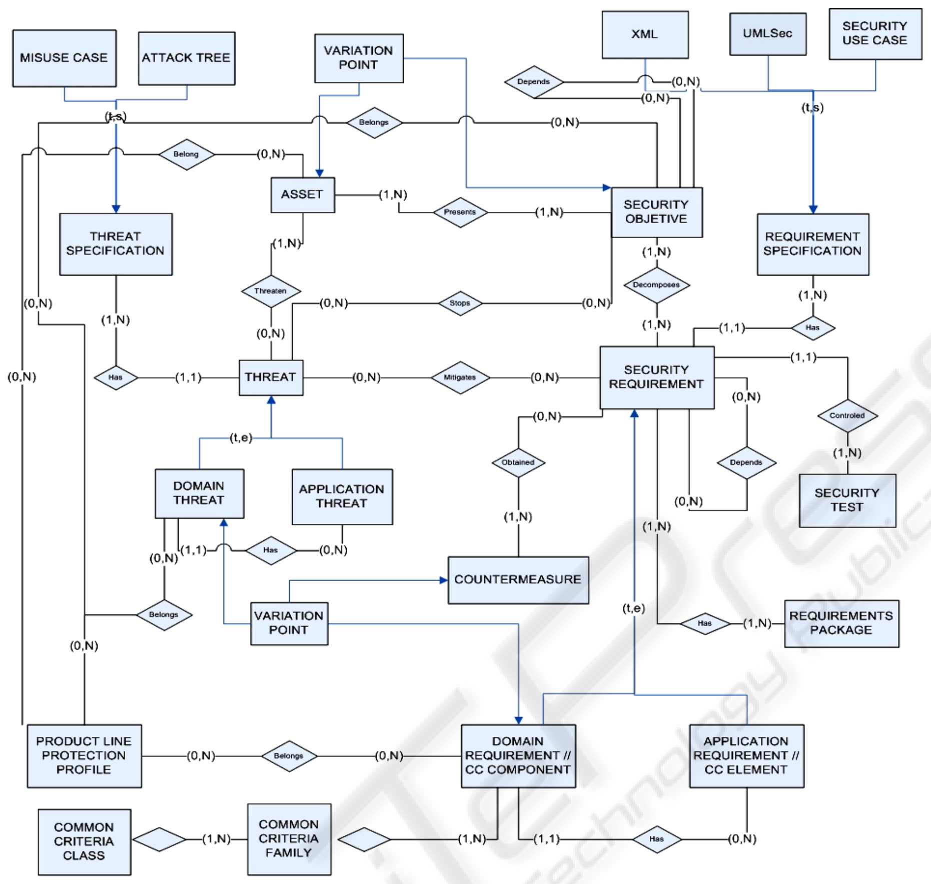


Fig. 3. Product Line Security Resources Meta-model.

5 Conclusions and Further Work

Nowadays, software security is generating a growing interest mainly due to the increasingly crucial nature of the IS with corresponding levels of new legal and governmental requirements. At the same time, there is an increasing need to obtain high-quality IS along with higher productivity. For this reason, software product line based development has become the most successful approach for ensuring quality, economic efficiency and manageability of software systems [2]. Nevertheless, requirements management and security of information are much more critical in SPL due to the complexity and extensive nature of them. Therefore, we believe that it is vital to deal with security at all stages of SPL development, especially in the management of security requirements, since these form the basis for the achievement of a robust IS.

Hence, the contribution of this work is that of providing a standard-based process that deals with security requirements from the early stages of SPL development in a systematic and intuitive way specially adapted to SPL based development, which is based on the use of the latest security requirements techniques, such as UMLSec [13], security use cases [5] or misuse cases [30]; as well as on the reuse of security artefacts, by providing a Security Resources Repository (SRR), together with the integration of the Common Criteria (ISO/IEC 15408) into the SPL lifecycle. Furthermore, it also conforms to the most relevant security standards with regard to the management of security requirements such as the aforementioned ISO/IEC 15408 and ISO/IEC 17799:2005 (sections: 0.3, 0.4, 0.6 and 12.1) and ISO/IEC 27001:2005 standard (sections: 4.2.1, 4.2.3, 4.3, 6.a, 6.b and A.12.1.1). Furthermore, it facilitates that the products of the SPL conform to these former standards as well as the fulfilment of the IEEE 830:1998 standard. In addition, SREPPLine suggests using a method to carry out the risk assessment which conforms to ISO/IEC 13335 (GMITS).

As the application of any methodology or requirements engineering process will normally fail because it has to be manually performed, further work is also needed to develop a new version of our previously developed CARE (Computer-Aided Requirements Engineering) tool (SREPTOOL [26]) in order to support and gather the new characteristics of our proposed security requirements engineering process for software product lines. Furthermore, we will carry out a refinement of the theoretical approach by proving it with a real case study to complete and deeply detail SREPPLine. Finally, we will work to complement this process in order to provide a holistic framework for security engineering in software product lines.

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