Steganography Hiding Patterns: A Brief Review

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Hiding Patterns describe the key idea of hiding techniques on an abstract level. They help cleaning up terminology, and can be used to form a taxonomy. The hiding patterns taxonomy has been subject to multiple adjustments and extensions leading to several publications. In this poster, **we recapitulate the key developments on hiding patterns**.

Development of Hiding Patterns

In **2015**, hiding patterns were initially proposed in a survey paper by Wendzel et al. that covered 109 hiding techniques for network covert channels (published 1987-2013). Eleven patterns were arranged in two categories: *storage* and *timing* patterns, of which storage patterns were divided into additional categories.

However, in the **following year**, a book by Mazurczyk et al. emerged that already revised the 2015-taxonomy by adding new and updated patterns as well as new classification levels for timing-based hiding methods: *protocol-agnostic* and *protocol-aware* timing methods. While protocol-agnostic hiding methods neither rely on nor consider specific protocol features (e.g., packet ordering), protocol-aware methods require the utilization of such features.

In **2018**, Cabaj et al. proposed two extensions for the 2016-taxonomy. First, they have shown that network steganography hiding methods can be applied to payload (which was excluded by the previous versions). Second, they have shown that several hiding methods are actually *hybrid*, i.e., the sender needs to apply a different hiding pattern than the receiver.

The concept of hiding patterns was initially applied to a new domain, namely cyber-physical systems, by Hildebrandt et al. in **2020**. In **2021**, a consortium consisting of authors from seven institutions presented a revised hiding pattern-based taxonomy for steganography.

First, the revision widened the limited focus on network communications so that the patterns became applicable to all domains of steganography. Second, the need to differentiate between the *embedding* process and the *representation* of hiding methods was introduced as a core element (this step can be considered as an enhancement of the hybrid patterns of Cabaj et al.).
Several of the key concepts and terms from **2015** were still kept.

New patterns were added to the taxonomy by different authors: Velinov et al. (**2019**), Mileva et al. (**2021**) and Hartmann et al. (**2021**). Some of these new patterns must be considered as indirect and/or hybrid hiding patterns.

Finally, Schmidbauer et al. extended the concept of hiding patterns to the domain of indirect covert channels in **2022**.

2015	Steffen Wendzel, Sebastian Zander, Bernhard Fechner, Christian Herdin: **Pattern-based Survey and Categorization of Network Covert Channel Techniques**, Computing Surveys (CSUR), ACM, Vol. 47(3), 2015.	Definition of Hiding Patterns First Taxonomy Presents Methodology and Concepts
2016	Wojciech Mazurczyk, Steffen Wendzel, Sebastian Zander, Amir Houmansadr, and Krzysztof Szczypiorski. **Information Hiding in Communication Networks: Fundamentals, Mechanisms, and Applications**. Chapter 3, Wiley-IEEE, 2016.	Several Improvements to the 2015-taxonomy
2018	Wojciech Mazurczyk, Steffen Wendzel, and Krzysztof Cabaj. 2018. **Towards Deriving Insights into Data Hiding Methods Using Pattern-based Approach**. In Proc. Second Interr Workshop on Criminal Use of Information Hiding (CUING). ACM, 10:1–10:10, 2018.	New Patterns; New Categorizations Hybrid Patterns Distributed Hiding Patterns
	Aleksandar Velinov, Aleksandra Mileva, Steffen Wendzel, Wojciech Mazurczyk: **Covert Channels in MQTT-based Internet of Things**, ACCESS, IEEE, Vol. 7, 2018.	New Sub-pattern (Value Influencing)
2020	Mario Hildebrandt, Robert Altschaffel, Kevin Lamshöft, Mathias Lange, Martin Szemkus, Tom Neubert, Claus Vielhauer, Yongdian Ding, and Jana Dittmann. **Threat Analysis of Steganographic and Covert Communication in Nuclear I&C Systems**. In International Conference on Nuclear Security: Sustaining and Strengthening Efforts, 2020.	First Work on CPS Hiding Patterns
2021	Aleksandra Mileva, Aleksandar Velinov, Laura Hartmann, Steffen Wendzel, and Wojciech Mazurczyk. 2021**. Comprehensive Analysis of MQTT 5.0 Susceptibility to Network Cov Channels**. Computers & Security (COSE), Vol. 104, Elsevier, 2021.	New Pattern (Artificial Reconnections)
	Laura Hartmann, Sebastian Zillien, Steffen Wendzel: **Analysis of New Covert Channels in CoAP**, in: Proc. DETONATOR workshop (part of Proc. EICC 2021), ACM, 2021.	New Pattern (Artificial Resets)
	Steffen Wendzel, Luca Caviglione, Wojciech Mazurczyk, Aleksandra Mileva, Jana Dittmann, Christian Krätzer, Kevin Lamshöft, Claus Vielhauer, Laura Hartmann, Jörg Keller, Tom Neubert: **A Revised Taxonomy of Steganography Embedding Patterns**. In: Proc. 16th ARES Conference, 2021.	First Hiding Patterns Taxonomy for Steganography
2022	T. Schmidbauer, S. Wendzel: **SoK: A Survey Of Indirect Network-level Covert Channels**. In: Proc. 17th ACM ASIA CCS, 2022.	First Taxonomy of Hiding Patterns for Indirect Network Covert Channels

Fig. 1: Key Publications on Hiding Patterns

Methodology:

Until now, a method for evaluating whether hiding techniques present new patterns, a unified description method to aid comparison and replicability, an educational tool, and a method for transfering a countermeasure from one pattern to another have been published.

2015	Steffen Wendzel, Carolin Palmer: **Creativity in Mind: Evaluating and Maintaining Advances in Network Steganographic Research**, J.UCS Vol. 21(12), 2015.	How to tell whether a hiding technique represents a new pattern or solely uses an already existing pattern.
2016	Steffen Wendzel, Wojciech Mazurczyk, Sebastian Zander: **Unified Description Method for Network Information Hiding Methods**, J.UCS Vol. 22(11), 2016.	How patterns can be used during peer review and making papers on hiding methods replicable and understandable (using patterns).
	Steffen Wendzel, Wojciech Mazurczyk: **An Educational Network Protocol for Covert Channel Analysis Using Patterns (Poster)**, ACM CCS 2016.	How to teach in academia using hiding patterns.
2019	Steffen Wendzel, Florian Link, Daniela Eller, Wojciech Mazurczyk: **Detection of Size Modulation Covert Channels Using Countermeasure Variation**, J.UCS, Vol. 25(11), 2019.	How to transfer a countermeasure that works for one pattern to work with another one.

Fig. 2: Publications on the Research Methodology of Hiding Patterns

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