

A Brief CCEAP Documentation

Steffen Wendzel (Worms University of Applied Sciences, Worms *and* Fraunhofer FKIE, Bonn)

version 0.2.3

A note before you start reading: An initial academic publication on CCEAP is also available:

- S. Wendzel and W. Mazurczyk: [An Educational Network Protocol for Covert Channel Analysis Using Patterns \(poster\)](#), in Proc. ACM Conference on Computer and Communications Security (CCS), pp. 1739-1741, ACM, 2016. You can also download the conference poster [here](#), it summarizes the content of the actual paper.
- Please send requests and feedback to the author: Steffen Wendzel, www.wendzel.de (steffen (at) wendzel (dot) de). Research on covert channel teaching is currently performed by [Steffen Wendzel and Wojciech Mazurczyk](#).

Introduction

The *Covert Channel Educational Analysis Protocol* (CCEAP) is a network protocol designed for teaching covert channels to professionals and students. For an introduction on network covert channels (network steganography), please have a look at [this publication](#).

CCEAP is an application layer protocol that is embedded into a simple TCP connection. The protocol is explicitly vulnerable against several so-called [hiding patterns](#). Hiding patterns represent the core ideas of how to hide data in network transmissions.

Why use CCEAP?

The key advantage of CCEAP is that it is based on hiding patterns. As shown in (Wendzel et al., 2015), the >100 known methods for hiding data in network transmissions can be represented by only 11 hiding patterns. Hence, it is enough to teach students these few hiding patterns instead of >100 hiding methods.

Another advantage of CCEAP is that basically all methods for hiding data in network transmissions can be explained by using only one protocol (=CCEAP). For this reason, switching network protocols while explaining hiding methods to students is not necessary anymore. The protocol's structure is simple and self-explanatory and its implementation is kept at a minimum level of code lines to make it especially accessible to students.

Installation

The tool requires gcc and Linux (or similar). Run `make` to build the two components of the tool: **client** and **server**.

Teaching Process in a Nutshell

The educational process is split into two parts. First, fundamentals are explained, secondly, exercises are performed and evaluated.

1. Preparing Students to Use CCEAP

The lecturer is required to introduce

- the CCEAP protocol (see below), and
- hiding patterns as they are described on our [project website](#) that also points to several of our recent publications in which we introduce the topic.

Please Note: Currently, CCEAP supports most of the storage channels patterns as well as some timing channel patterns. However, a few hiding patterns as well covert channels for OSI layers 1-2 are not supported. For a detailed explanation of these terms, please see our book [Network Information Hiding in Communication Networks](#), Chapters 2 and 3.

2. Exercises

In the exercises, students should try to create covert channels **or** should try to determine the type (pattern) of a given covert channel. Therefore, the lecturer can perform one of two exercises:

- The lecturer can ask the *students to establish a hidden communication that represents a given pattern*. The pattern can be one of the known patterns of the available [pattern collection](#), e.g. [Value Modulation](#) or [Reserved/Unused](#). Therefore, the students need to find out how to create a covert channel for the particular pattern using the CCEAP protocol by analyzing the protocol structure and the **client** tool's command line parameters.
- Alternatively, the lecturer can ask the students to *determine the hiding pattern for a given traffic recording or for given tool parameters* that were used to run the client.

CCEAP Protocol

The protocol contains two components: A CCEAP main header and options headers (between 0-128). The options headers will be concatenated to the main

header.

Main Header

The main header contains three words. The first contains a *Sequence Number* (8 bit), the indicator of how many options headers are attached (*Number of Options*, 8 bits), the length of the destination address in bytes (*Destination Length*, 8 bits) and an unused *Dummy* field (8 bits). The following two words contain the destination address (an ASCII value) that is padded with **X** bytes if too short for two words.

0	8	16	24	32
+-----+				
Seq.No.	Number	Dest.	Dummy	
	Options	Length	(Unused)	
+-----+				
Destination Address and Padding				
(Word 1)				
+-----+				
Destination Address and Padding				
(Word 1)				
+-----+				

The sequence number is incremental and starts with 1 by default (this can all be configured!). The number of options is zero by default.

Options Headers

The options header contains a freely definable *Identifier*, *Type* and *Value* field (8 bits each) and another *Dummy* field (also 8 bit).

0	8	16	24	32
+-----+				
Identi-	Type	Value	Dummy	
fier			(Unused)	
+-----+				

Tool Architecture and User-Guide

The implementation of the CCEAP protocol is split into two components, a client and a server. The client transfers CCEAP protocol packets to the server. Users can freely define how the particular fields of the CCEAP header are filled and how optional header components are embedded. The server, on the other hand, simply displays the received content which allows to view whether packet data were transmitted in the desired way.

All actions can be performed over the network or on the local host. The easiest way is to open two X terminals (e.g. GNOME Terminal) and start the server in one terminal and the client in the other.

Example Walk-through for an Exercise

Let us assume that the exercise given to the students was to create a covert channel that uses the [Reserved/Unused](#) pattern. The students look up the pattern description, which tells:

The covert channel encodes hidden data into a reserved or unused header/PDU element.

By analyzing the protocol structure of CCEAP, the students find an unused header field, namely the *Dummy* field, which is 8 bits in size. The field could be used to place hidden data in the way as described by the pattern. By running `./client -h`, the students check whether they can manipulate the Dummy field in some way:

```
$ ./client -h
CCEAP protocol implementation. Copyright (C) 2016 Steffen Wendzel
...
The following parameters are supported by CCEAP client v.0.4.1:
...
-D x    Destination IP x to connect to
-P x    TCP port x to connect to
...
-u x    Use digit x instead of 0 as 'dummy' value in the main header
```

The parameter `-u` can obviously be used for creating a Reserved/Unused pattern-based covert channel. To this end, the students run the server on the localhost port 2222:

```
$ ./server -P 2222
...
CCEAP - Covert Channel Educational Analysis Protocol (Server)
=> version: 0.4.1, written by: Steffen Wendzel, www.wendzel.de
```

Please note that the use of an additional `-v` parameter provides verbose output for the client and for the server and that the parameter `-h` works for both, server and client.

Next, the students run the client and connect to localhost (127.0.0.1), port 2222. They set the value of the Dummy field to 42:

```
$ ./client -D 127.0.0.1 -P 2222 -u 42
...
connecting ... connected.
sending: .....
```

sending done.

By default, the client sends 10 packets with incremental sequence number. Therefore, the server will receive and display now 10 packets with the same content. Of course, such parameters can be changed as desired. The typical packet output is shown as follows:

```
received data (12 bytes):
> time diff to prev pkt: 0.000
> sequence number:      1
> destination length:   0
> dummy value:          42
> destination + padding: XXXXXXXX
> number of options:    0
```

More detailed outputs will be provided when the server receives more complex packets from the client, e.g. packets containing optional headers.

Supported Hiding Patterns

Currently, the below listed hiding patterns are supported by CCEAP.

Storage Channel Patterns:

- [Size Modulation](#)
- [Sequence Modulation](#)
- [Add Redundancy](#)
- [Random Value](#)
- [Value Modulation](#)
- [Reserved/Unused](#)

Timing Channel Patterns:

- [Artificial Message/Packet Loss](#) (a.k.a. [PDU Corruption](#))
- [Artificial Retransmission](#)
- [Manipulated Message Ordering](#)
- [Interpacket Times](#)
- [Rate/Throughput](#), indirectly supported via the *Interpacket Time* Pattern

An explanation of how each pattern is addressed by CCEAP can moreover be found in our CCS'16 poster (Wendzel and Mazurczyk, 2016), cf. 'Further Reading/Publications on CCEAP' section at the end of the document.

Further Reading

Publications on CCEAP:

- S. Wendzel and W. Mazurczyk: [An Educational Network Protocol for Covert Channel Analysis Using Patterns \(poster\)](#), in Proc. ACM Conference on Computer and Communications Security (CCS), pp. 1739-1741, ACM, 2016. You can also download the conference poster [here](#), it summarizes the content of the actual paper.

Publications on Information Hiding Patterns:

- S. Wendzel, S. Zander, B. Fechner, C. Herdin: [Pattern-based Survey and Categorization of Network Covert Channel Techniques](#), ACM Computing Surveys, ACM, 2015. Early version available for free download [here](#).
- Chapter 3 of: W. Mazurczyk, S. Wendzel, S. Zander, A. Houmansadr, K. Szczypiorski: [Network Information Hiding in Communication Networks](#), Wiley IEEE-Press, 2016.
- S. Wendzel, C. Palmer: [Creativity in Mind: Evaluating and Maintaining Advances in Network Steganographic Research](#), Journal of Universal Computer Science (J.UCS), 2015.

Publications on Fundamentals of Network Covert Channels/Network Steganography:

- W. Mazurczyk, S. Wendzel, S. Zander, A. Houmansadr, K. Szczypiorski: [Network Information Hiding in Communication Networks](#), Wiley IEEE-Press, 2016.
- S. Zander, G. Armitage, P. Branch: [A survey of covert channels and countermeasures in computer network protocols](#), Computing Surveys and Tutorials, IEEE, 2007.
- S. Wendzel, W. Mazurczyk, L. Caviglione, M. Meier: [Hidden and Uncontrolled—On the Emergence of Network Steganographic Threats](#), Proc. ISSE, Springer, 2014.
- J. Lubacz, W. Mazurczyk, K. Szczypiorski: [Principles and overview of network steganography](#), IEEE Comm. Magazine, IEEE, 2014.
- B. Carrara, C. Adams: [A Survey and Taxonomy Aimed at the Detection and Measurement of Covert Channels](#), Proc. 4th ACM Workshop on Information Hiding and Multimedia Security, ACM, 2016.
- C. H. Rowland: [Covert channels in the TCP/IP protocol suite](#), First Monday, Vol. 2(5), 1997.
- S. Wendzel, J. Keller: [Low-Attention Forwarding for Mobile Network Covert Channels](#), Proc. Communications and Multimedia Security, LNCS 7025, pp. 122-133, Springer, 2011.
- several other surveys and papers on the topic exist, cf. Google Scholar.

Websites:

- [Network Information Hiding Patterns Project](#)
- Europol EC3 initiative [Criminal Use of Information Hiding \(CUING\)](#)
- TU Vienna [Network Covert Channel Lab](#), cf. T. Zseby, F. Iglesias Vázquez, V. Bernhardt, D. Frkat, R. Annessi: [A Network Steganography Lab on](#)

Detecting TCP/IP Covert Channels, IEEE Transactions on Education,
IEEE; 2016.