Secure communications below the hearing threshold

Improved approaches for auditive steganography

Marcus Nutzinger Rainer Poisel Jürgen Wurzer

Institute of IT Security Research
St. Pölten University of Applied Sciences, Austria

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Introduction

What? – Cryptology, Cryptography and Steganography

Cryptography

- Study and practice of hiding information
- Protection of secret data
- Data transfer obvious

Steganography

- Science of covert communication
- Conceals the existence of secret information

Cryptology

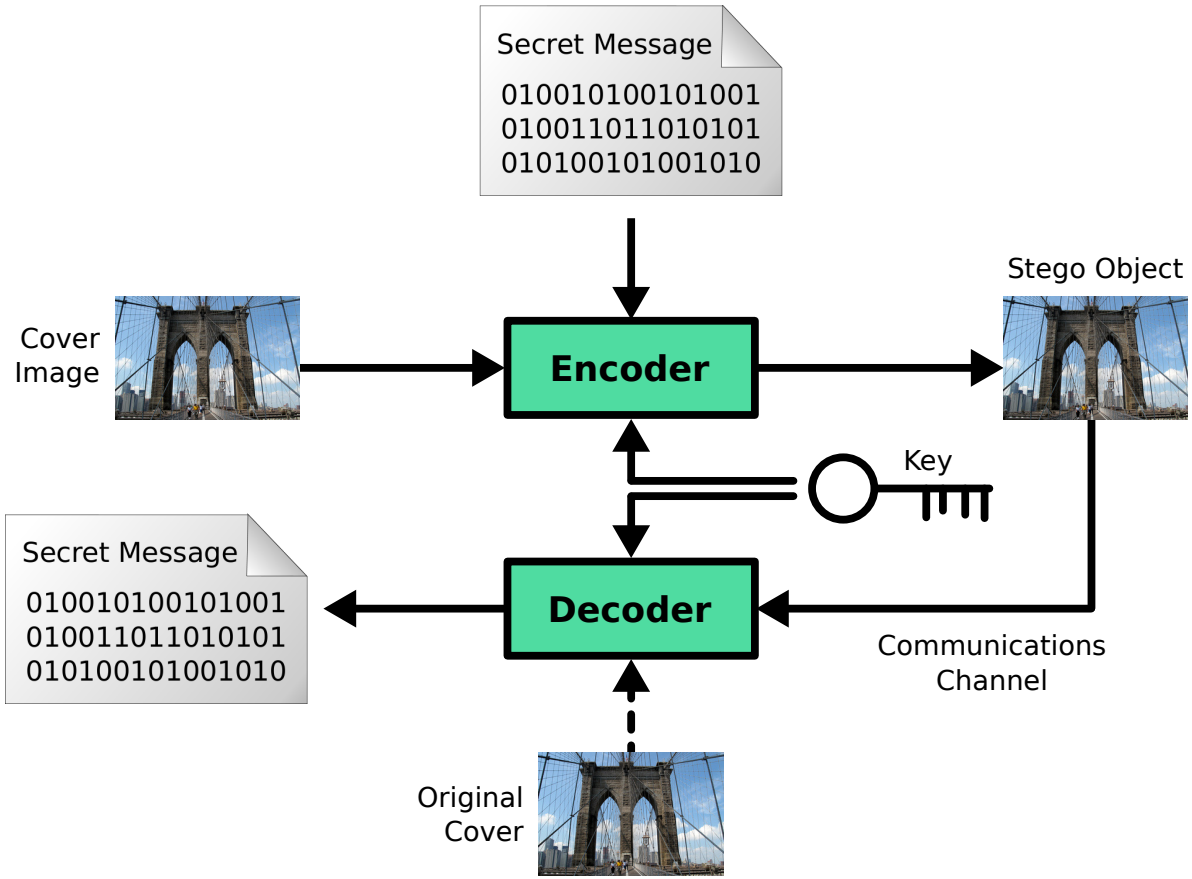
Science that incorporates both cryptography and cryptanalysis.

Introduction

What? – Steganography in Brief

Different cover media

- Technical steganography: digital images, audio and video files



Introduction

Why? – Filtering of Internet Services and Applications

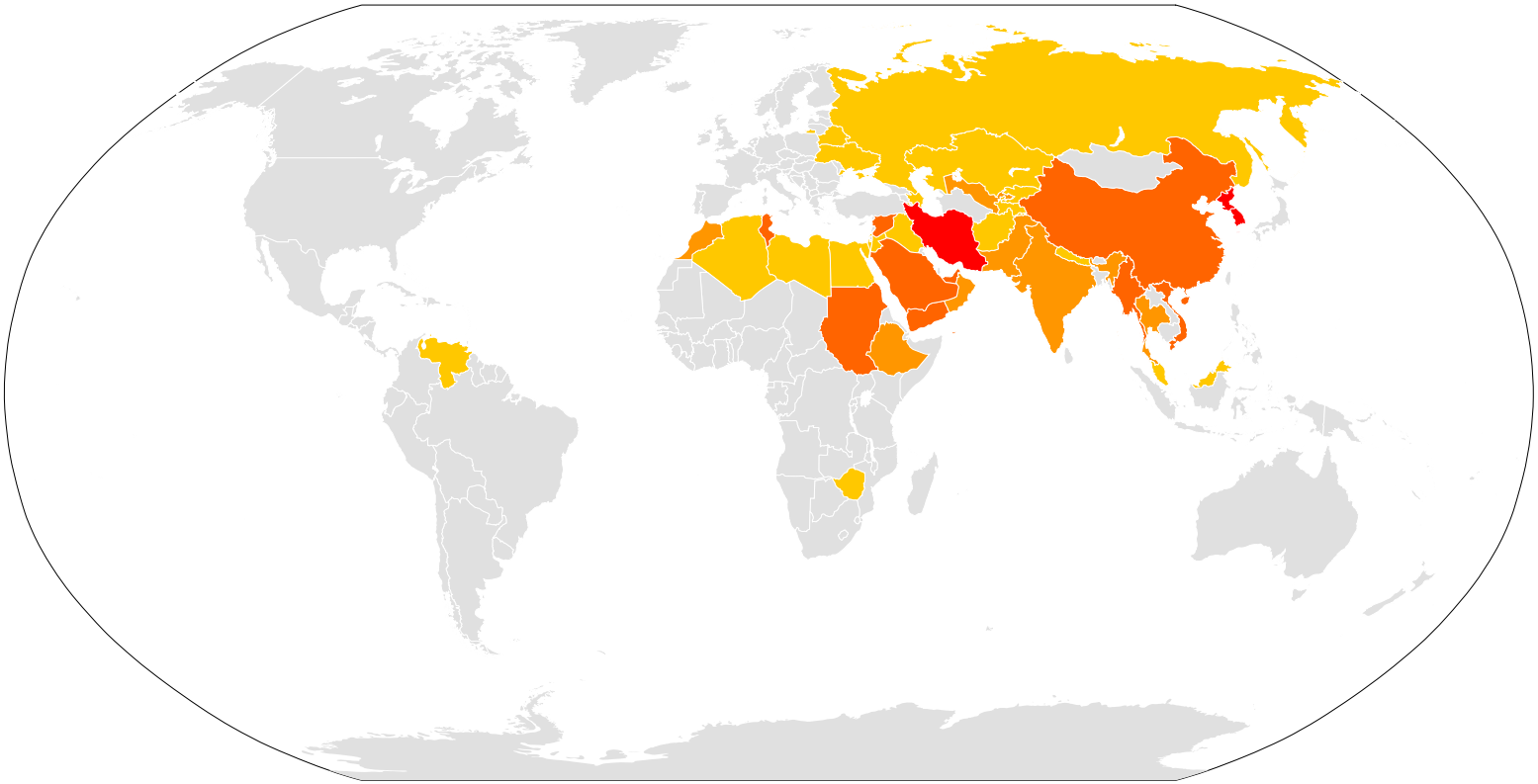
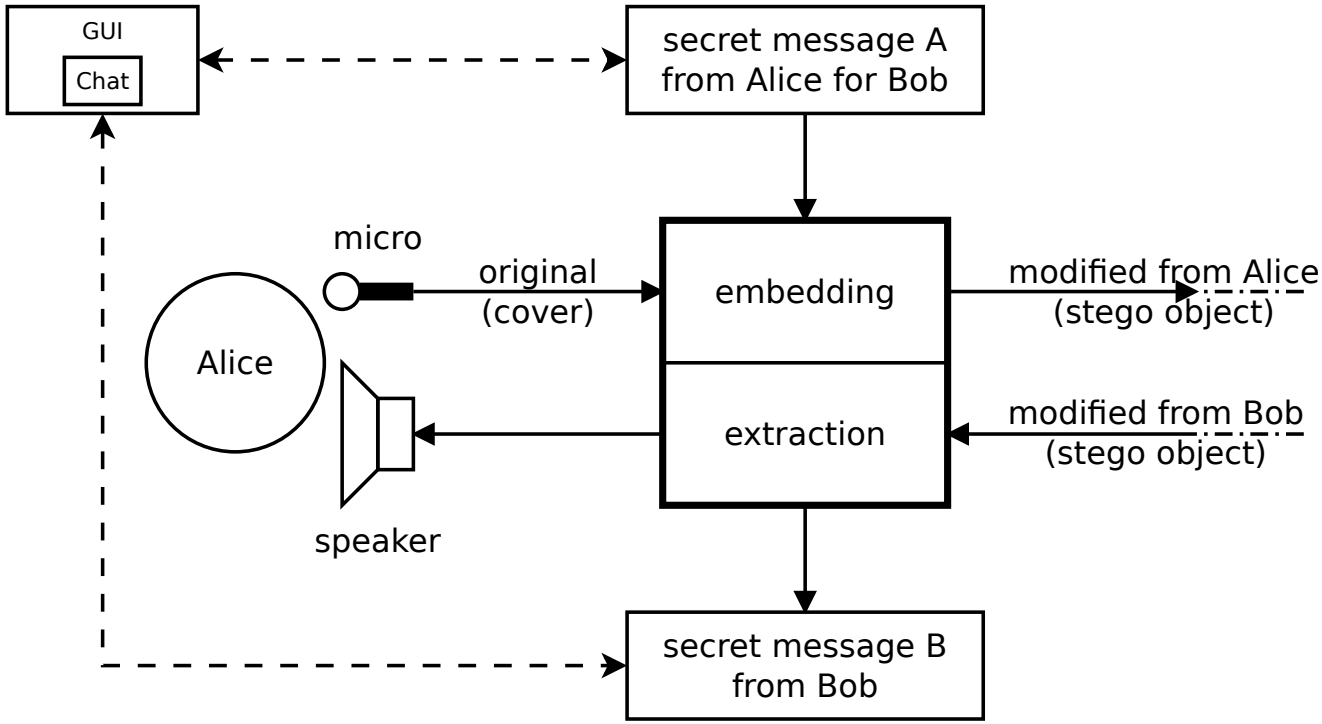


Figure: Worldmap of internet filtering (Source: OpenNet Initiative, 2010)

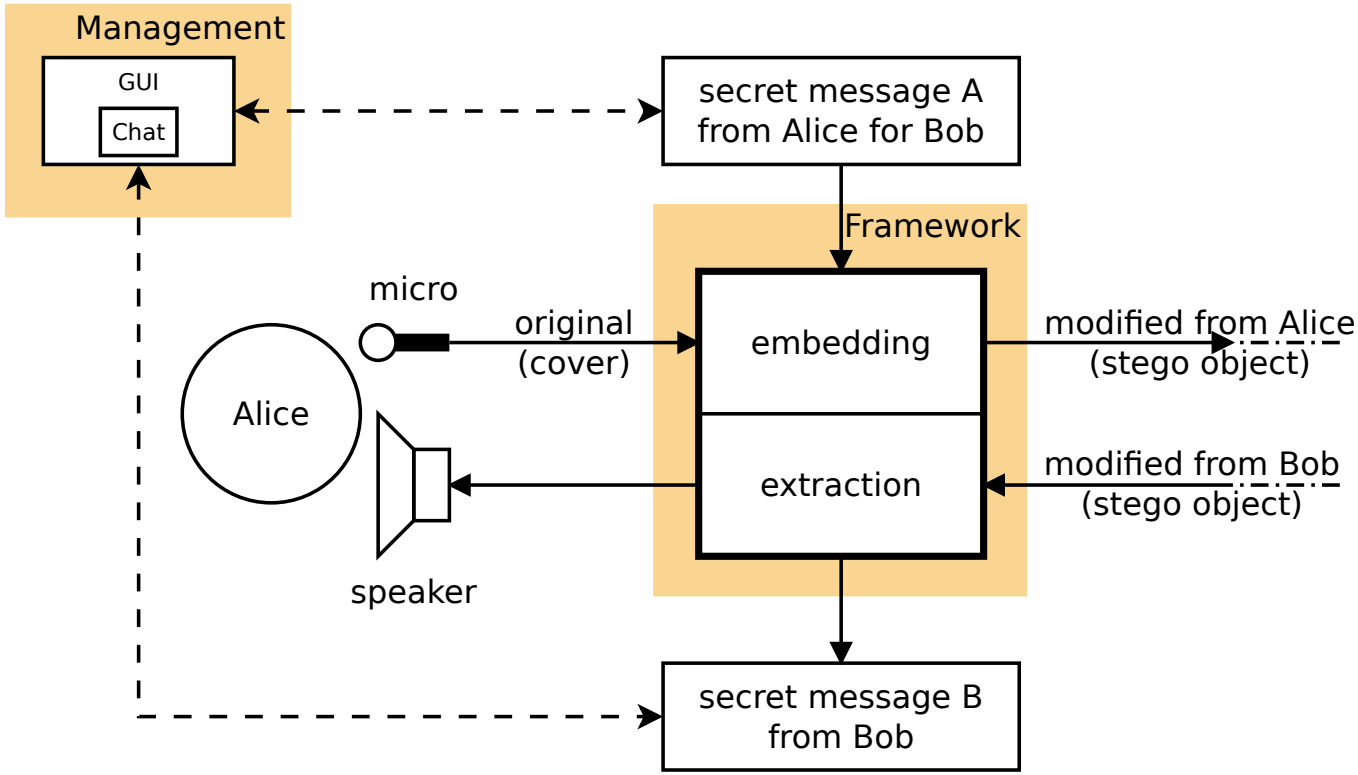
Functional Overview

How? – The Framework



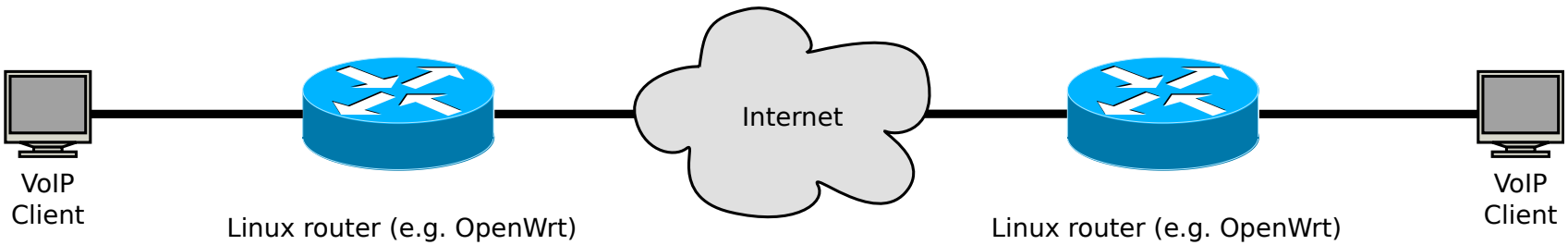
Functional Overview

How? – The Framework



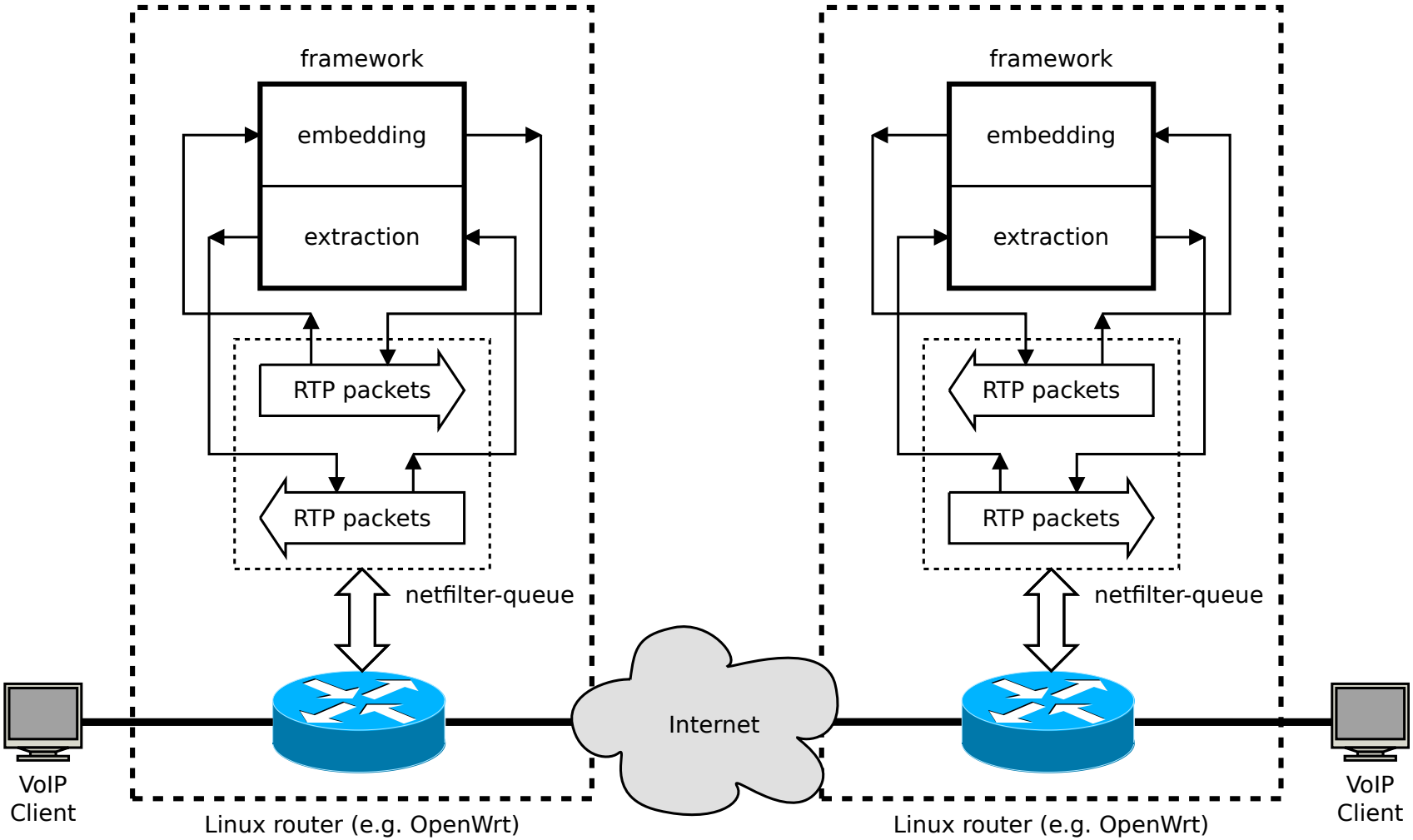
Functional Overview

Cover Media – VoIP



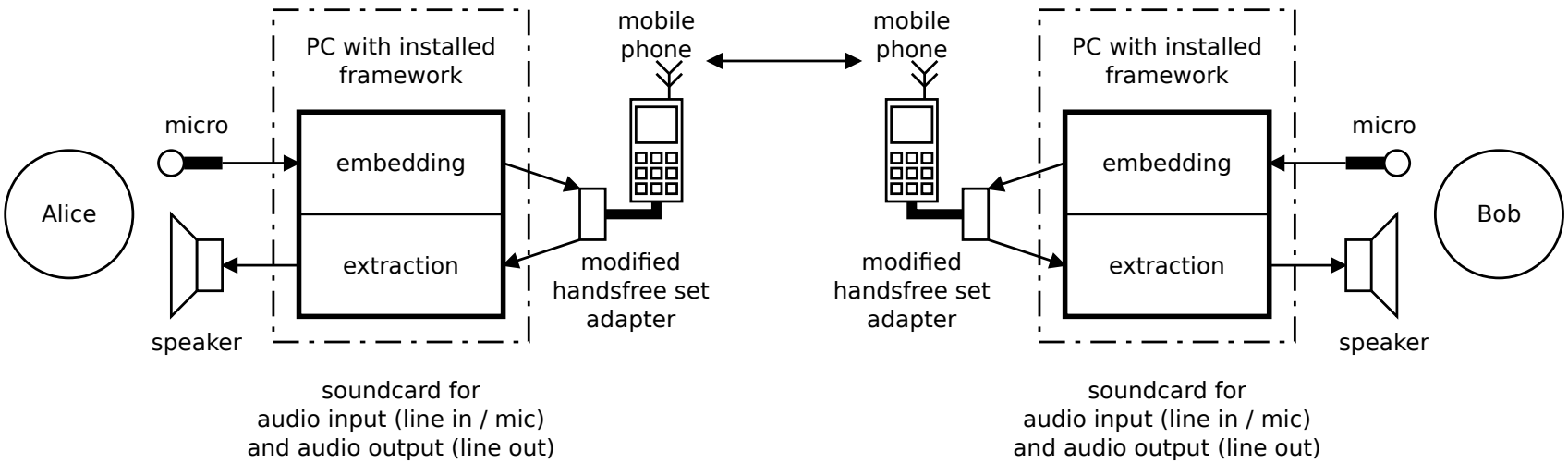
Functional Overview

Cover Media – VoIP



Functional Overview

Cover Media – GSM



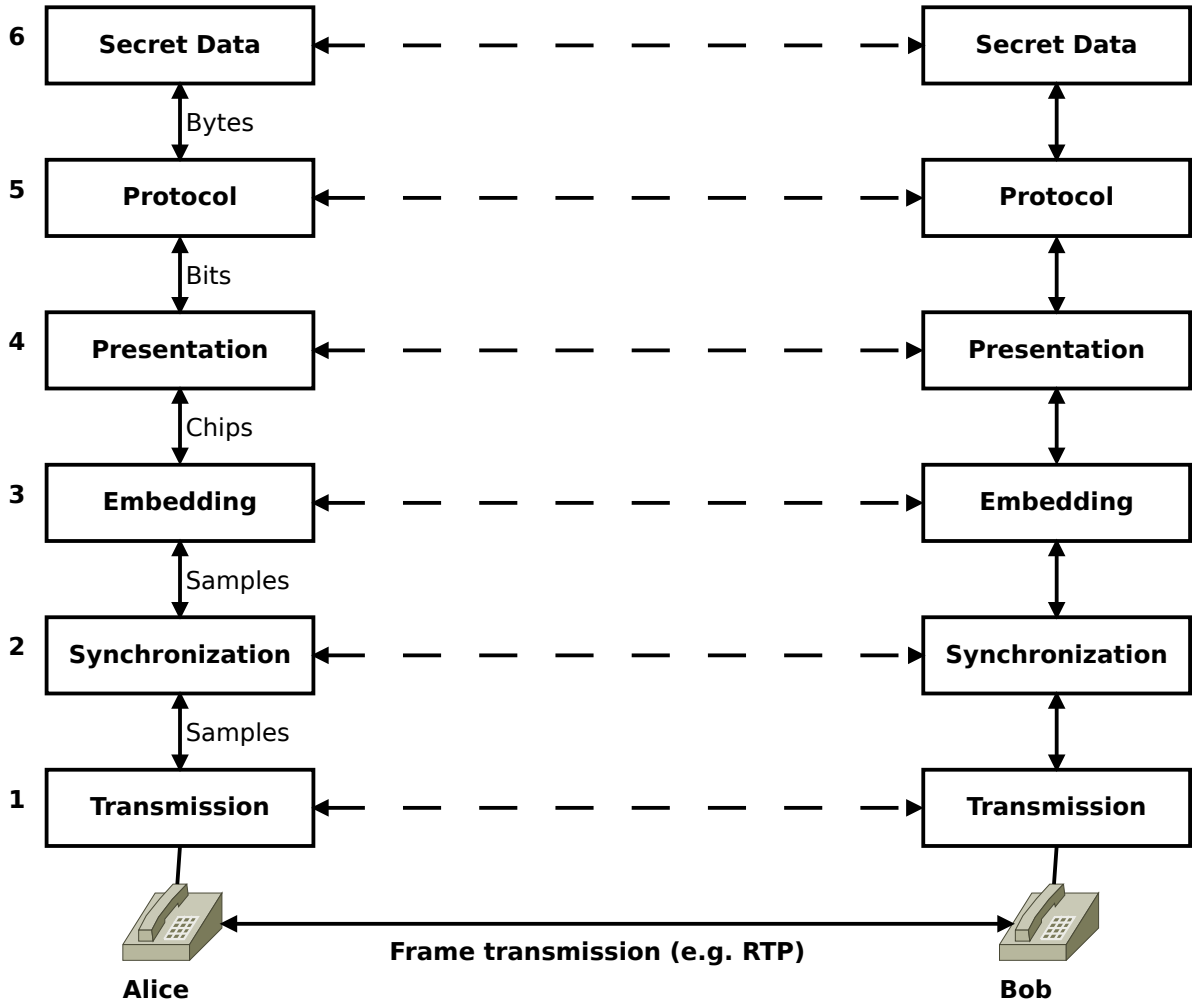
Layered Model

Tasks | Components

- Embedding secret data into the cover medium
- Protocol for data flow handling
  - Integrity checks
  - Segmentation of secret data
  - Acknowledgements
  - Sequence numbers
- Management of component instantiation
- Interfaces for third party software

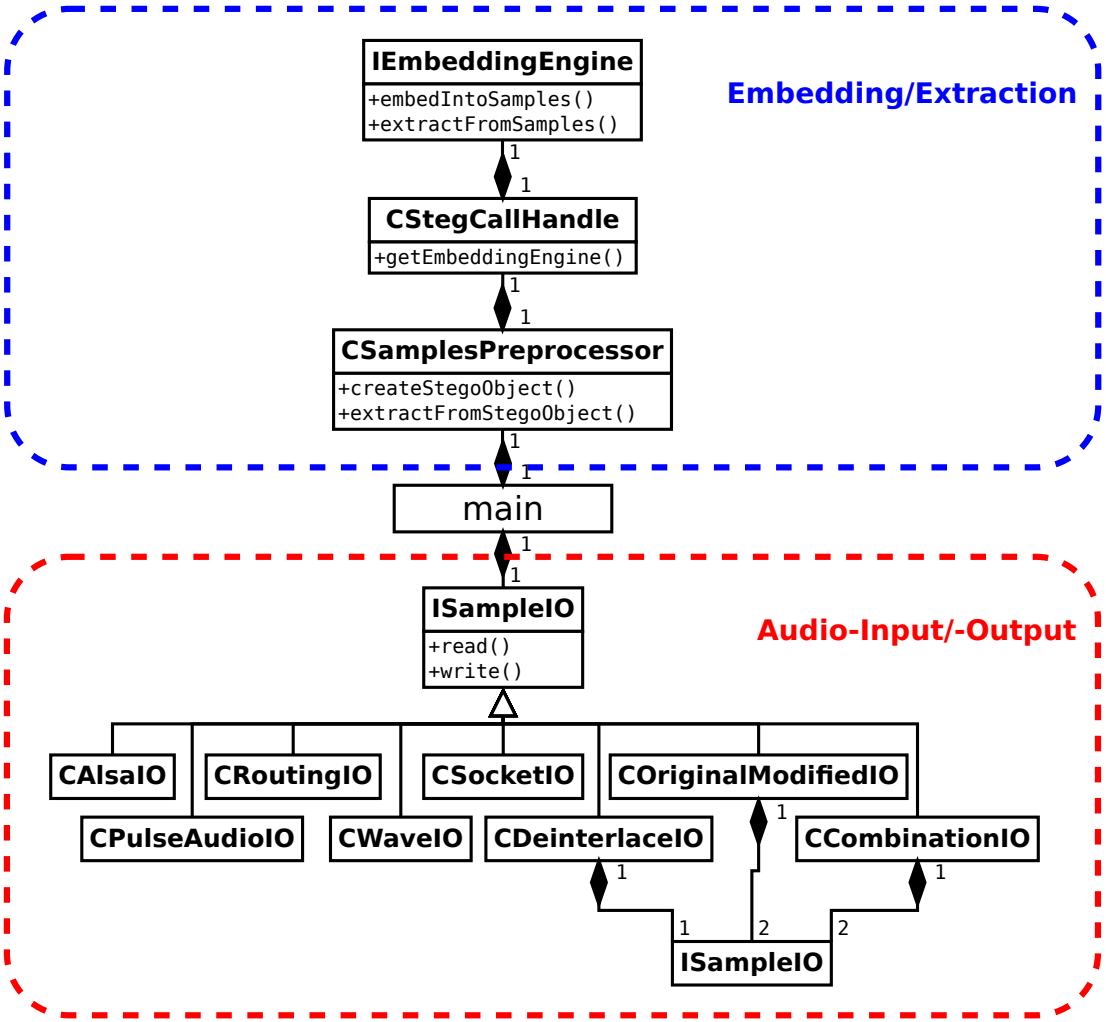
Layered Model

Steganographic Data Exchange



Layered Model

Software Architecture of the IO-components



Steganographic Algorithms

Overview

"Digital" Algorithms

- Samples are processed independently
- Codec-specific
  - LSB Hiding

"Analogue" Algorithms

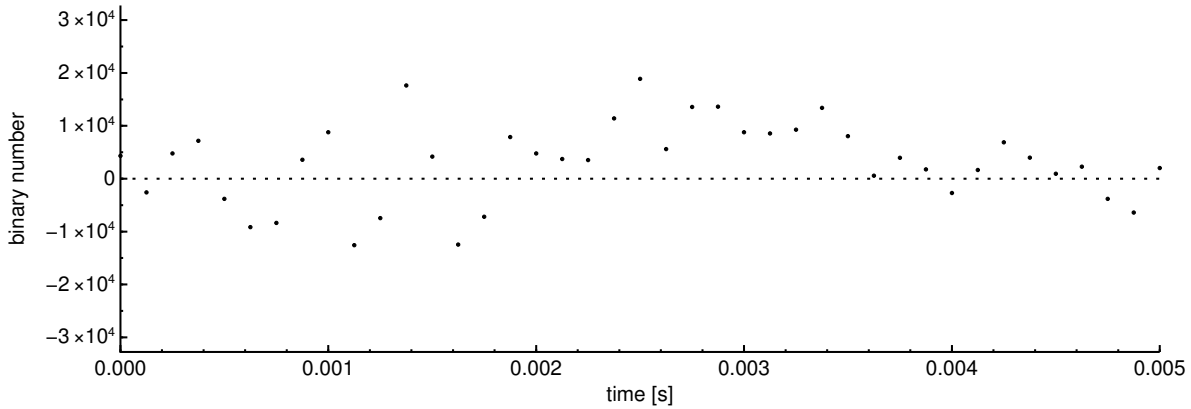
- Number of samples is seen as contiguous signal
  - Echo Hiding – time domain
  - Spread Spectrum – time or frequency domain
  - Phase Coding – frequency domain

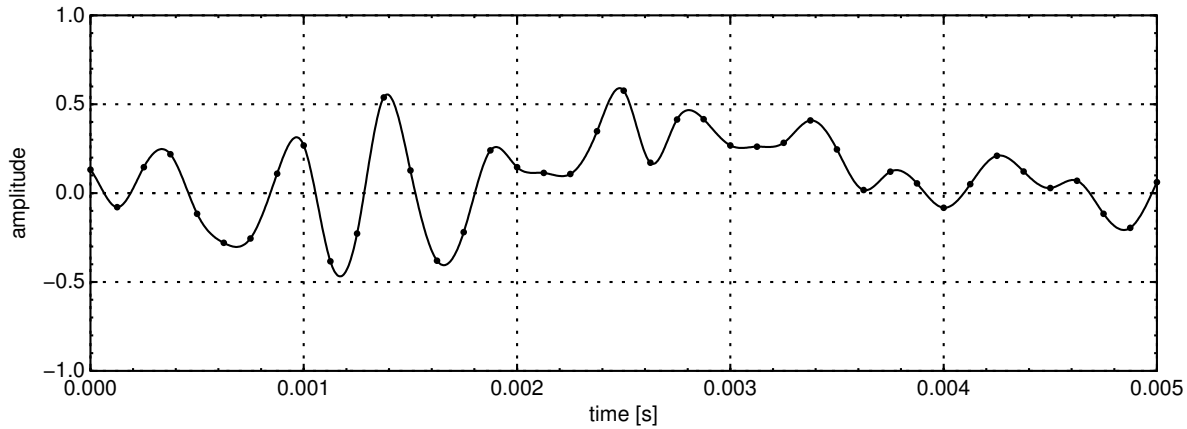
Steganographic Algorithms

Analogue Representation

From audio format (PCM, MP3, . . .) to floating-point

- Decoding of coded sample values before modification



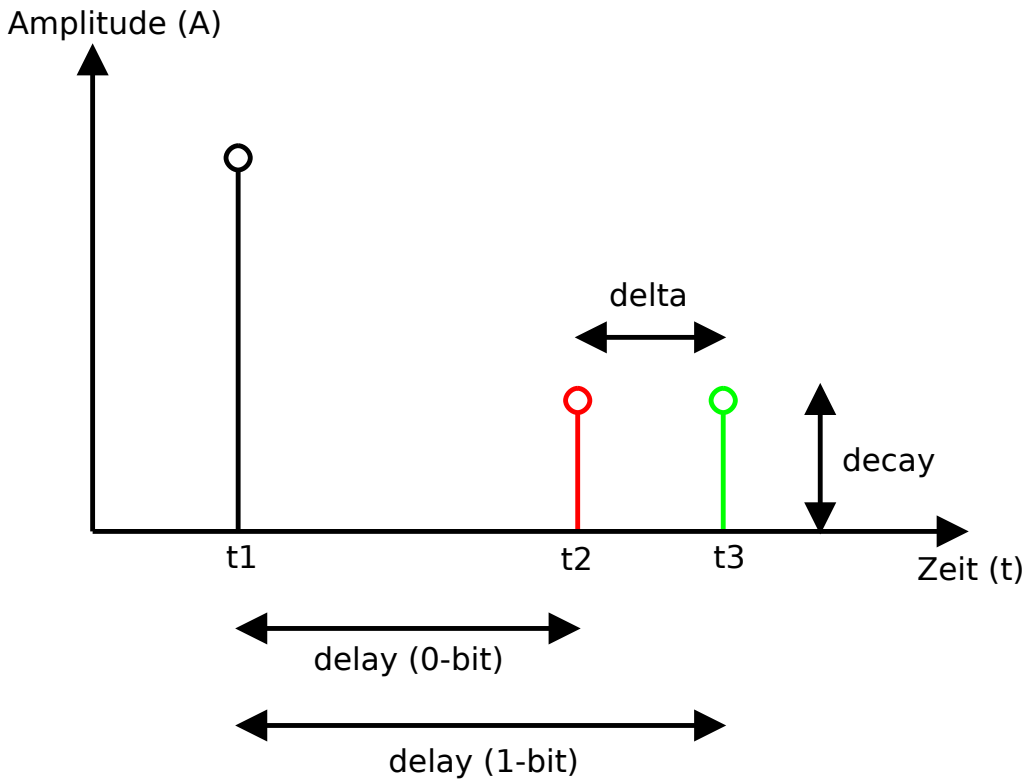


Steganographic Algorithms

Echo Hiding

Three important parameters

- Delay, decay and space between chosen delays
- Further: blocksize



Steganographic Algorithms

Echo Hiding

Echo generation

- Addition of delayed and decayed part of signal

Echo detection

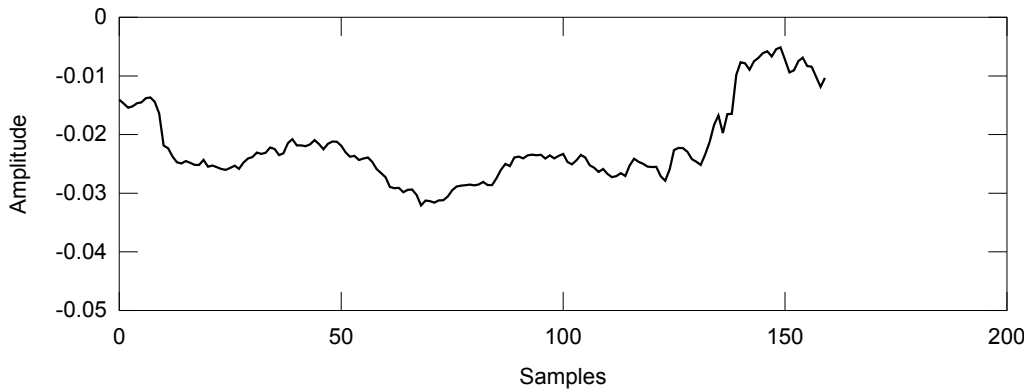
- Calculation of *Cepstrum*
- FFT and log
- Seperates periodic parts (i.e. echos) and signal
- Idea: Periodic parts shown as peaks

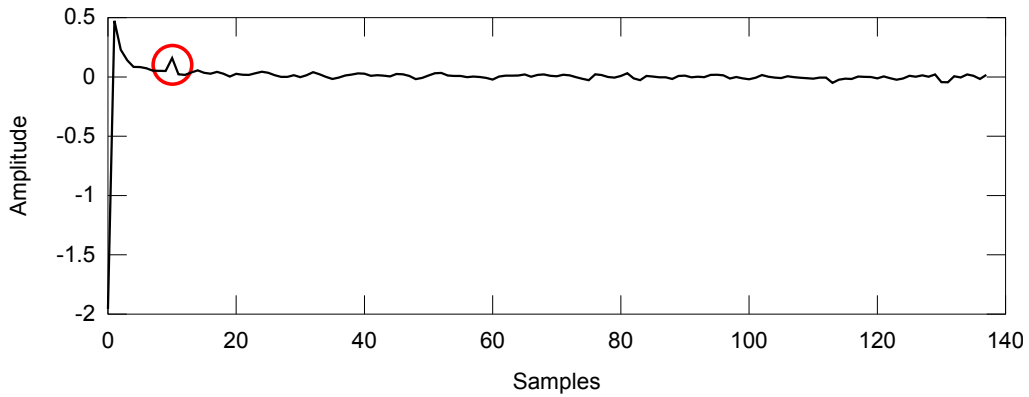
Steganographic Algorithms

Echo Hiding

Example

- $f_s = 8kHz$, $delay = 1.25ms$
- Not always as reliable (silent parts, natural echos, . . .)



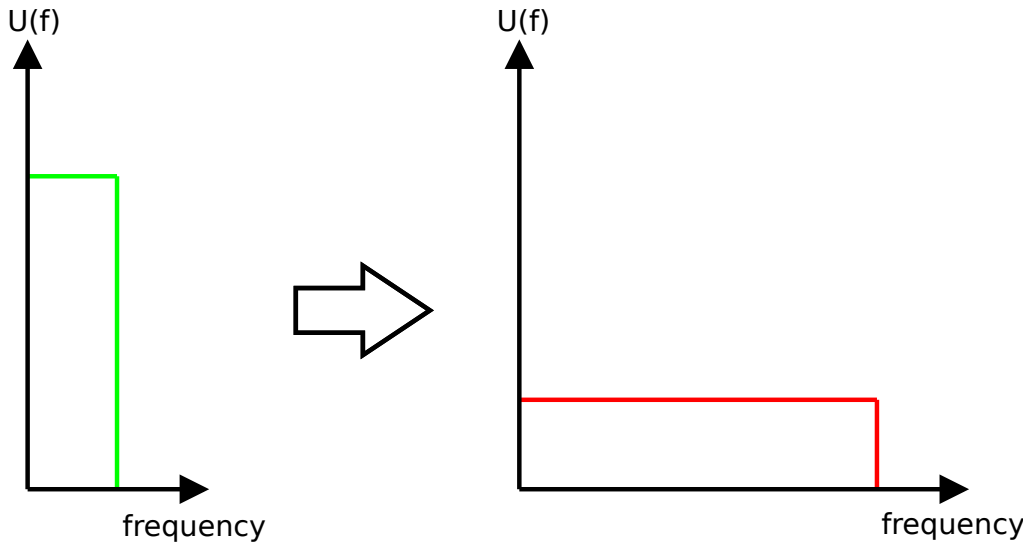


Steganographic Algorithms

Spread Spectrum

Overview

- Narrow band signal is spread over a large bandwidth
- Signal vanishes in noise floor
- Spreading code is needed for retrieval
  - Has to be exchanged before communication
  - Can be generated via PN-sequence generator (LFSR)

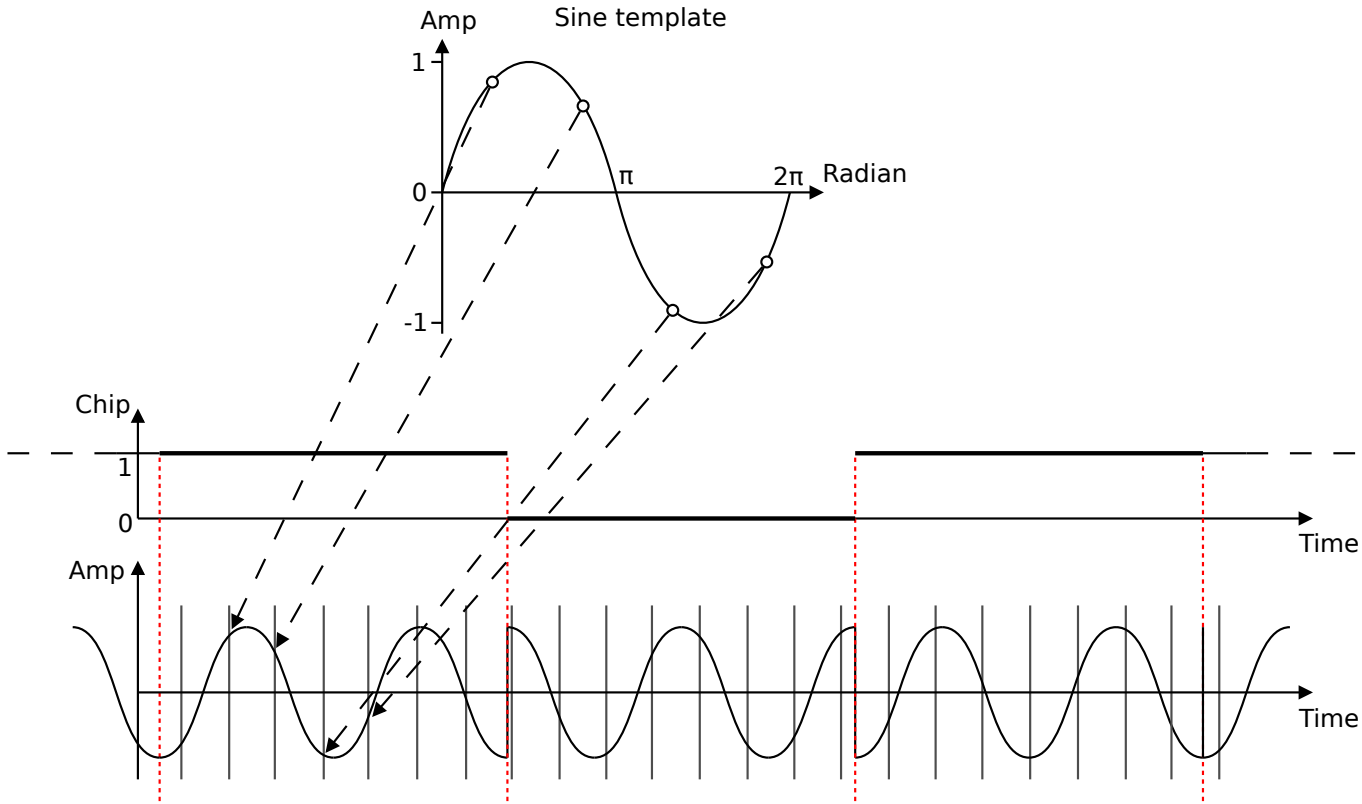


Steganographic Algorithms

Spread Spectrum

Spreading process

- BPSK modulation with sine carrier (variable frequency)
- Specific samples are calculated on-the-fly from template

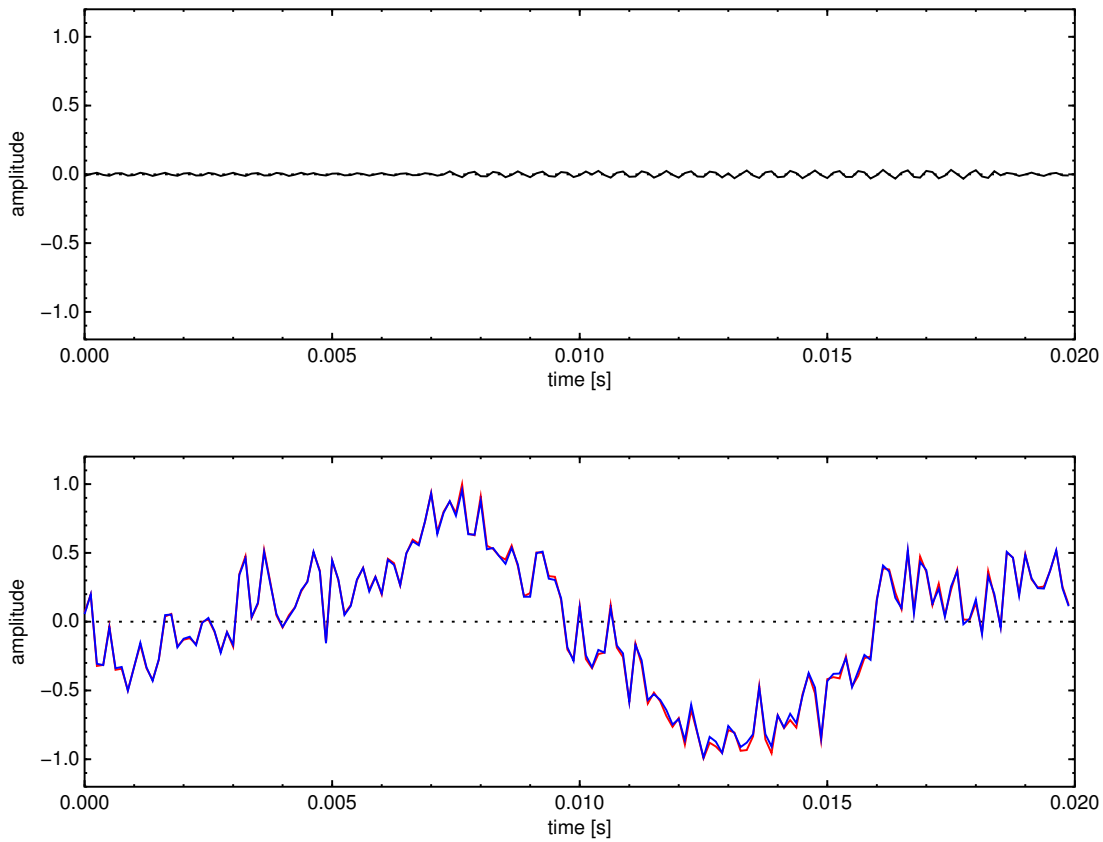


Steganographic Algorithms

Spread Spectrum

Example – Embedding

- Add modulated chip sequence to audio signal
- Red = original signal, blue = modified signal

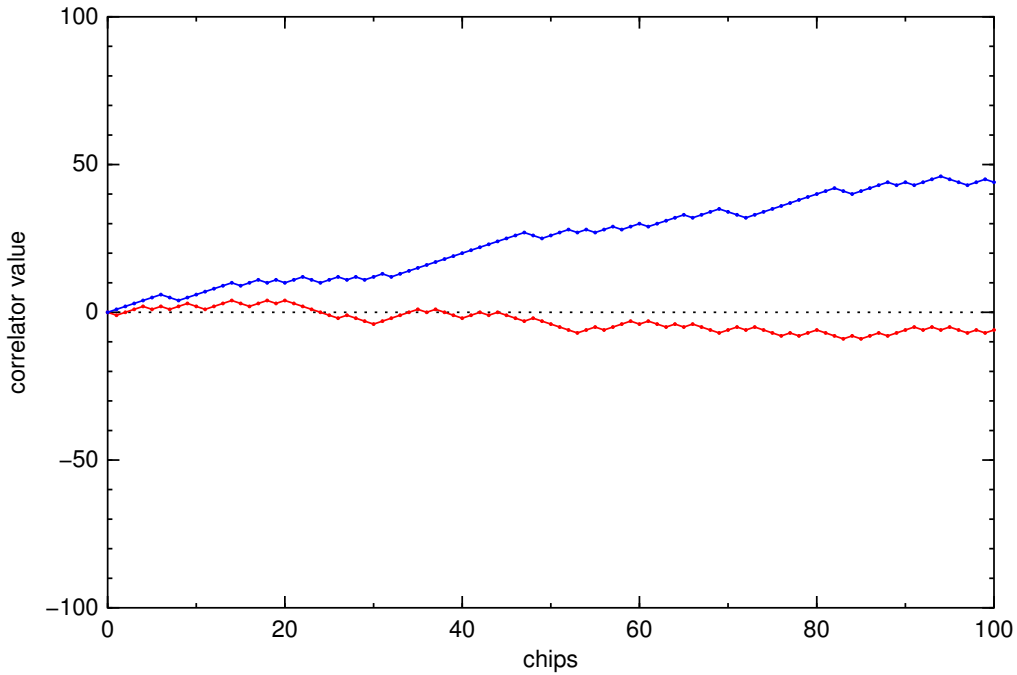


Steganographic Algorithms

Spread Spectrum

Extraction

- Multiplication of received signal with sine carrier
- Mean value over chip time as input for correlator
- Correlation against both chips sequences
- Example: blue = matching sequence

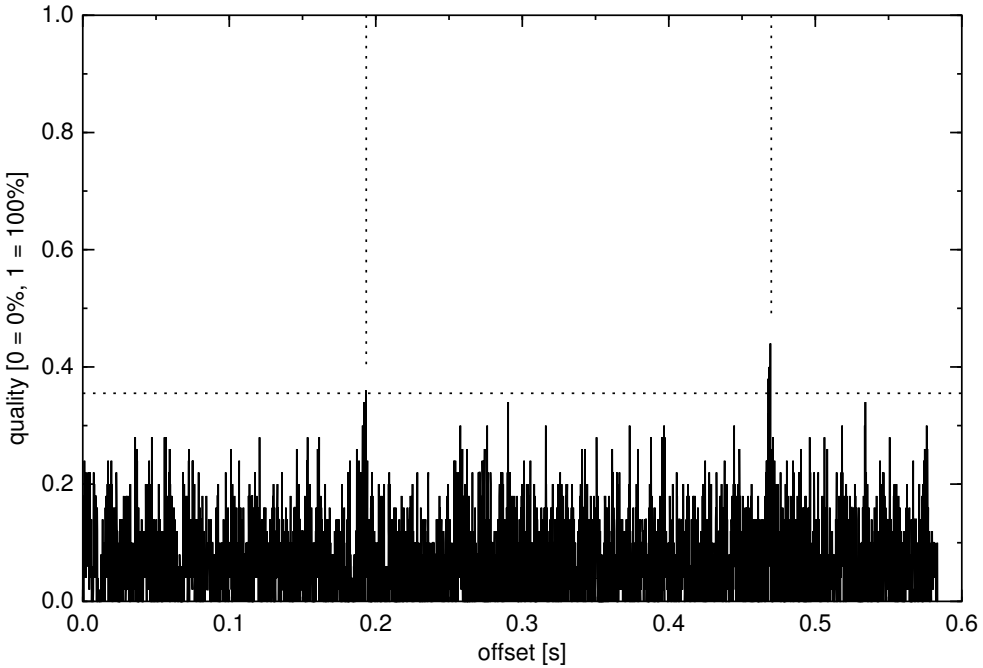


Steganographic Algorithms

Spread Spectrum

Extraction – Synchronization

- Important issue for spread spectrum communication
- Searching the chip sequence start offset
- Compute correlator value for various possible offsets
- Example: histogram of bit quality by time offset

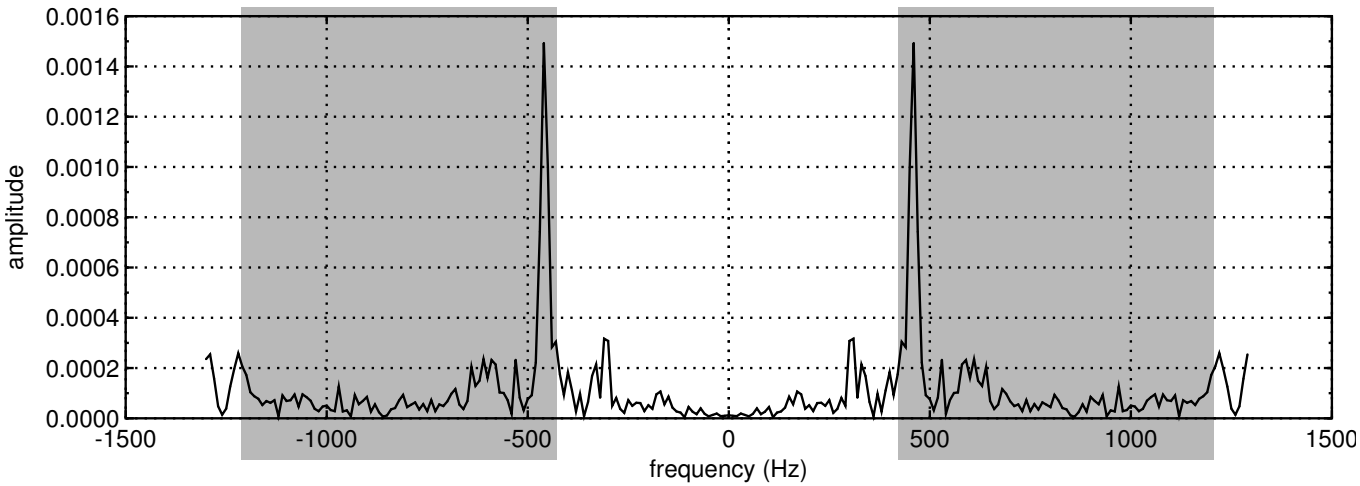


Steganographic Algorithms

Phase Coding

Representation of the audio signal

- FFT of configured time duration ⇒ embedding delay
- For embedding, selection of affected frequency range possible
- Example:
  - chosen frequency interval [400,1200]
  - negative frequencies are modified accordingly

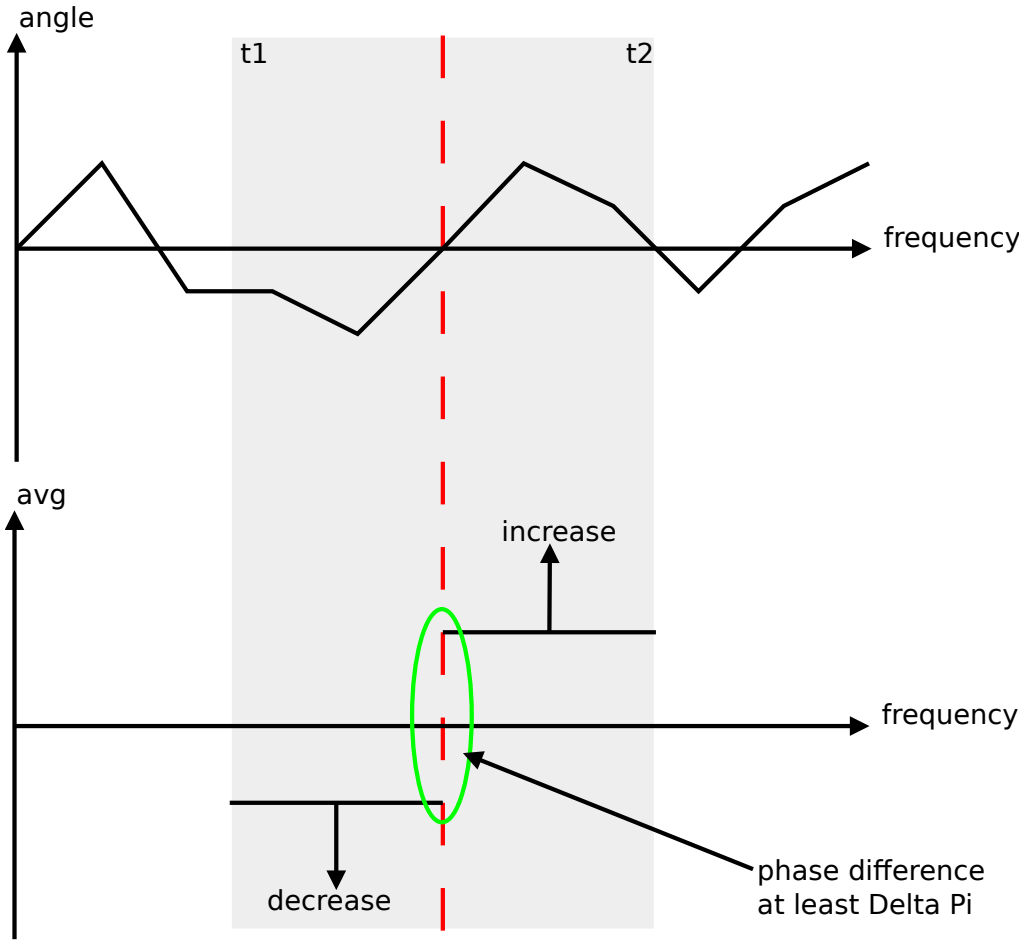


Steganographic Algorithms

Phase Coding

Embedding via phase difference

- Mean value of adjacent parts of signal is adjusted

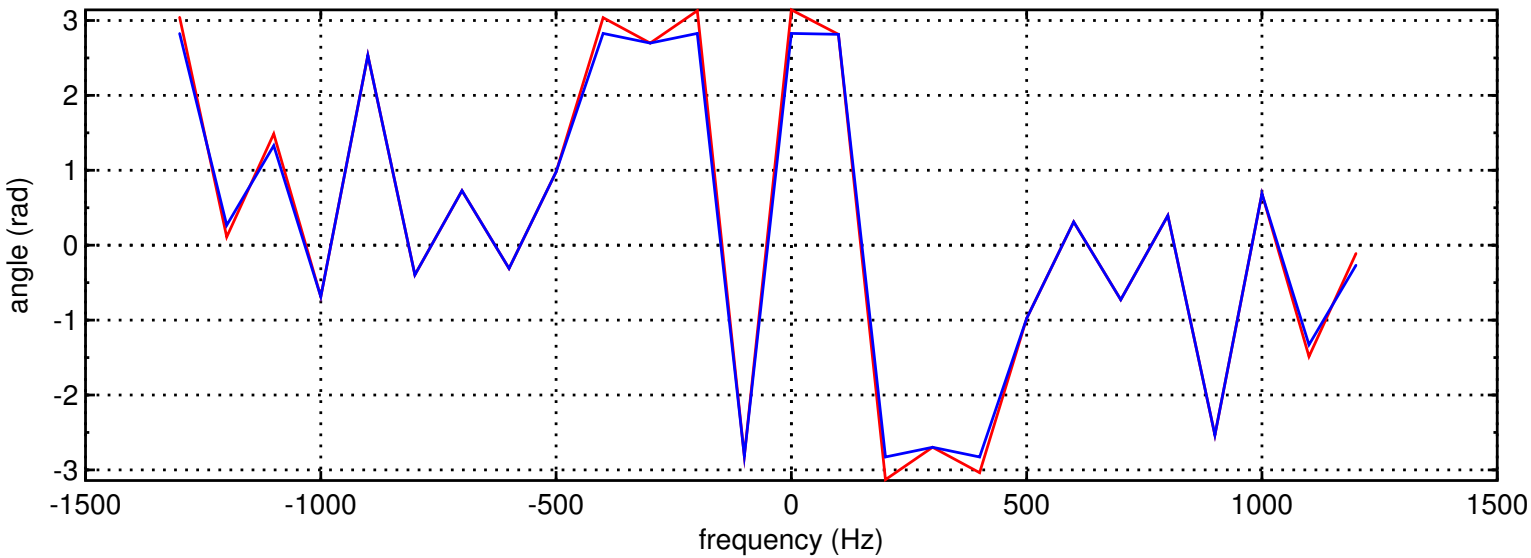


Steganographic Algorithms

Phase Coding

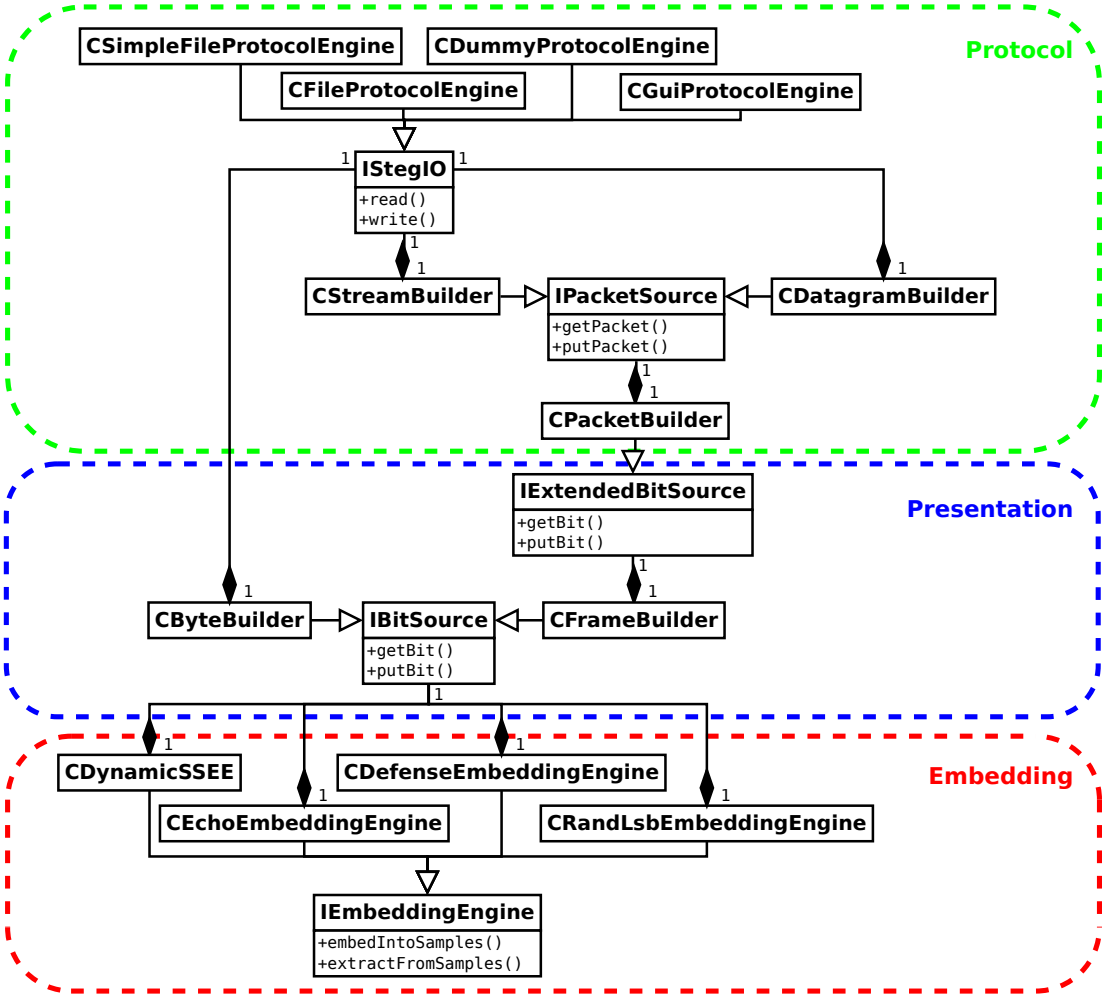
Example

- Minimum phase difference $= \pi/10$
- Red $=$ original phase, blue $=$ modified phase



Steganographic Algorithms

Software Architecture of the Embedding Components



Defense

Analyzing Robustness

- No steganalysis
- Different approaches
  - Noise
  - Jitter
  - Frequency shifting (semitone)
  - Signal cancelling

Implementation

Platforms - Commodity Hardware

Mipsel

- Asus WL-500g Premium v1, based on Broadcom 4704
- (modified) OpenWrt SDK
- Port to other platforms:
  - Routing-Interface
  - Audio-Interface

OpenWrt SDK: Adaptions

- Support for NFQUEUE
- Additional packages added
- Customized firewall settings
- Customized start scripts

Implementation

Platforms - Mobile- and Smartphones

Possibly usage on smartphones

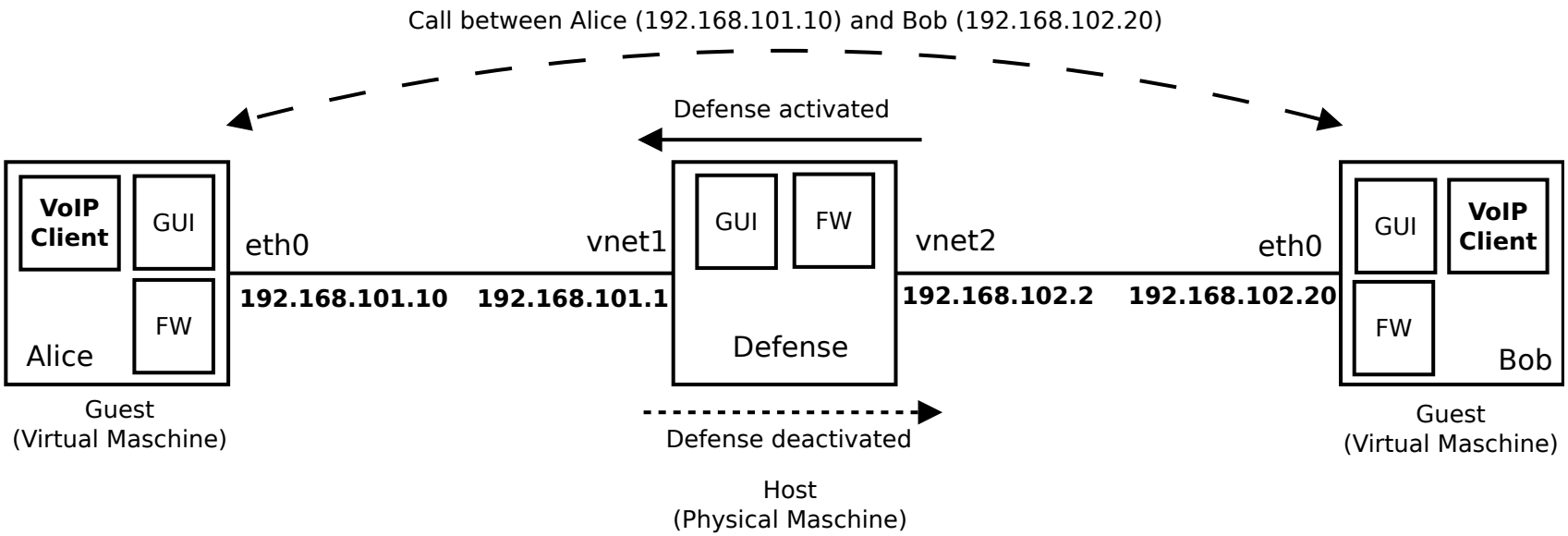
- currently only Linux based phones considered
- e. g. Android powered smartphones
  - NDK allows for reuse of our C++ codebase

Scenarios

- VoIP
- Raw Voice-Data

Demonstration

Setup



Outlook

Future scenarios

- Video streams as cover medium
- Windows-Port
- Better usability
- Improved data throughput
- Smaller, more powerful devices
- Use of steganographic loaders

Thank you for your attention!
Any questions?