Unobservable Covert Streaming for Internet Censorship Circumvention

Síntese de Vídeo para Evasão de Censura na Internet

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Repressive regimes monitor Internet access

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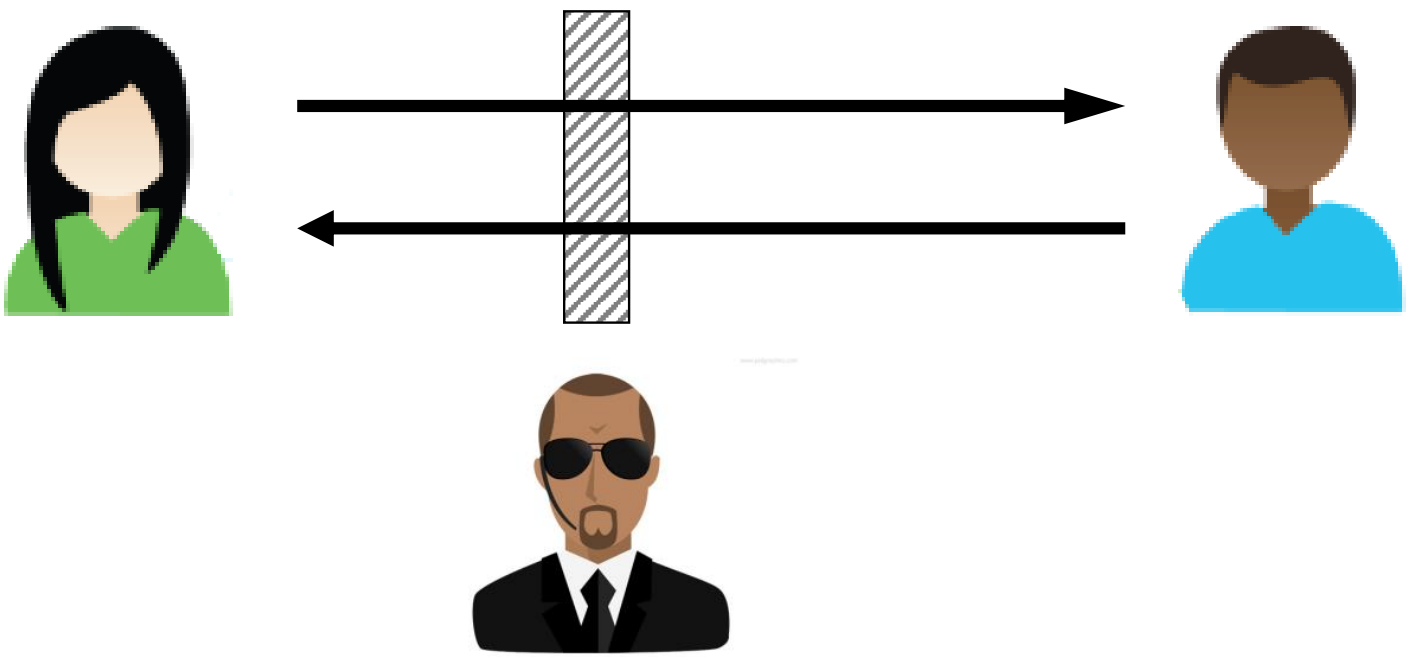

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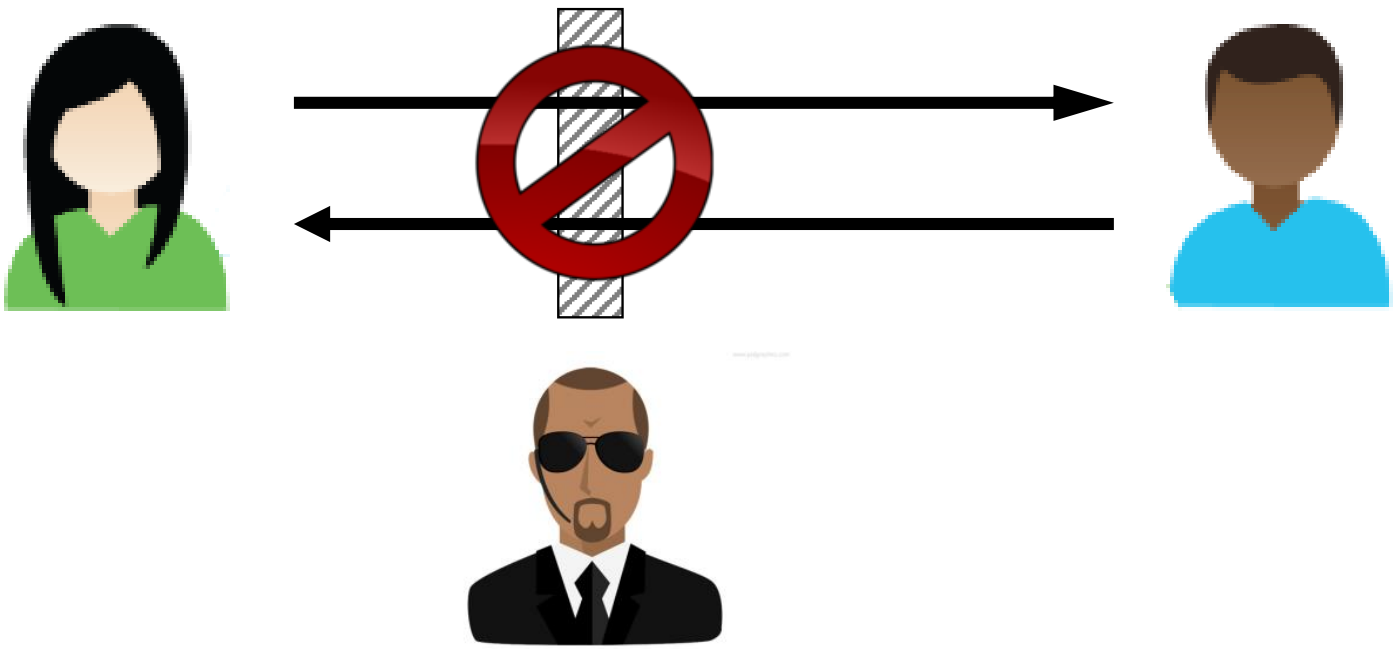
Censors monitor tra□c flows

- Citizens may be prevented from accessing/publishing information



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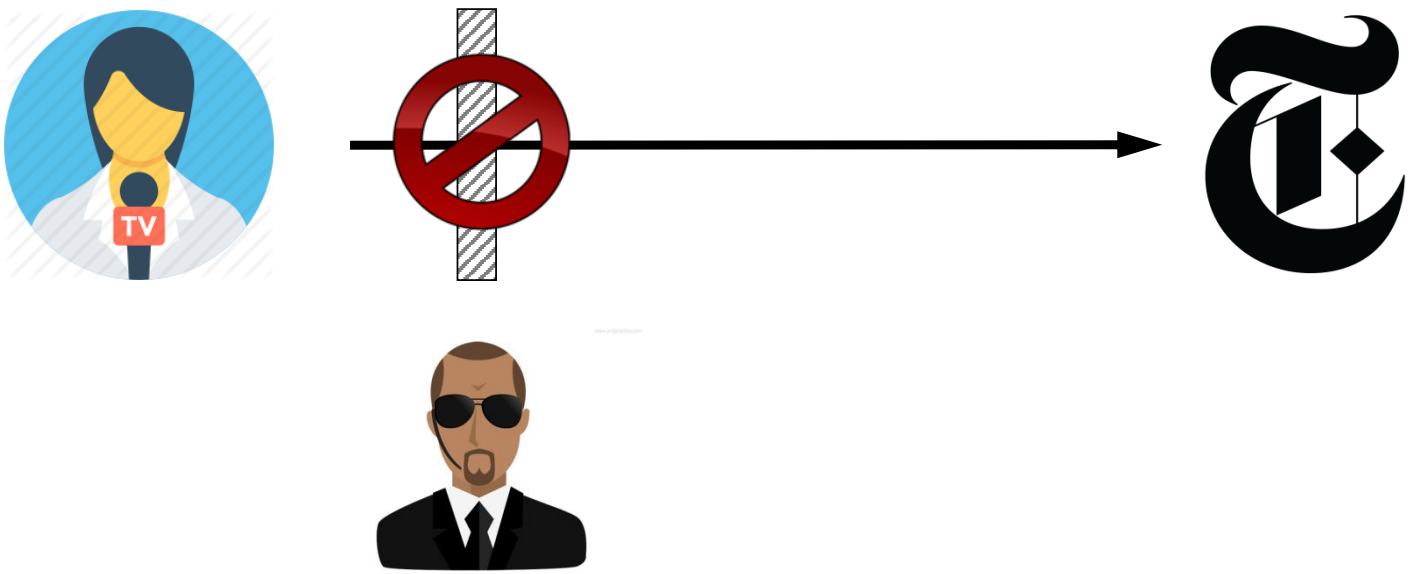

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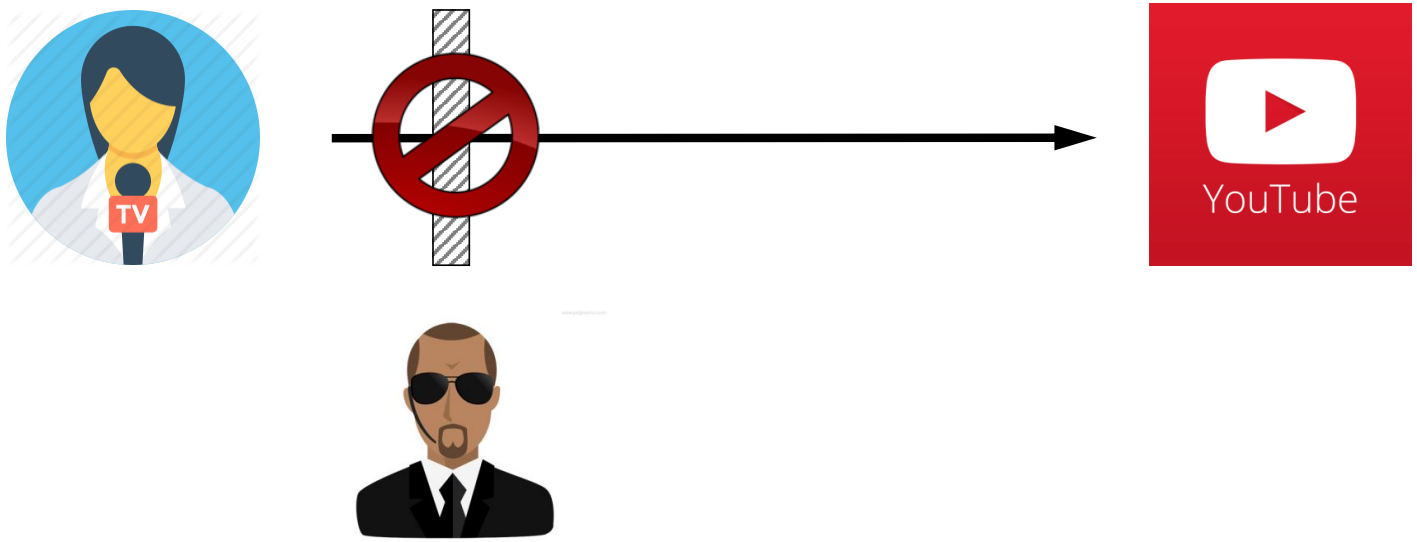

The censor avoids blocking all communication channels

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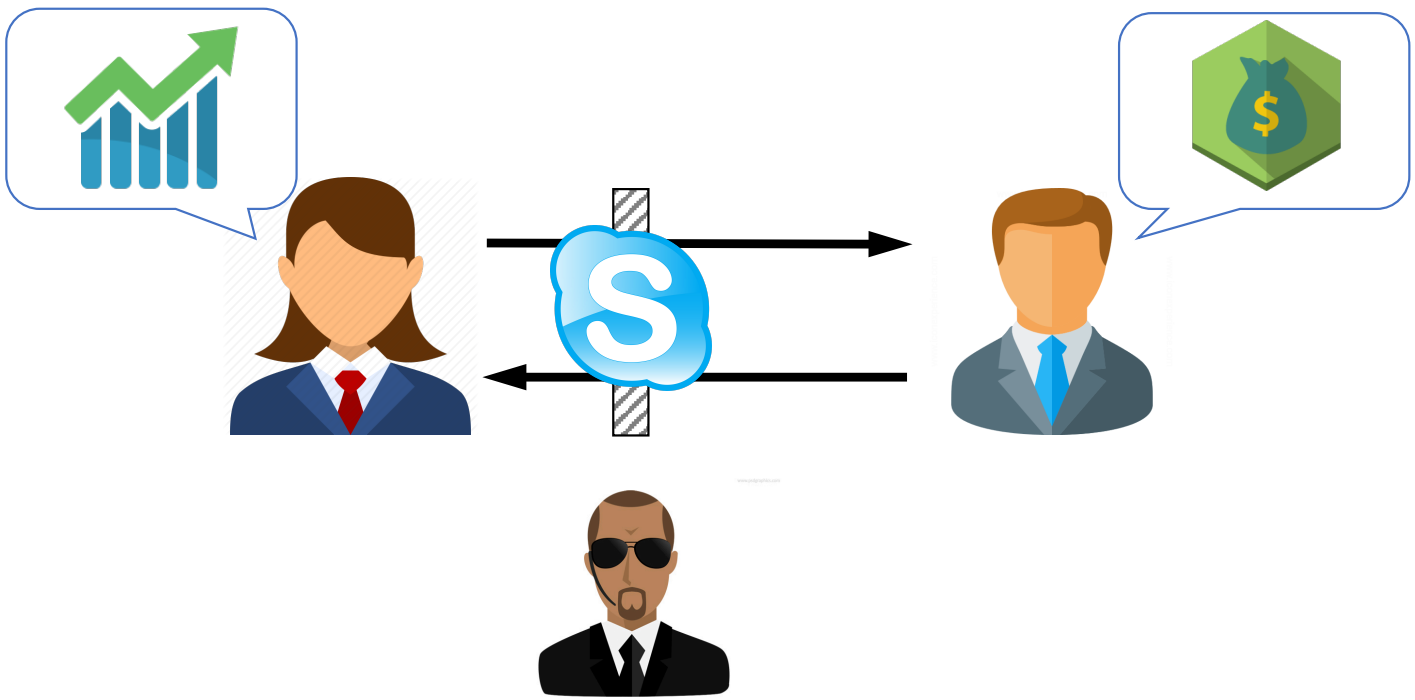
Preservation of critical communication services

- Important to assure the regime's sustainability



How does the censor block rightful information?

Several techniques:

- HTTP requests filtering
- DNS Hijacking
- Blocking of IP ranges

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Detection / blocking of covert channels

- Network Perturbations (Active Attacks)
- Statistical Tra□c Analysis (Passive Attacks)

Tunneling data through multimedia protocols

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Desirable characteristics:

- Resistance to active/passive attacks
- Arbitrary data transmission
- Interactive communication
- Reasonable throughput

Paper contributions

This paper proposes a censorship resistant communication system which o□ers the transmission of data:

- Through TCP/IP
- Without the need to change client/server applications
- Resistant against active attacks
- Resistant against *state-of-the-art* tra□c analysis

Agenda

1. Introduction
2. Our solution
   - Threat Model
   - Design
   - Implementation
3. Evaluation
4. Conclusions

Threat Model

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Hypothesis

- The video-conferencing application encrypts the content of the packets carrying multimedia data (ex: Skype)

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Censor's Capabilities:

- *Deep Packet Inspection*
- Observe, store and analyze tra□c flows
- Apply artifical constraints on the network

Threat Model

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- The video-conferencing application encrypts the content of the packets carrying multimedia data (ex: Skype)

Censor's Capabilities:

- *Deep Packet Inspection*
- Observe, store and analyze tra□c flows
- Apply artifical constraints on the network

Censor's Limitations:

- Unable to decipher the content of Skype packets
- Not in collusion with the video-conferencing service provider
- Attempts to minimize collateral damage

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Agenda

Communication Model

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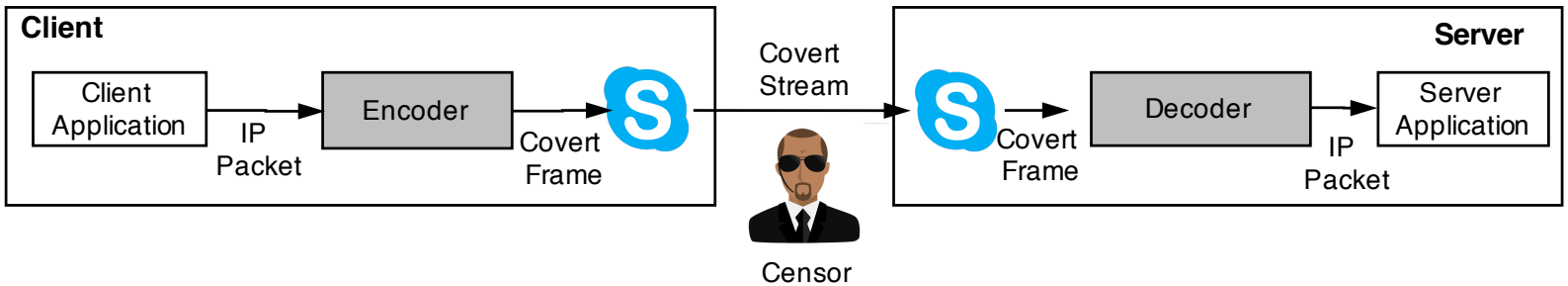

Allow the communication between client/server applications:

- through TCP/IP
- modulating data into video-frames
- sending the modified frames through Skype

Design Challenges

1. Conflicting encoding requirements
   - Data tunneling changes the patterns of Skype streams
2. Preserve the signature of legitimate Skype tra□c
   - Characterize Skype streams
3. Periodic adaptation
   - Skype streams' patterns are a□ected by network conditions
4. Synchronization resistant to active attacks
   - The censor may attempt to prevent the channel's synchronization

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How to encode IP packets into video?

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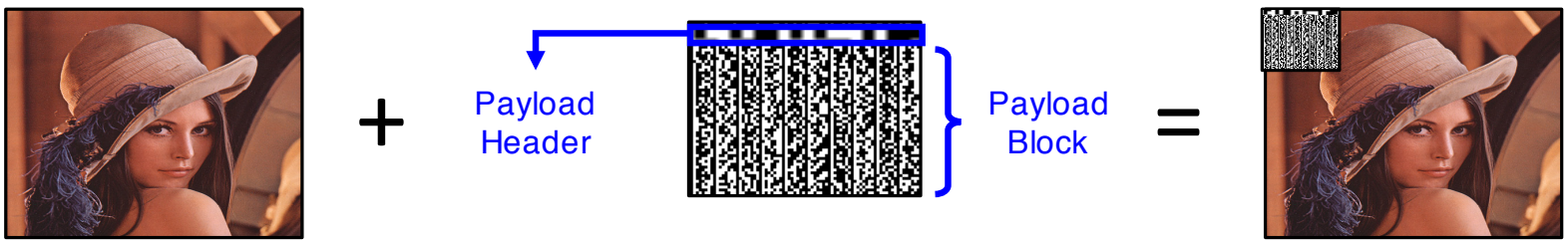
1 - Conflicting encoding requirements

Encoding of IP packets in pixels



(a) Carrier Frame (b) Payload Frame (c) Covert Frame

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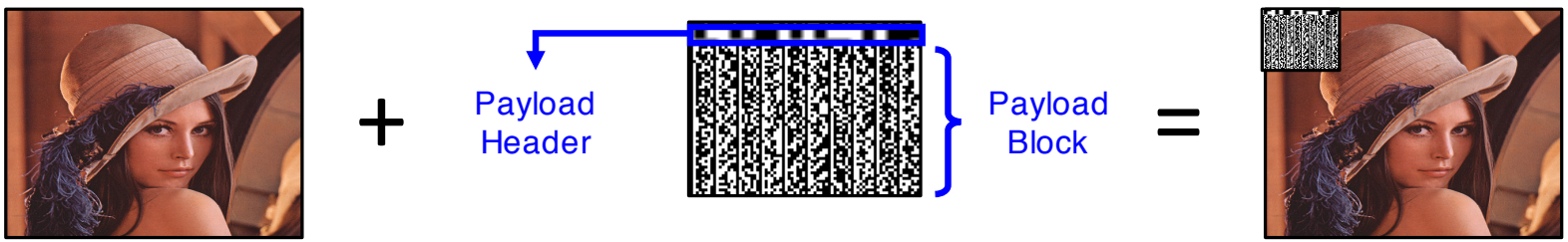

(a) Carrier Frame (b) Payload Frame (c) Covert Frame

Name	Description
s_p	payload frame area (pixel$\times$pixel)
s_c	cell size (pixel$\times$pixel)
b_c	color encoding (bits)
r_p	payload frame rate (frames/s)

How to find a balance between observability and throughput?

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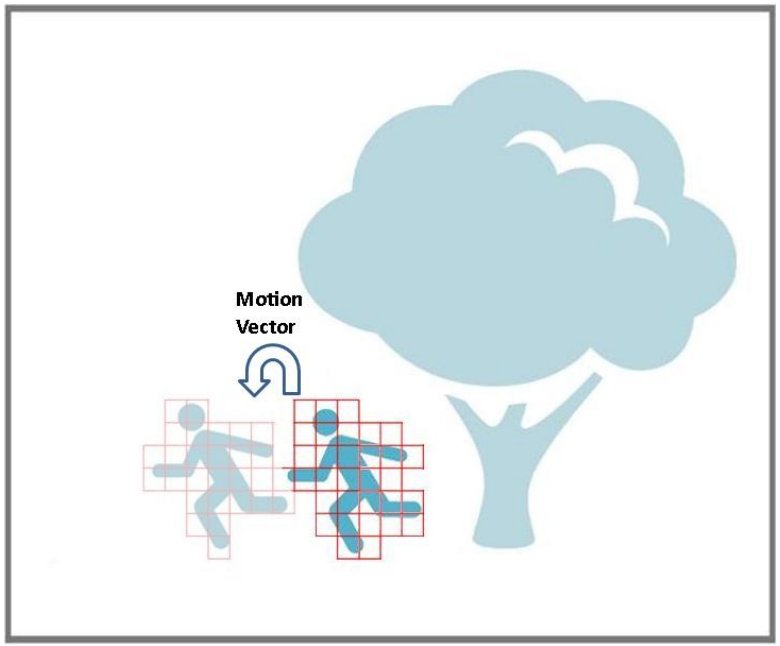

1 - Conflicting encoding requirements

- Compression leverages similarities between frames
- "Irregular" frames change tra□c patterns
- Data encoding must be adjusted

How to create unobservable streams?

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2 - Preserve the signature of legitimate Skype traffic

- Quantitatively characterize Skype streams
  - Packet length frequency distribution
- Quantify the differences between Skype streams
  - *Earth Mover's Distance*

Implementation Challenges

- Network Interaction
  - How to make TCP/IP communication possible?
- Video Processing
  - How to combine frames?
- Skype Interaction
  - How to send covert frames without modifying Skype?

Implementation - Client

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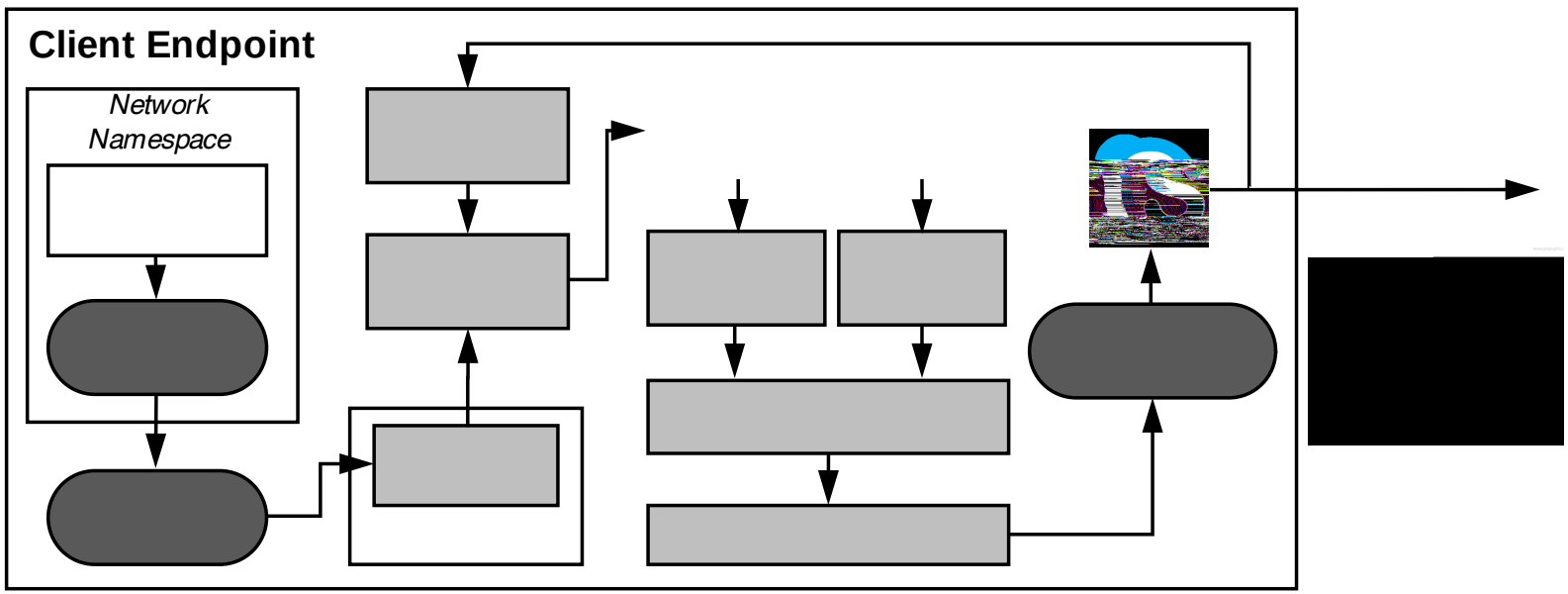

Implementation - Server

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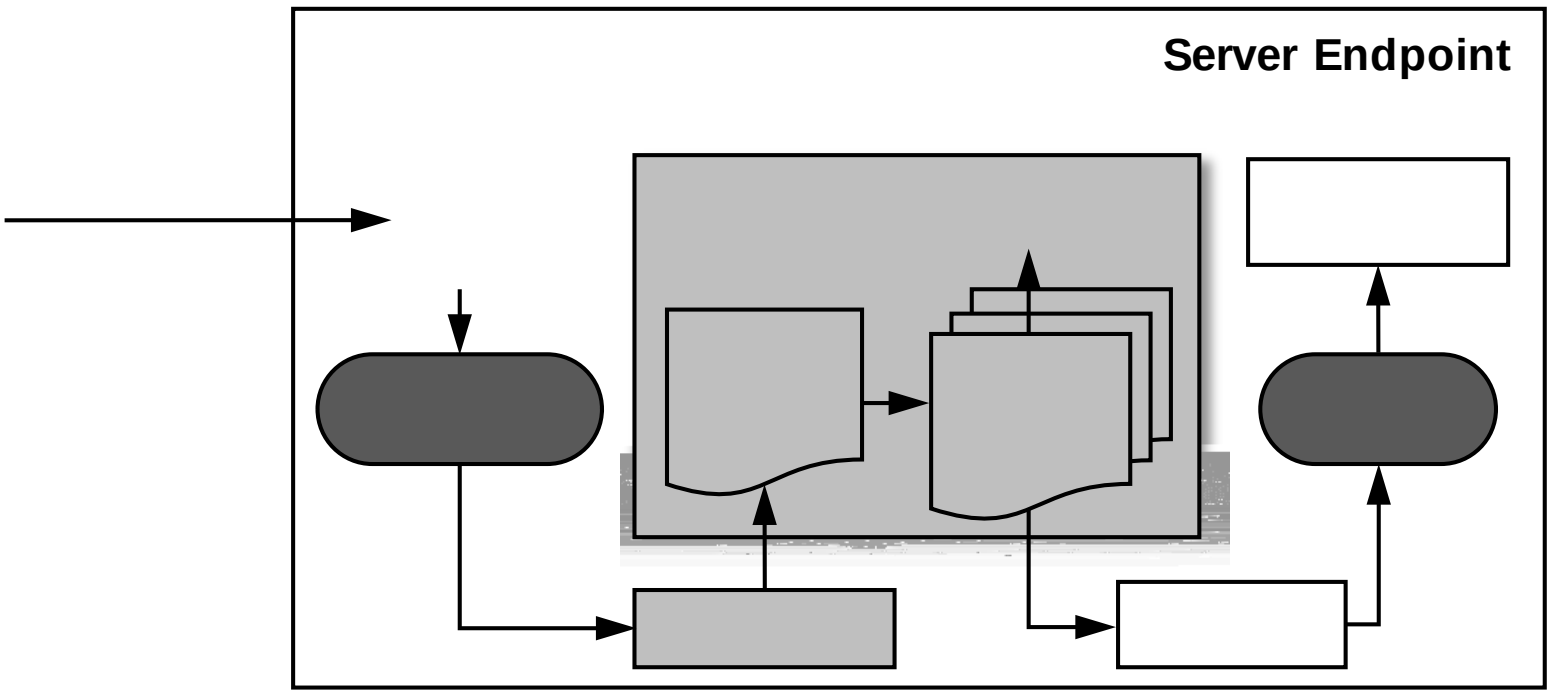

Aditional Implementation Features

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- IP packets fragmentation / reconstruction
- Error correction
- Encoding parameters calibration
- Attack resistant parameter negotiation

Agenda

Evaluation Steps

1. Definition of observability metrics
2. Verification of di□erences between streams
3. Stability of Skype streams' tra□c patterns
4. Skype streams classification
5. Generation of unobservable channels
6. Performance of the obtained channels

Experiments Configuration

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Experiments Configuration

- 2 VMs 32bit Linux Ubuntu 14.04.3 LTS - 2GB RAM - 4 virtual CPUs
- Skype v4.3.0.37

Streams Datasets

- 30 videos representing legitimate Skype calls
- 30 videos extracted from Youtube

Definition of observability metrics

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Characteristic Function - Create a stream signature

- Frequency distribution of packet lengths

Definition of observability metrics

Characteristic Function - Create a stream signature

- Frequency distribution of packet lengths

Similarity Function - Quantify differences among streams

- *Earth Mover's Distance*
  - Cost of transforming signature f_1 on signature f_2

Are there differences among regular/irregular streams?

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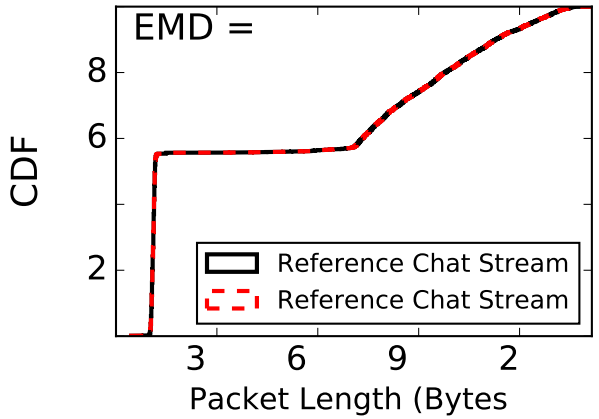

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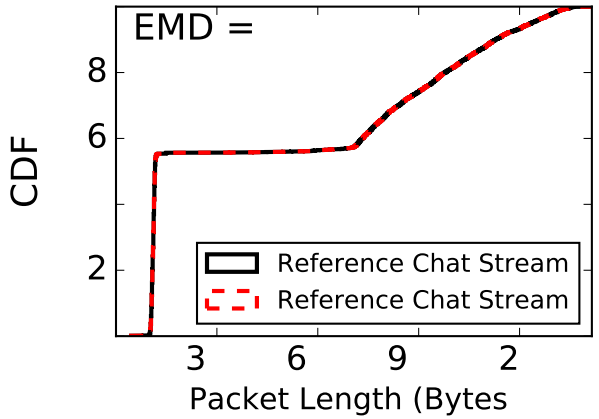

Characterization of Skype streams

- Regular/irregular streams exhibit distinct patterns

Are these patterns reliable for stream classification?

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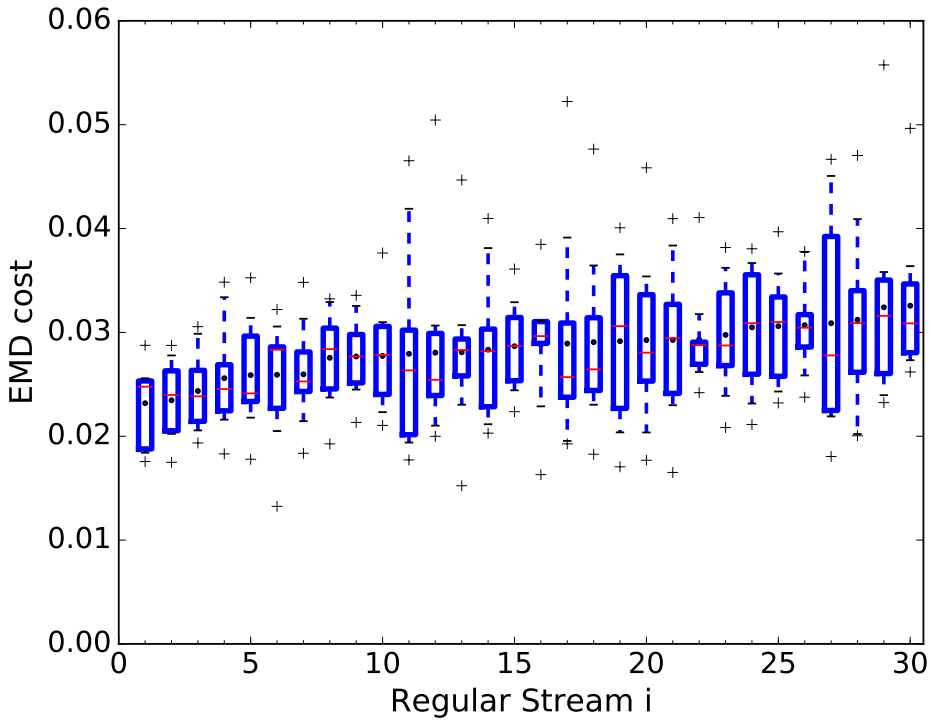

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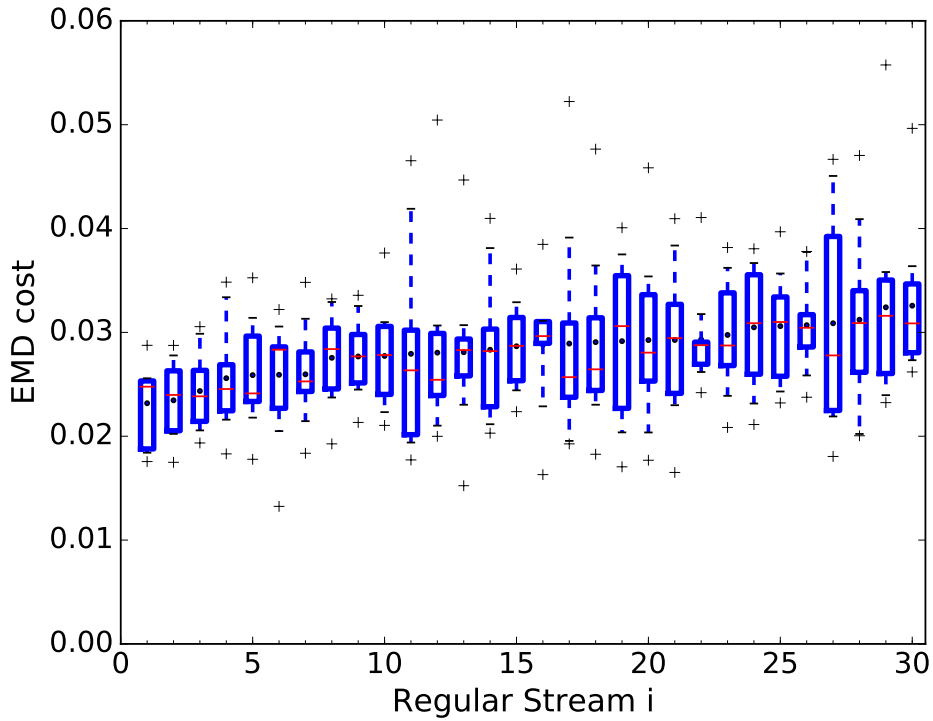

Characterization of Skype streams

- These patterns appear to be stable
  - Max. di□erence of 2% (between 25% and 75% quartiles)

Is it possible to accurately distinguish Skype streams?

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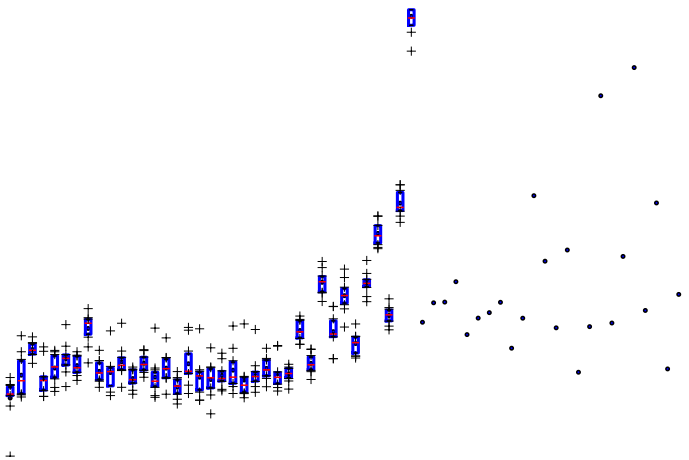

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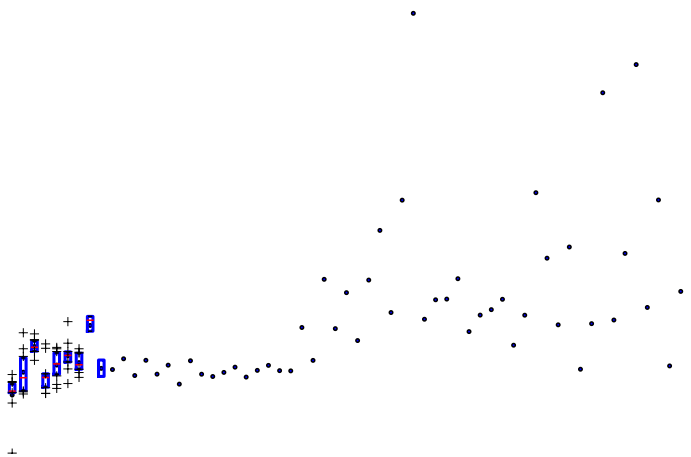

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Is it possible to create unobservable streams?

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Recall the encoding parameters

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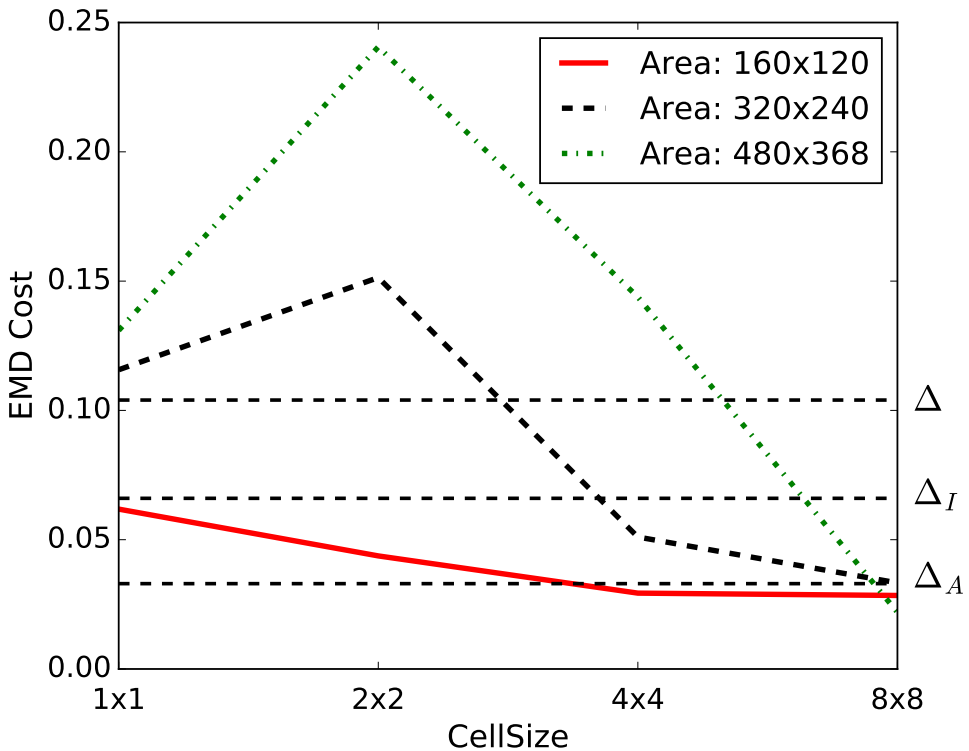
1 - Payload area VS Cell Size

- Bits p/Cell = 1



What is the performance of this channel?

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Can we support the execution of typical applications?

Use cases

- Comparison of execution time
  - System use vs Open channels
- Interactive sessions
  - 10x - 20x time overhead

Case	W/ System	W/o System	Overhead
A. Wget	1m 9s 830ms	7ms	9,975.7×
B. FTP	2m 45s	8s 528ms	19×
C. SMTP	2m 42s	37s 913ms	4.3×
D. SSH	1m 51s 493ms	6s 485ms	17.2×
E. Telnet	1m 17s 471ms	7s 670ms	10.1×
F. Chat Netcat	1s 147ms	11ms	133×
G. Tunel SSH	3m 46s 55ms	21s 940ms	10.3×

Results

This paper o□ers the following results:

- Implementation of the system
  - Linux / Skype
- An empirical demonstration of the transfer of arbitrary data in an unobservable way
- An experimental study of the system's performance

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