Preventing Side-Channel Leaks in Web Traffic: A Formal Approach

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IMDEA Software Institute

joint work with

Michael Backes and Boris Köpf

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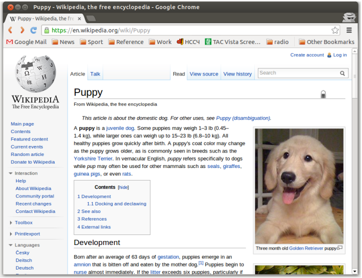

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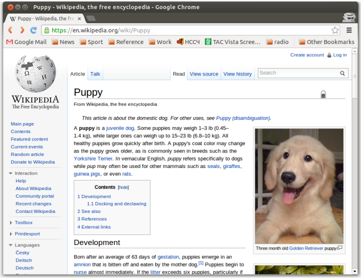

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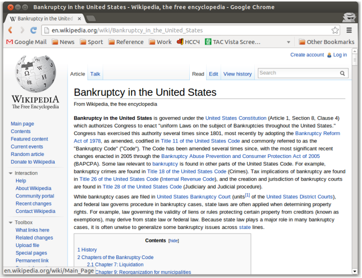

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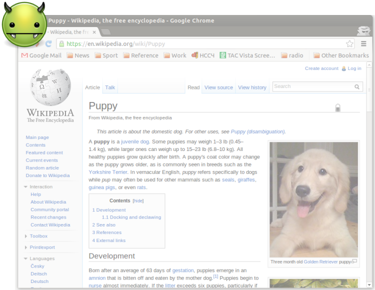

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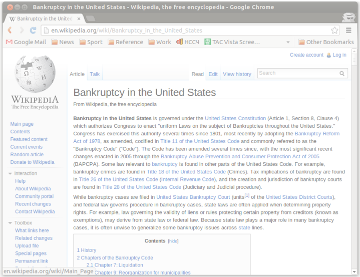

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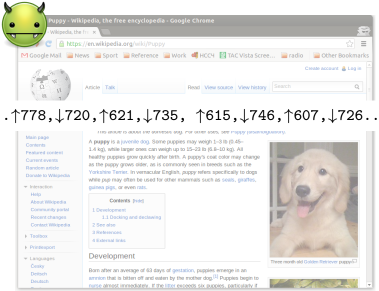

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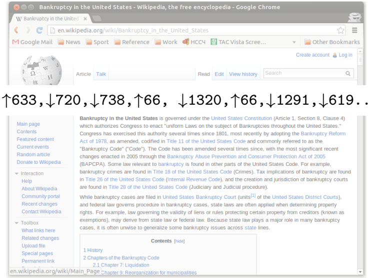

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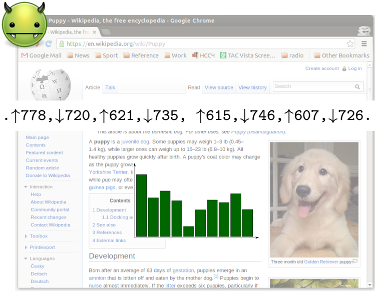

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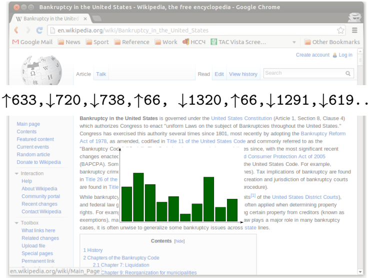

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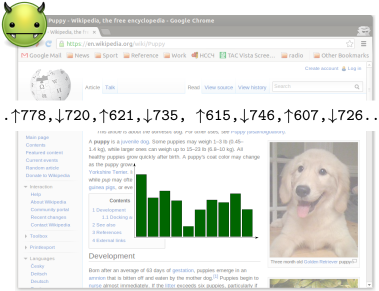

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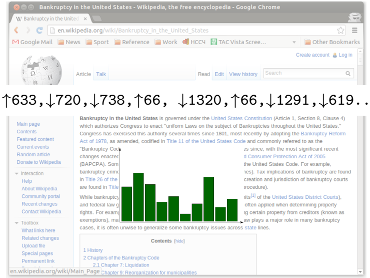

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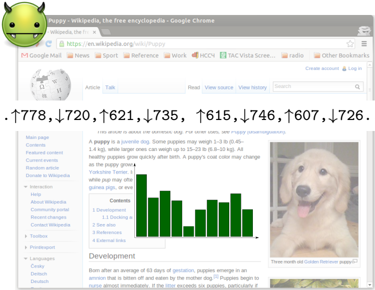

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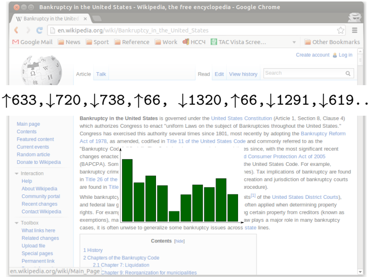

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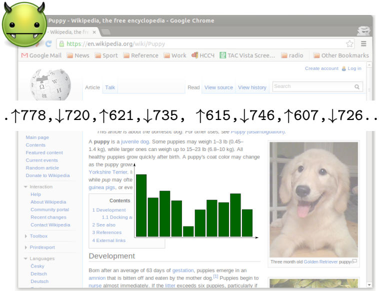

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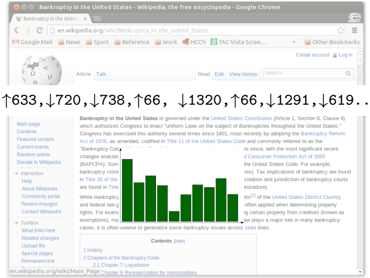

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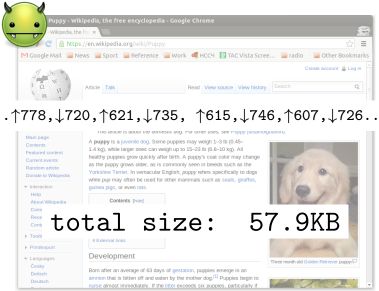

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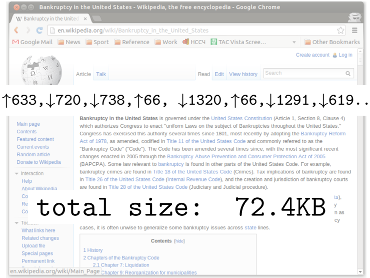

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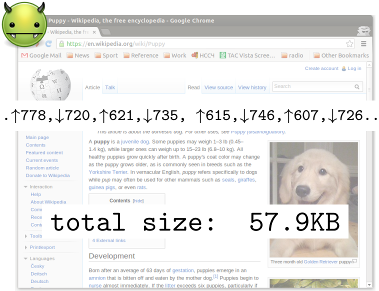

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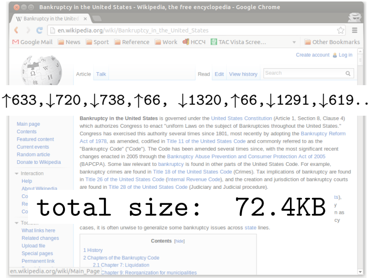

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Bankruptcy in the United States is governed under the United States Constitution (Article 1, Section 8, Clause 4) which authorizes Congress to enact "uniform Laws on the subject of Bankruptcies throughout the United States." Congress has exercised this authority several times since 1801, most recently by adopting the Bankruptcy Reform Act of 1978, as amended, codified in Title 11 of the United States Code and commonly referred to as the "Bankruptcy Code" ("Code"). The Code has been amended several times since, with the most significant recent changes enacted in 2005 through the Bankruptcy Abuse Prevention and Consumer Protection Act of 2005 (BAPCPA). Some law relevant to bankruptcy is found in other parts of the United States Code. For example, bankruptcy crimes are found in Title 18 of the United States Code (Crimes). Tax implications of bankruptcy are found in Title 26 of the United States Code (Internal Revenue Code), and the creation and jurisdiction of bankruptcy courts are found in Title 28 of the United States Code (Judiciary and Judicial procedure).

total size: 72.4KB

cases, it is often unwise to generalize some bankruptcy issues across state lines.

Contents [hide]

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- an attack: compare distributions of packet sizes (Liberatore et al.'06)
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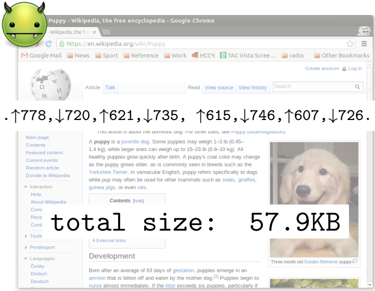
- other attacks still possible (Lu et al.'10, Dyer et al.'12)

How to show that a countermeasure is "good"?

Leaks in Web Traffic



This article is about the domestic dog. For other uses, see Puppy (disambiguation).

A **puppy** is a juvenile dog. Some puppies may weigh 1–3 lb (0.45–1.4 kg), while larger ones can weigh up to 15–23 lb (6.8–10 kg). All healthy puppies grow quickly after birth. A puppy's coat color may change as the puppy grows older, as is commonly seen in breeds such as the Yorkshire Terrier. In vernacular English, *puppy* refers specifically to dogs while *pup* may often be used for other mammals such as seals, giraffes, guinea pigs, or even rats.

Contents [hide]

4 External links

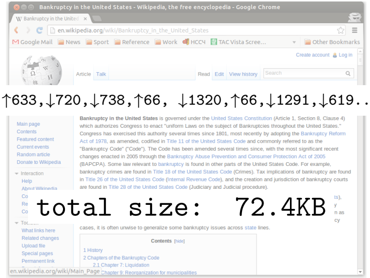
Development

Born after an average of 63 days of gestation, puppies emerge in an amnion that is bitten off and eaten by the mother dog.[1] Puppies begin to nurse almost immediately. If the litter exceeds six puppies, particularly if

Three month old Golden Retriever puppy

...↑778,↓720,↑621,↓735, ↑615,↓746,↑607,↓726...

total size: 57.9KB



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- a countermeasure: Traffic morphing (Wright et al.'09)
- other attacks still possible (Lu et al.'10, Dyer et al.'12)

How to show that a countermeasure is "good"?

- previous work: empirically show that a particular attack does not work

Our approach

Reason *formally* about strength of countermeasures

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1. models of web applications, web traffic, users and adversaries

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Main contributions:

- simple, yet realistic models

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Main contributions:

- simple, yet realistic models
- efficient algorithms for measuring and reducing information leakage

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2. derive security guarantees based on model

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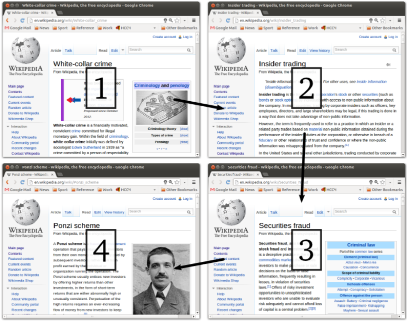
Main contributions:

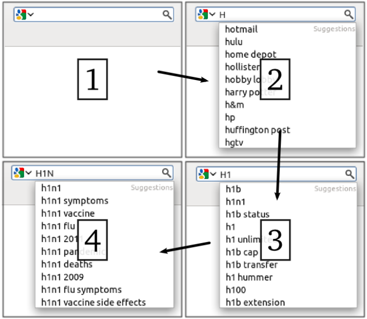
- simple, yet realistic models
- efficient algorithms for measuring and reducing information leakage
- demonstrate approach in case studies

Modeling web applications

Static website



Auto-suggest input field



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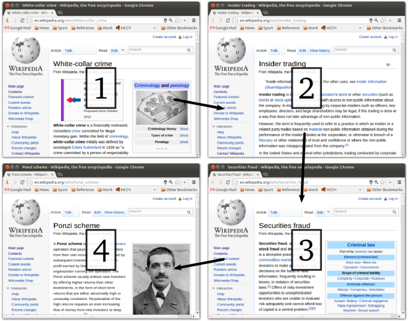

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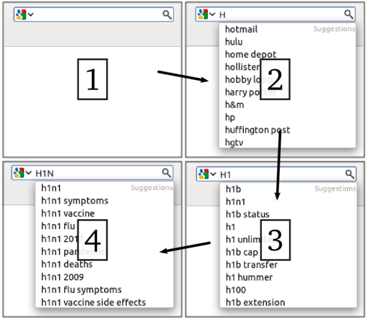

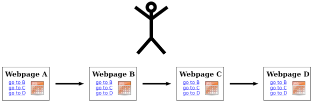

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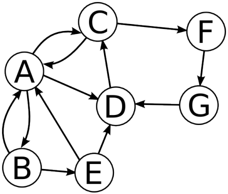

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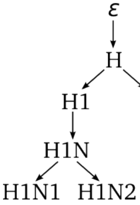
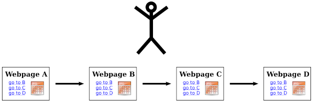
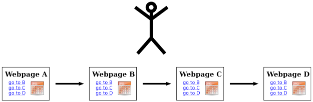




The traffic channel



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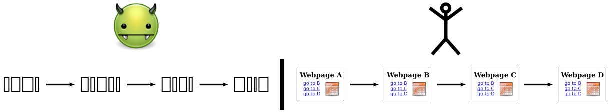

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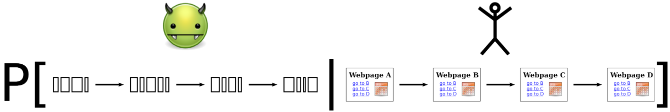

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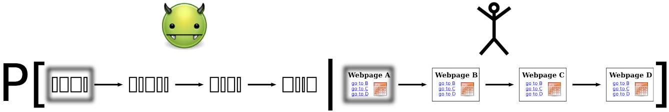

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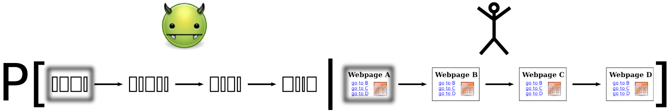

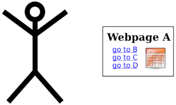

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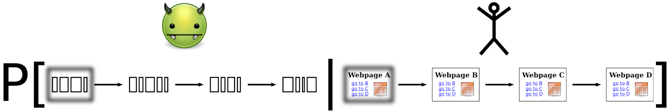

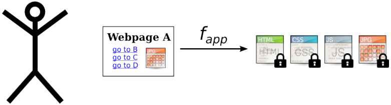

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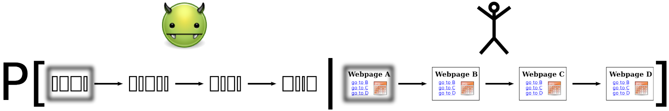

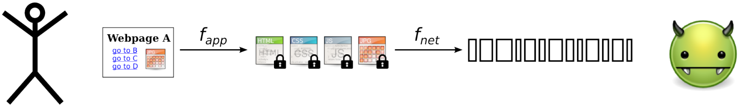

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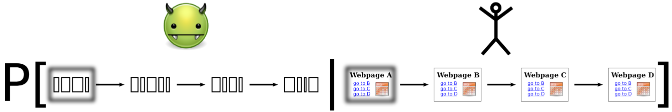
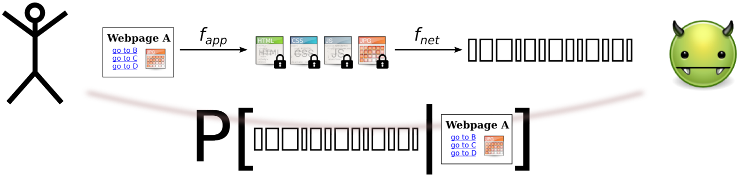
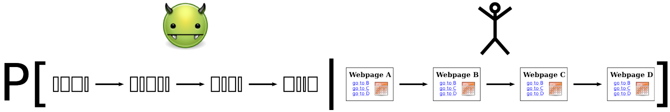




Measuring security in the system



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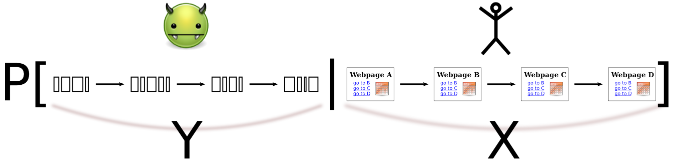

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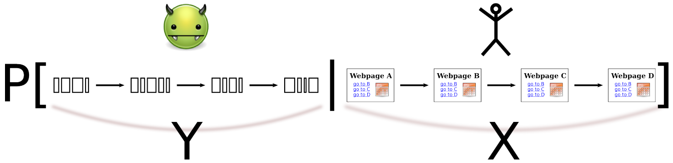

- security measure: difficulty of guessing X when Y is known

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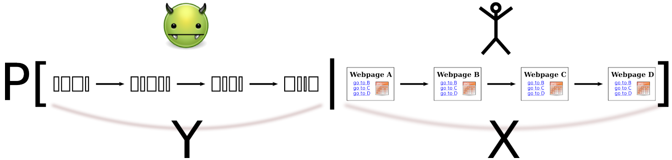

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- expected $\#$ guesses: captured by entropy H (Massey'94)

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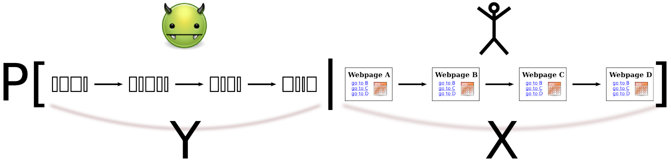

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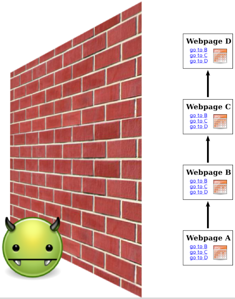

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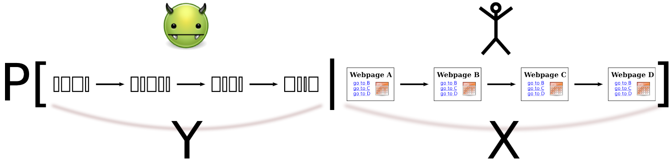

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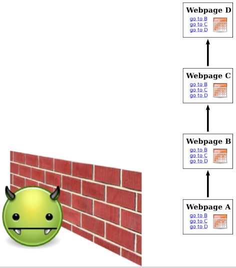
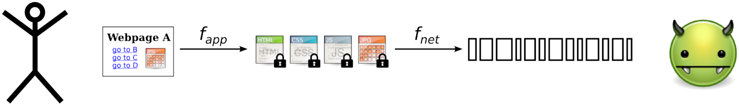


- initial uncertainty $H(X)$
- remaining uncertainty $H(X|Y)$

Traffic modifiers: countermeasures, network protocols



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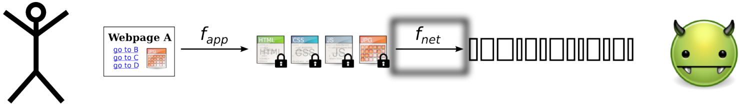

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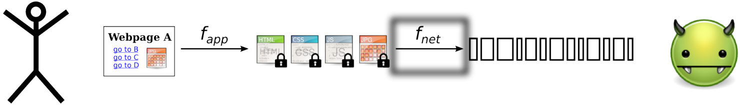
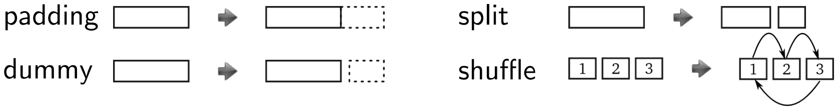


Basic traffic modifiers:



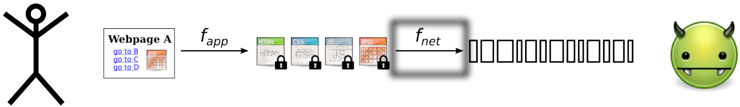
padding

dummy

split

shuffle

Traffic modifiers: countermeasures, network protocols



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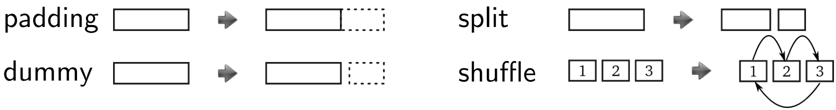
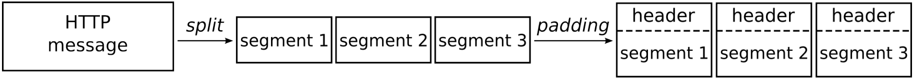
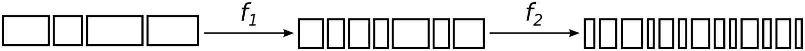


Example (Packet segmentation)



Composition theorem

Composed traffic modifier $f_2 \circ f_1$:



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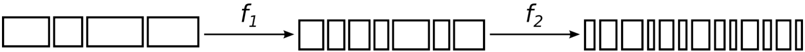

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$$H(X|Y_2 \circ Y_1) \geq H(X|Y_1)$$

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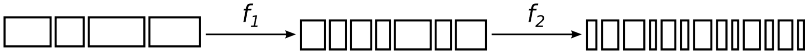

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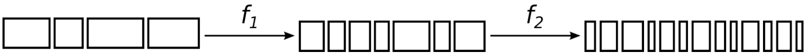

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Consequence: relative security guarantees for free

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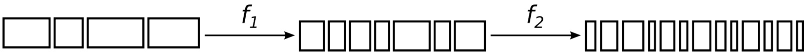

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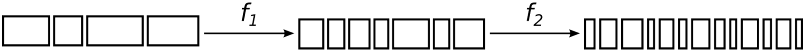

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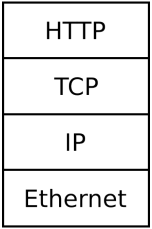
- security guarantees preserved when message passes protocol stack



How to evaluate real-world websites?

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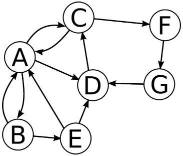

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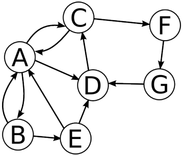

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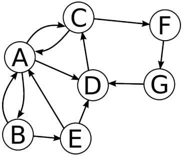

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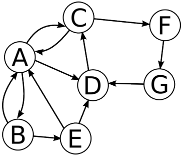

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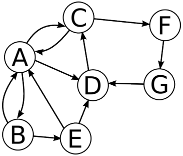

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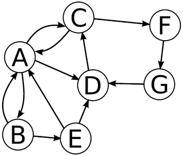

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How to evaluate real-world websites?

Computing the remaining uncertainty:

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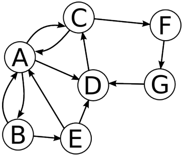

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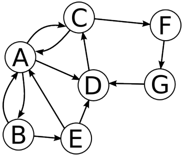

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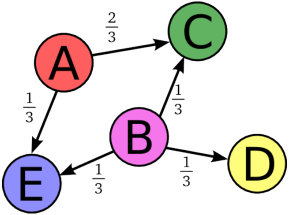
- random surfer: follow random link or jump to random page

Path-aware countermeasures



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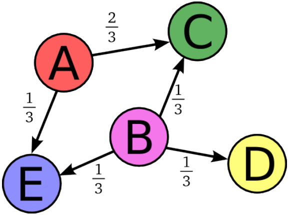

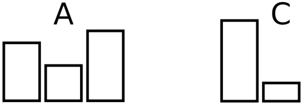

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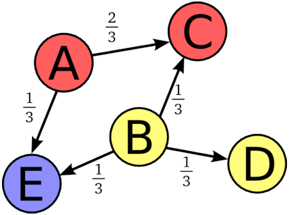

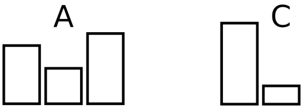

Countermeasures make vertices indistinguishable

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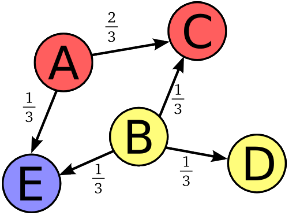

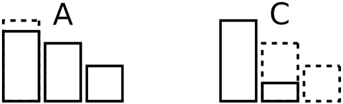

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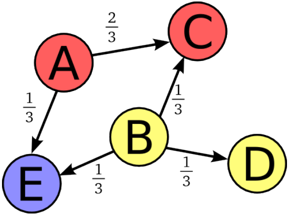

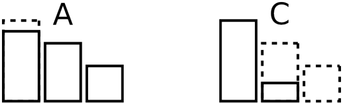

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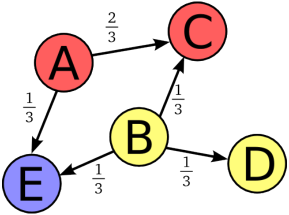

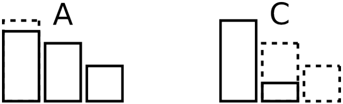

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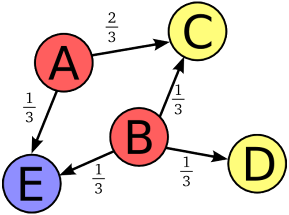

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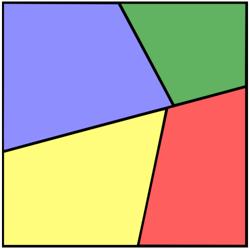
⇒ ensure partition of vertices is a *probabilistic bisimulation*

Path-aware countermeasures (2)



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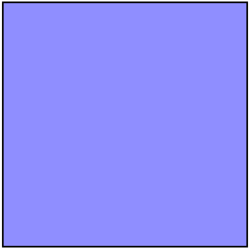

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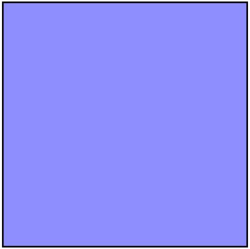

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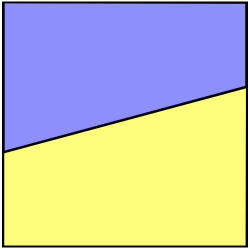

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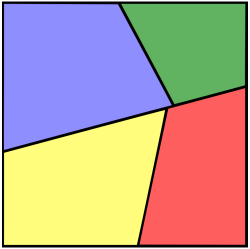

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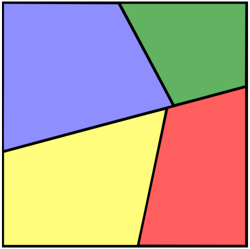

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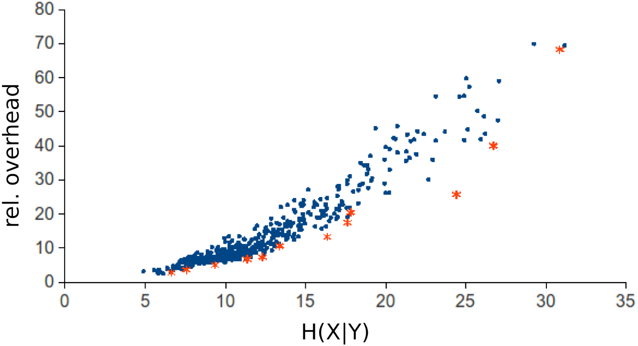
Case study

Trading security for overhead : 500 random bisimiulations



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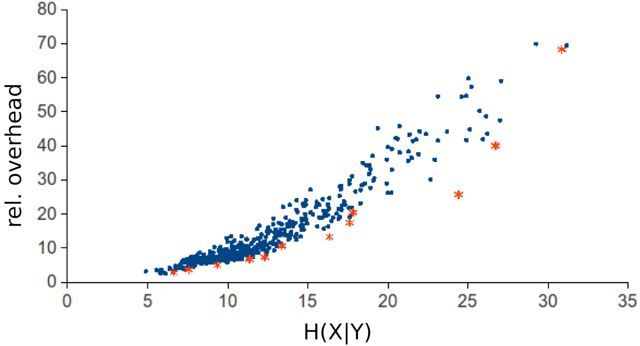

Bonus material in the paper

- limits on overhead of path-aware countermeasure
- case study: auto-complete field
- using other entropy measures
- timing leaks: combining security guarantees with predictive timing mitigation (Askarov et al.'10)

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