PADERBORN UNIVERSITY

Towards Automated DNS Censorship Circumvention

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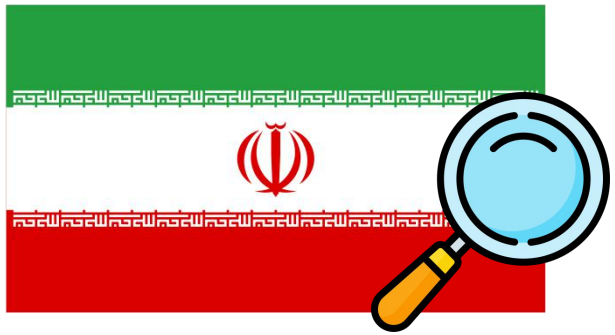
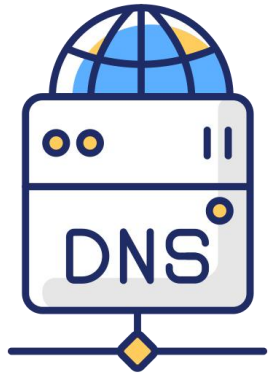
Felix Lange
19.02.2026

Motivation



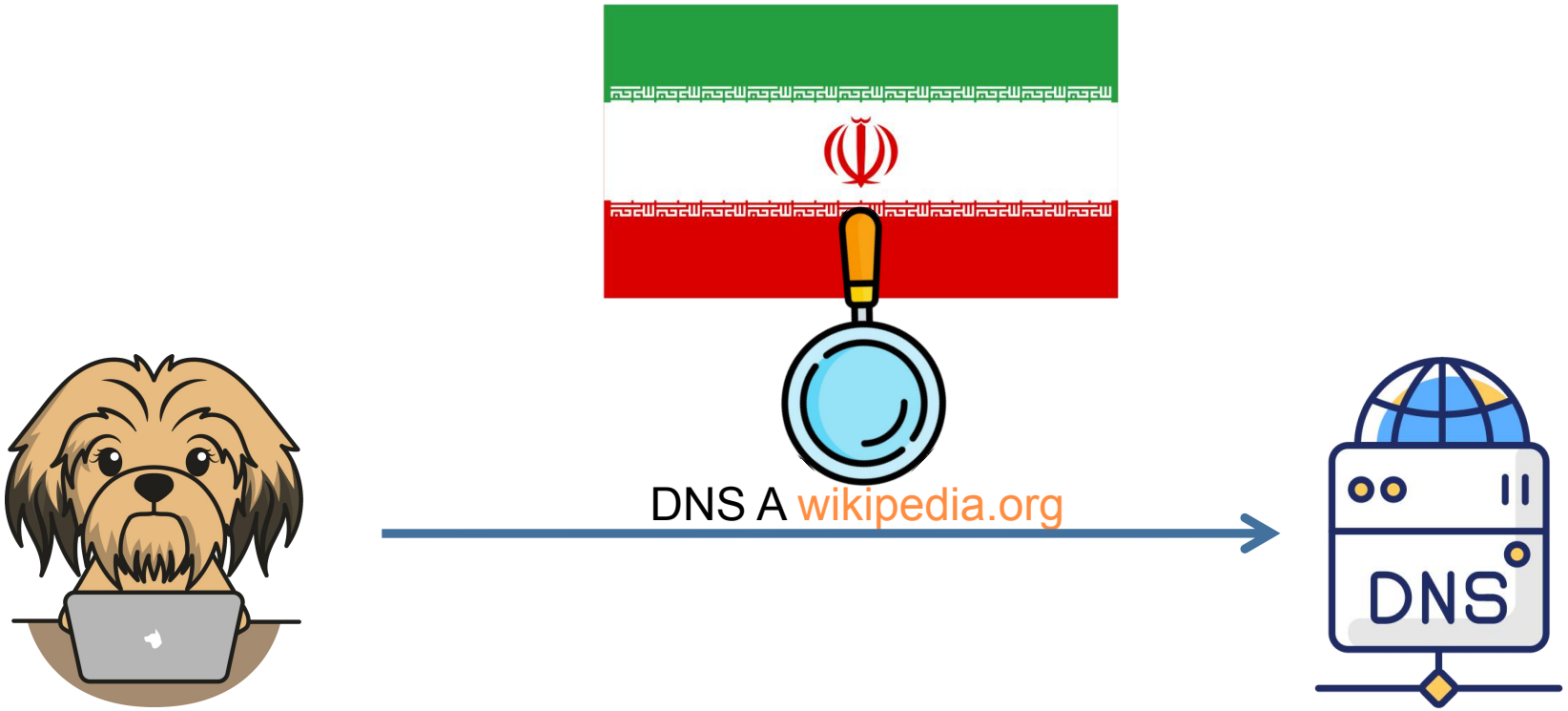
DNS A wikipedia.org

DNS A 185.15.59.224



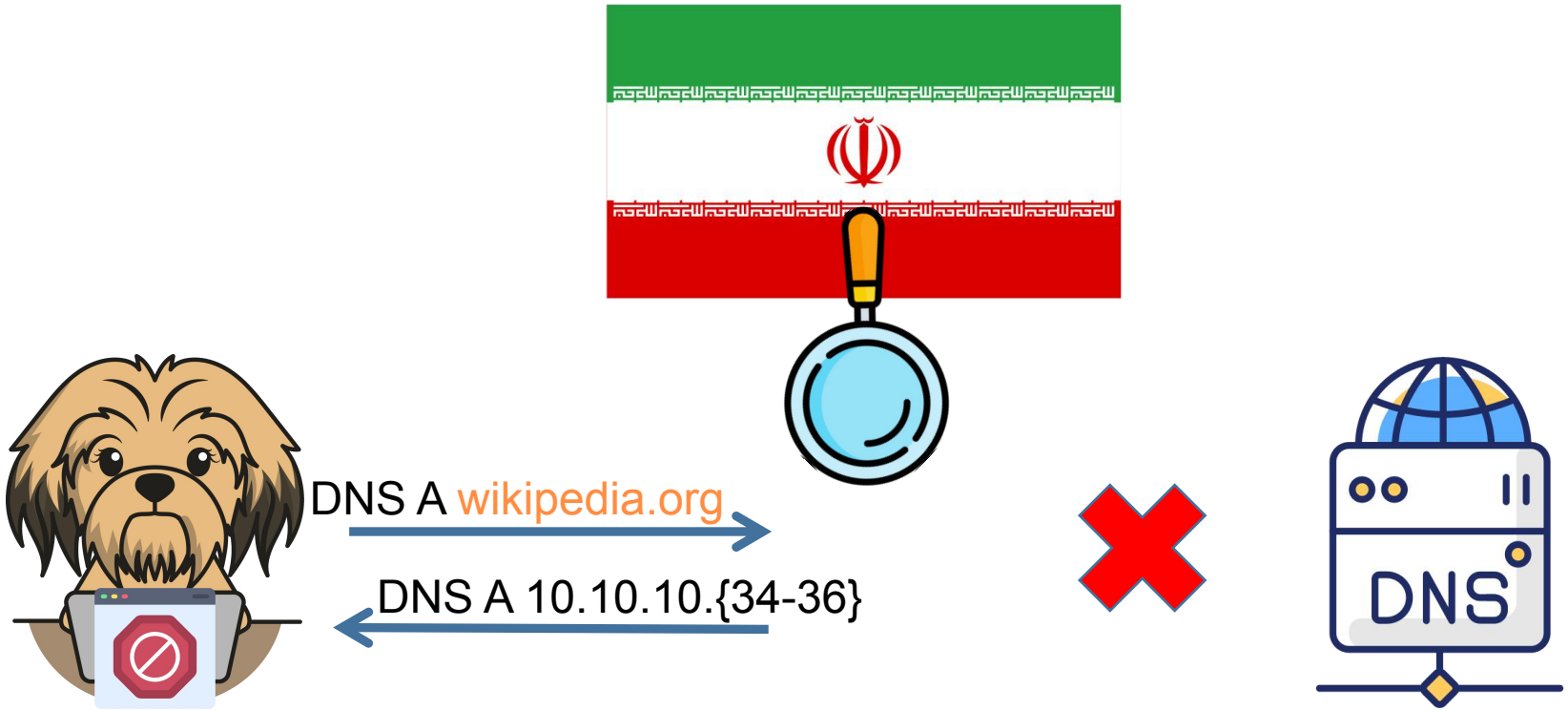
...	...
wikipedia.org	185.15.59.224
...	...

Motivation

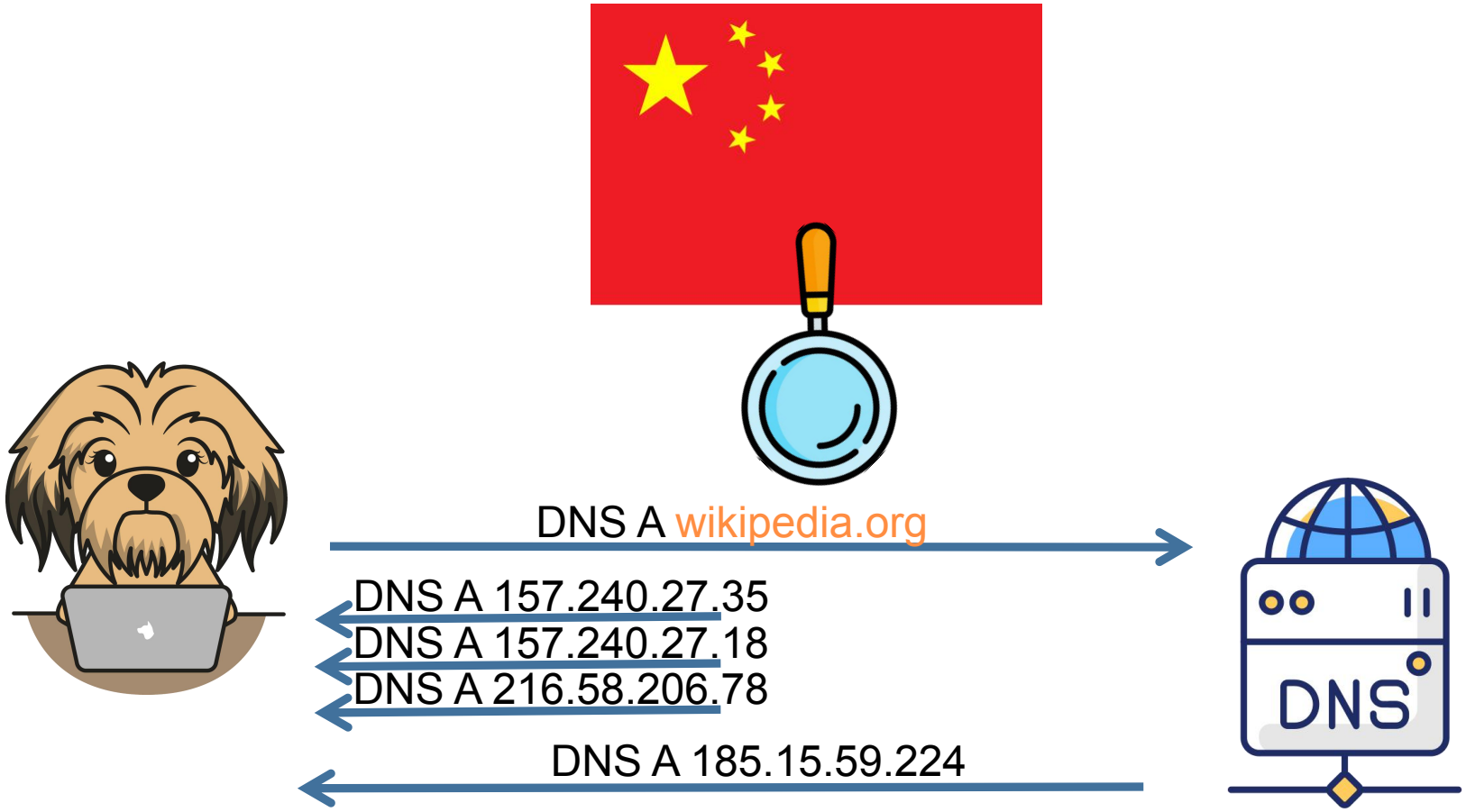


Motivation

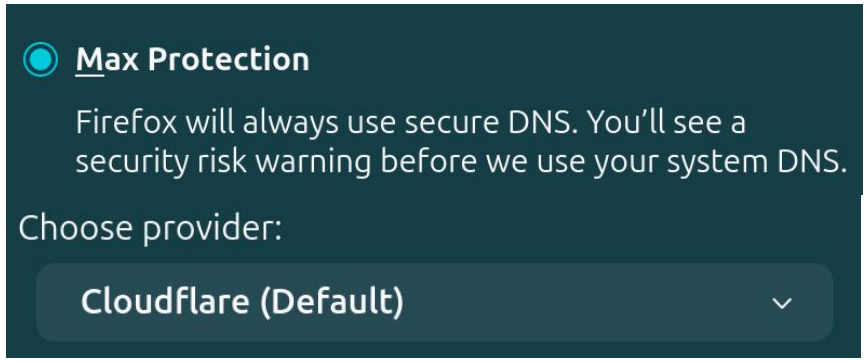
DNS Censorship in Iran

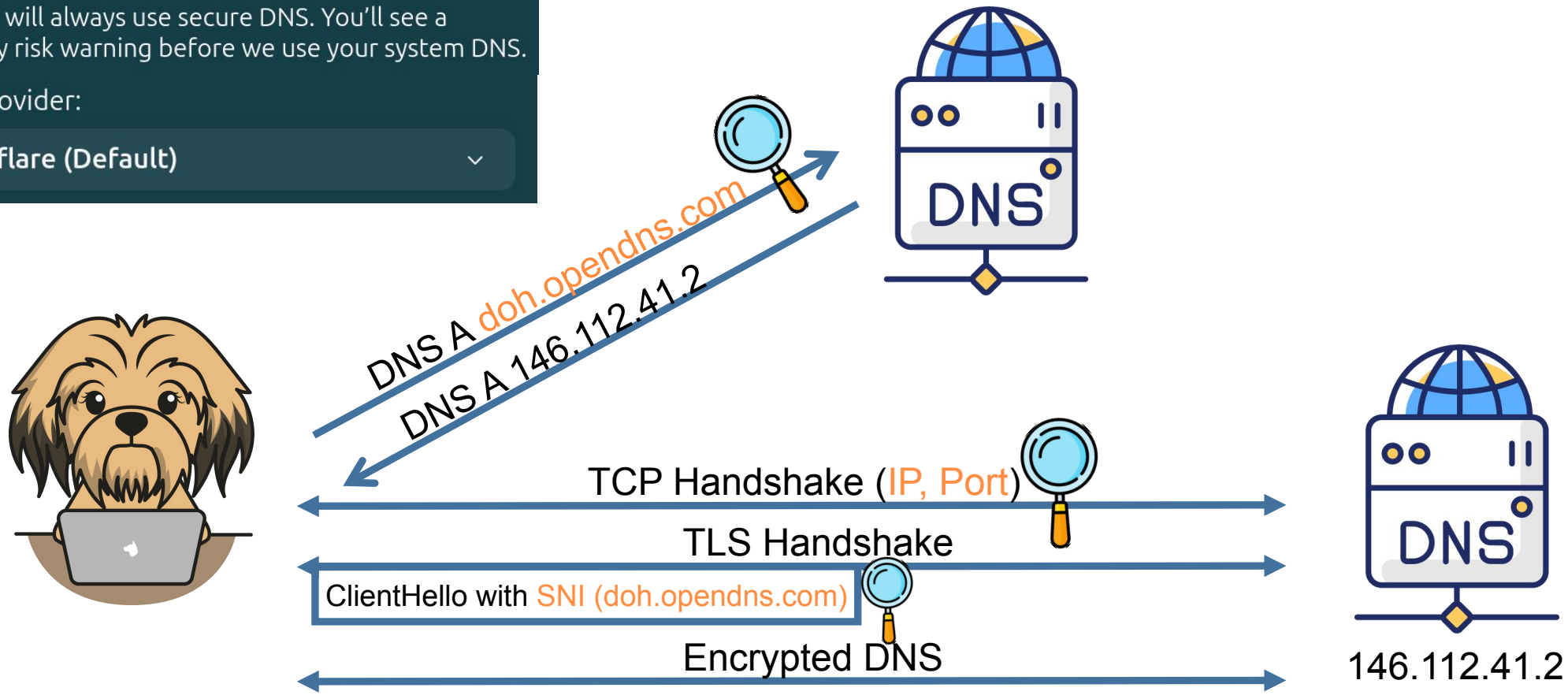


DNS Censorship in China



Encrypted DNS in Browsers ~~to the Rescue?~~





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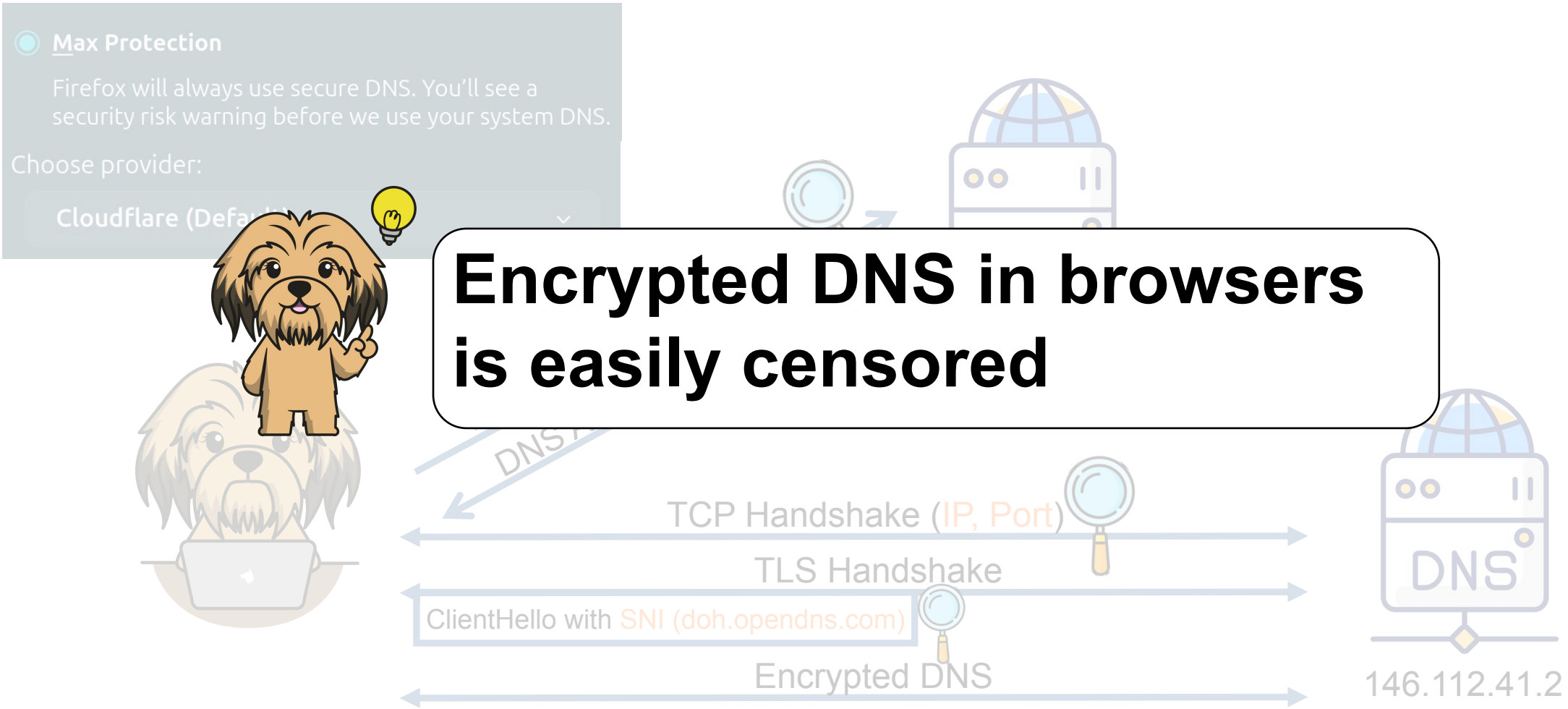
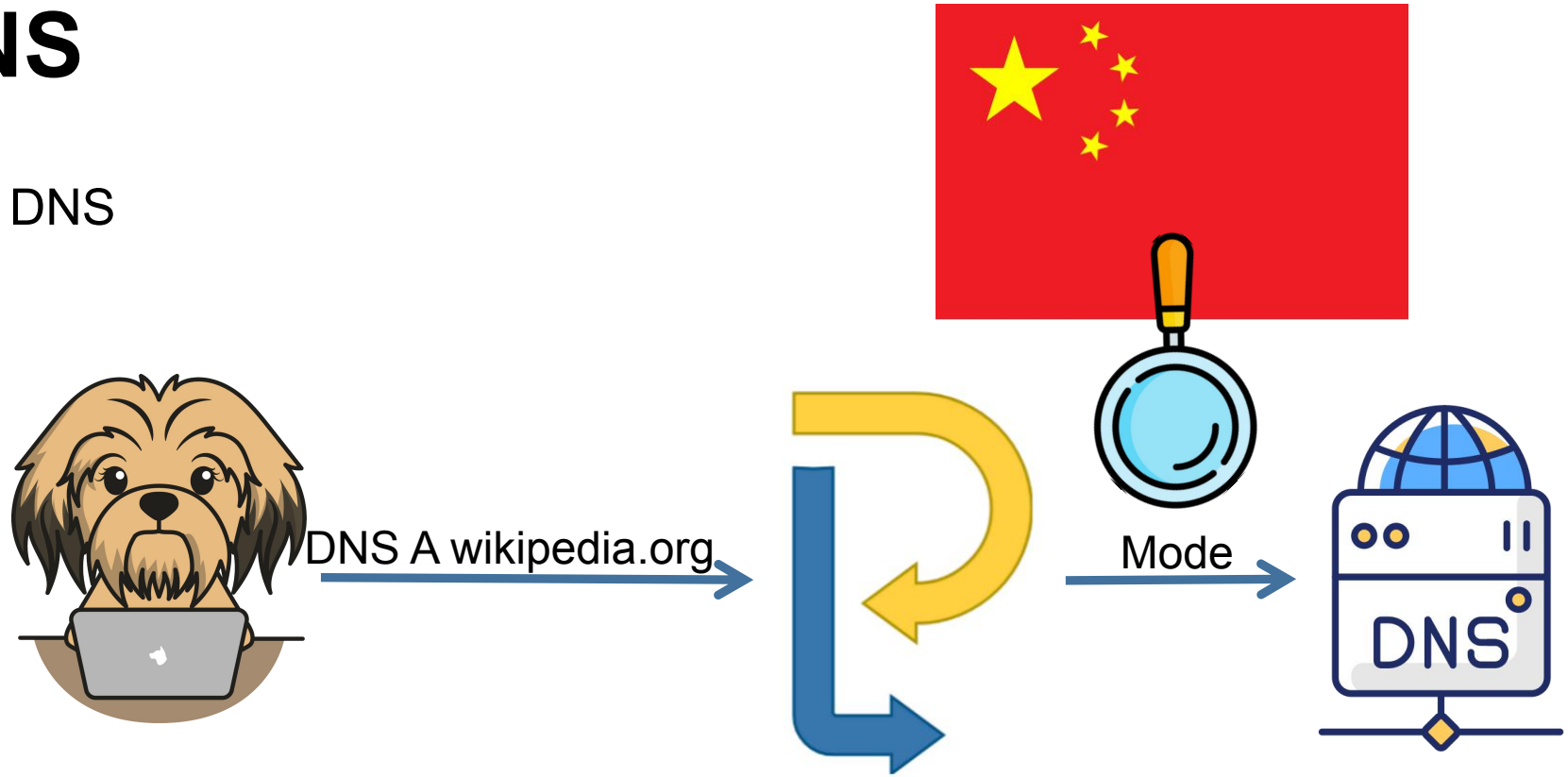


DPYProxy-DNS

- DPYProxy extended for DNS
- 8 Modes



DPYProxy-DNS

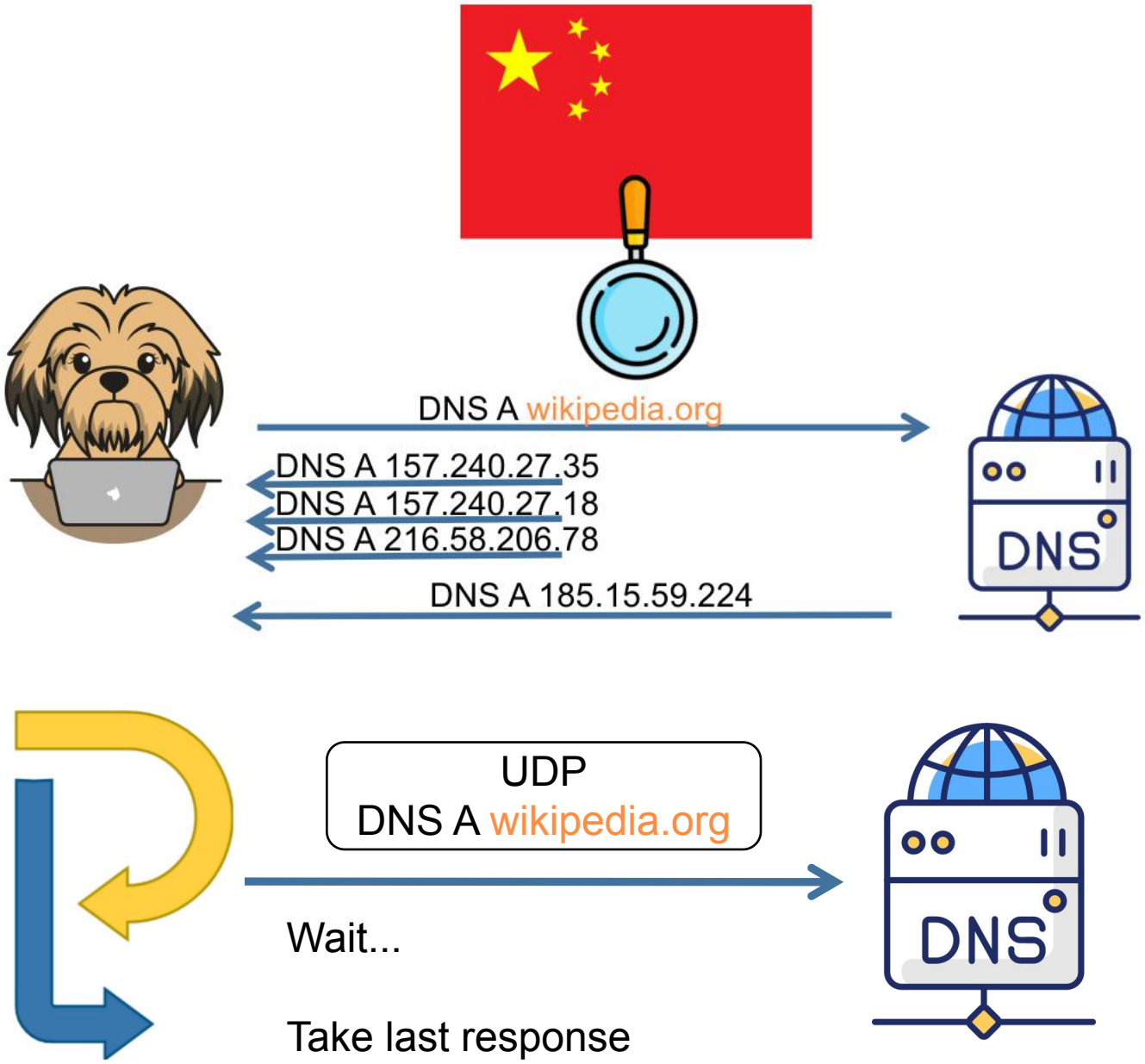
- DPYProxy extended for DNS
- 8 Modes

- Unencrypted:
  - UDP

DPYProxy-DNS

- DPYProxy extended for DNS
- 8 Modes

- Unencrypted:
  - UDP
  - Last Response



DPYProxy-DNS

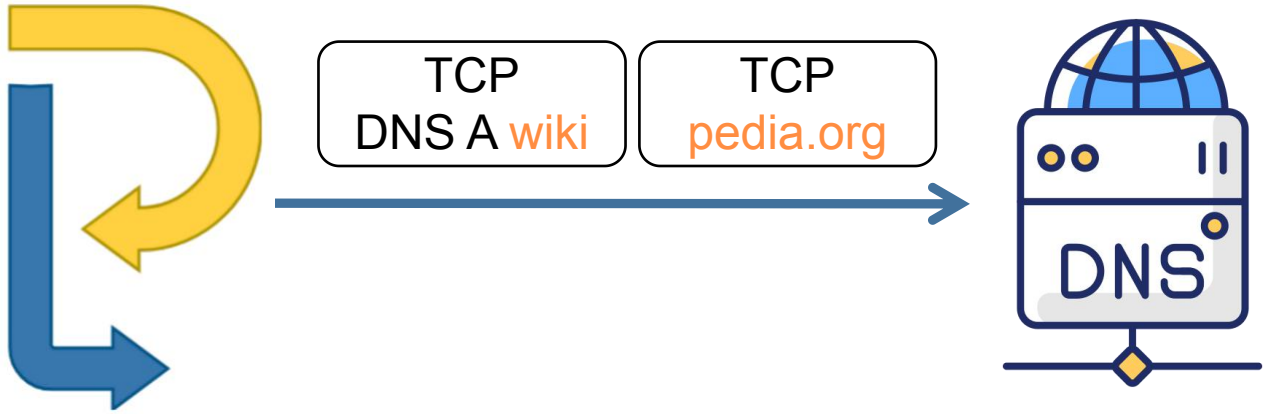
- DPYProxy extended for DNS
- 8 Modes

- Unencrypted:
  - UDP
  - Last Response
  - TCP

DPYProxy-DNS

- DPYProxy extended for DNS
- 8 Modes

- Unencrypted:
  - UDP
  - Last Response
  - TCP
  - TCP Segmentation

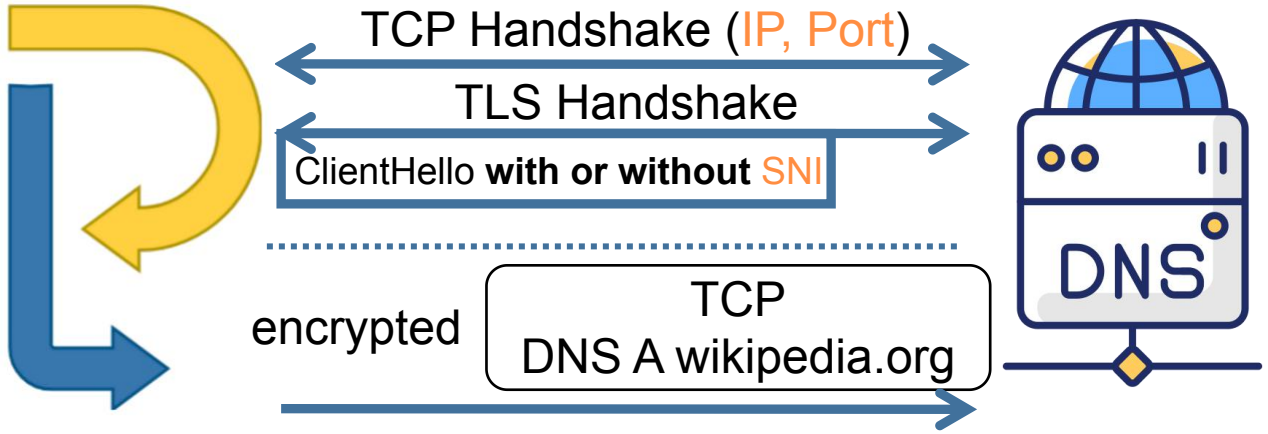


DPYProxy-DNS

- DPYProxy extended for DNS
- 8 Modes

- Unencrypted:
  - UDP
  - Last Response
  - TCP
  - TCP Segmentation

- Encrypted:
  - DNS over TLS (DoT)

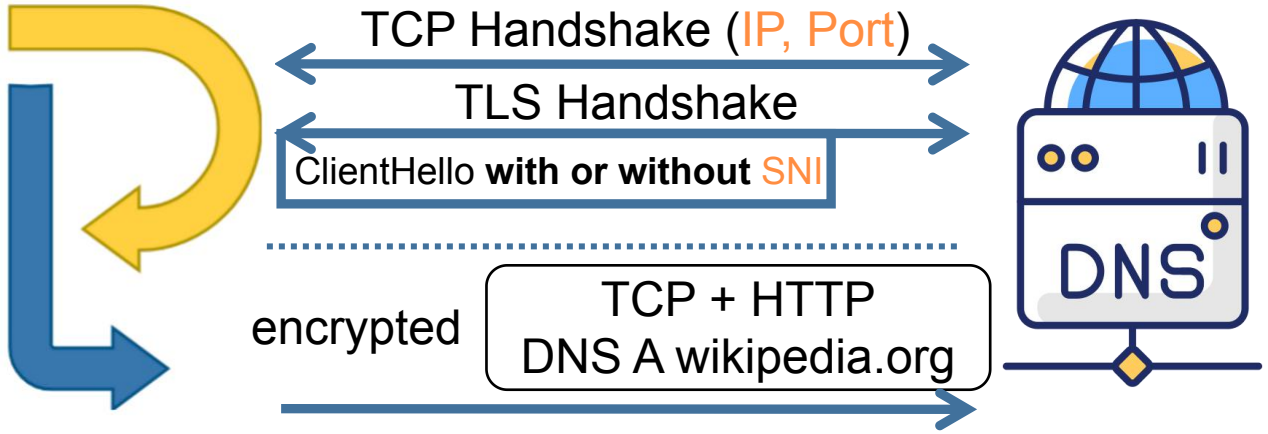


DPYProxy-DNS

- DPYProxy extended for DNS
- 8 Modes

- Unencrypted:
  - UDP
  - Last Response
  - TCP
  - TCP Segmentation

- Encrypted:
  - DNS over TLS (DoT)
  - DNS over HTTPS (DoH)

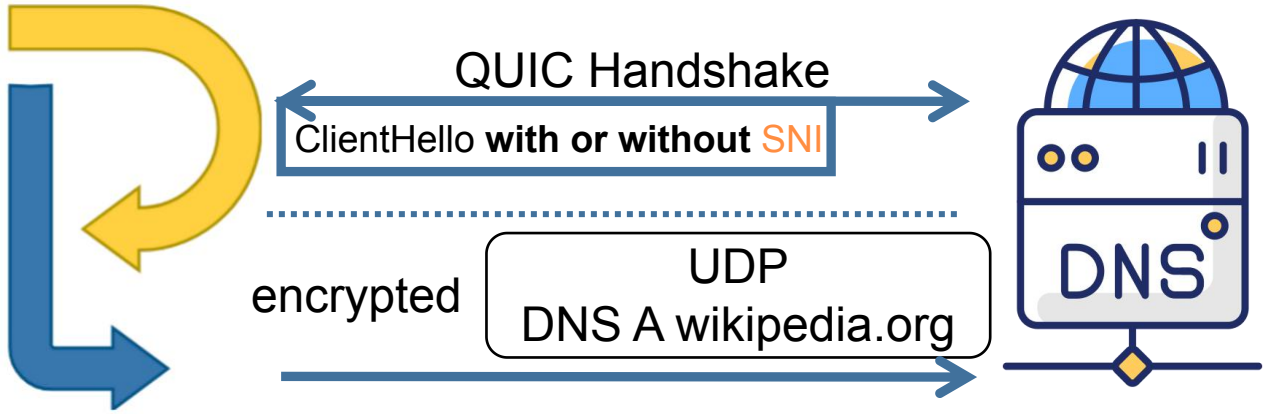


DPYProxy-DNS

- DPYProxy extended for DNS
- 8 Modes

- Unencrypted:
  - UDP
  - Last Response
  - TCP
  - TCP Segmentation

- Encrypted:
  - DNS over TLS (DoT)
  - DNS over HTTPS (DoH)
  - DNS over QUIC (DoQ)

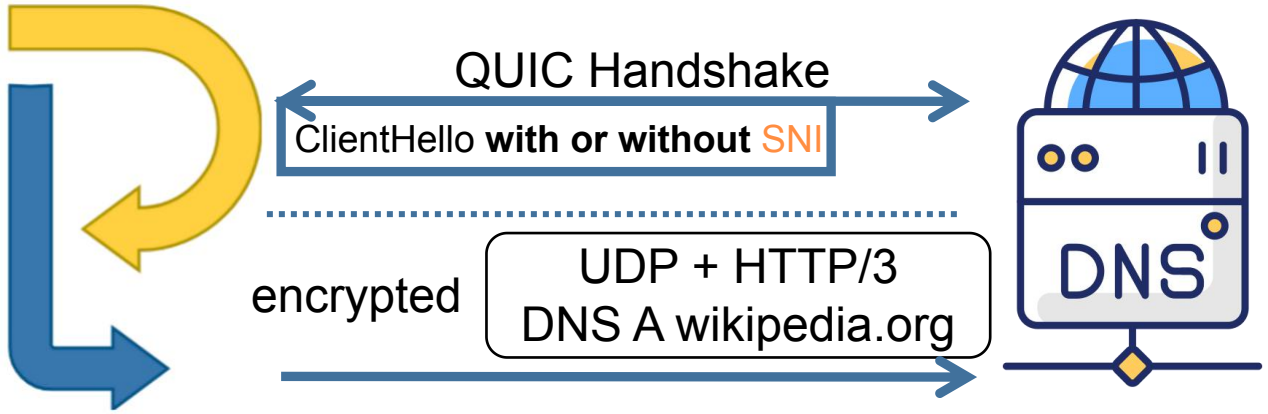


DPYProxy-DNS

- DPYProxy extended for DNS
- 8 Modes

- Unencrypted:
  - UDP
  - Last Response
  - TCP
  - TCP Segmentation

- Encrypted:
  - DNS over TLS (DoT)
  - DNS over HTTPS (DoH)
  - DNS over QUIC (DoQ)
  - DNS over HTTPS/3 (DoH3)



DPYProxy-DNS

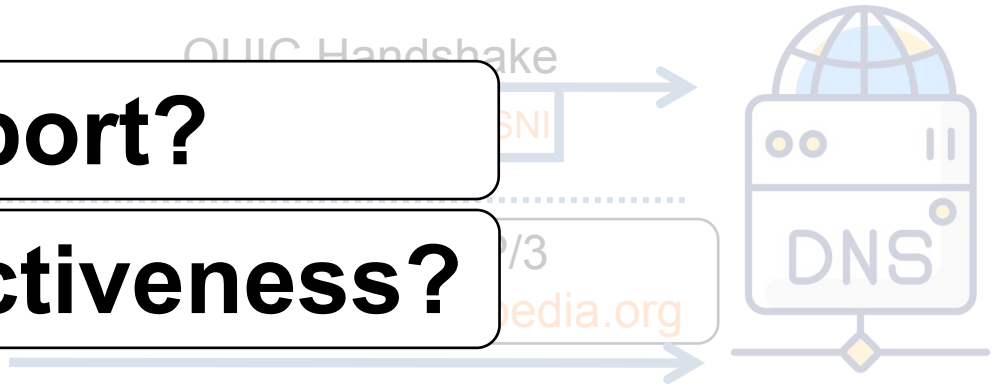
DPYProxy extended for DNS

8 Modes

- Unencrypted:
  - UDP
  - Last Response
  - TCP
  - TCP Segmentation
- Encrypted:
  - DNS over TLS (DoT)
  - DNS over HTTPS (DoH)
  - DNS over QUIC (DoQ)
  - DNS over HTTPS/3 (DoH3)

Support?

Effectiveness?



Public Resolver Support

	Unencrypted				Encrypted			
	UDP	Last Resp.	TCP	TCP Seg.	DoT	DoH	DoH3	DoQ
Adguard (6)								
Cisco (6)								
Cisco Chromium (1)								
CleanBrowsing (5)								
CleanBrowsing (1)								
Cloudflare (6)								
Gcore (2)								
Google (2)								
Mullvad (6)								
NextDNS (2)								
Quad9 (6)								
Wikimedia (1)								
Yandex (6)								
# Supporting								

Public Resolver Support

	Unencrypted				Encrypted			
	UDP	Last Resp.	TCP	TCP Seg.	DoT	DoH	DoH3	DoQ
Adguard (6)	●	●	●	●				
Cisco (6)	●	●	●	●				
Cisco Chromium (1)	●	●	●	●				
CleanBrowsing (5)	●	●	●	●				
CleanBrowsing (1)	●	●	●	●				
Cloudflare (6)	●	●	●	●				
Gcore (2)	●	●	●	●				
Google (2)	●	●	●	●				
Mullvad (6)	–	–	–	–				
NextDNS (2)	–	–	–	–				
Quad9 (6)	●	●	●	●				
Wikimedia (1)	–	–	–	–				
Yandex (6)	●	●	●	●				
# Supporting	41	41	41	41				

● = Supported mode.
– = Unsupported mode.

Tested:
No SNI / SNI

Public Resolver Support

	Unencrypted				Encrypted			
	UDP	Last Resp.	TCP	TCP Seg.	DoT	DoH	DoH3	DoQ
Adguard (6)	●	●	●	●	●IP	●IP	●IP	●IP
Cisco (6)	●	●	●	●	●IP	●IP	–	–
Cisco Chromium (1)	●	●	●	●	–	●IP	–	–
CleanBrowsing (5)	●	●	●	●	●	●	–	–
CleanBrowsing (1)	●	●	●	●	●	–	–	–
Cloudflare (6)	●	●	●	●	●IP	●IP	●IP	–
Gcore (2)	●	●	●	●	–	–	–	–
Google (2)	●	●	●	●	●IP	●IP	●IP	–
Mullvad (6)	–	–	–	–	●	●	–	–
NextDNS (2)	–	–	–	–	●	●	●	●
Quad9 (6)	●	●	●	●	●IP	●IP	–	–
Wikimedia (1)	–	–	–	–	●	●	–	–
Yandex (6)	●	●	●	●	●IP	●IP	–	–
# Supporting	41	41	41	41	47	47	16	8

● = Supported mode.
– = Unsupported mode.
IP = The resolver's certificate contains its IP address, allowing certificate validation without the SNI. Unmarked resolvers only possess domain certificates.

Public Resolver Support

	Unencrypted				Encrypted			
	UDP	Last Resp.	TCP	TCP Seg.	DoT	DoH	DoH3	DoQ
Adguard (6)	●	●	●	●	●IP	●IP	●IP	●IP
Cisco (6)	●	●	●	●	●IP	●IP	–	–
Cisco Chro								
Clean								
Brows								
are (								
(2)								
e (2)	●	●	●	●	●IP	●IP	●IP	–
llvad (6)								
NextDNS (2								
Quad9 (6)	●	●	●	●	●	●	–	–
Wikimedia (1)	–	–	–	–	●	●	–	–
Yandex (6)	●	●	●	●	●IP	●IP	–	–
# Supporting	41	41	41	41	47	47	16	8

● = Supported mode.
– = Unsupported mode.
IP = The resolver's certificate contains its IP address, allowing certificate validation without the SNI. Unmarked resolvers only possess domain certificates.

Unencrypted, DoT, DoH widely supported

SNI never required

Unencrypted Censorship Circumvention

	UDP		Last Resp.		TCP		TCP Seg.	
	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷
Adguard (6)								
Cisco (4)								
Cisco (2)								
Cisco Chromium								
CleanBrowsing (3)								
CleanBrowsing (2)								
CleanBrowsing (1)								
Cloudflare (5)								
Cloudflare (1)								
Gcore (2)								
Google (2)								
Mullvad (6)								
NextDNS (2)								
Quad9 (4)								
Quad9 (2)								
Wikimedia								
Yandex (5)								
Yandex (1)								
# Working								

Unencrypted Censorship Circumvention

	UDP		Last Resp.		TCP		TCP Seg.	
	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷
Adguard (6)	○	○			○	○		
Cisco (4)	○	○			○	○		
Cisco (2)	○	○			○	○		
Cisco Chromium	○	○			○	○		
CleanBrowsing (3)	○	○			○	○		
CleanBrowsing (2)	○	○			○	○		
CleanBrowsing (1)	○	○			○	○		
Cloudflare (5)	○	○			○	○		
Cloudflare (1)	○[1]	○			○[1]	○		
Gcore (2)	○	○			○	○		
Google (2)	○	○			○	○		
Mullvad (6)	–	–			–	–		
NextDNS (2)	–	–			–	–		
Quad9 (4)	○	○			○	○		
Quad9 (2)	○	○			○	○		
Wikimedia	–	–			–	–		
Yandex (5)	○	○			○	○		
Yandex (1)	○	○			○	○		
# Working	0	0			0	0		

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.

[1] Not working due to complete IP blocking via packet dropping.

Unencrypted Censorship Circumvention

	UDP		Last Resp.		TCP		TCP Seg.	
	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷
Adguard (6)	○	○	●	○	○	○		
Cisco (4)	○	○	●	○	○	○		
Cisco (2)	○	○	●	○	○	○		
Cisco Chromium	○	○	●	○	○	○		
CleanBrowsing (3)	○	○	●	○	○	○		
CleanBrowsing (2)	○	○	●	○	○	○		
CleanBrowsing (1)	○	○	●	○	○	○		
Cloudflare (5)	○	○	●	○	○	○		
Cloudflare (1)	○[1]	○	○[1]	○	○[1]	○		
Gcore (2)	○	○	●	○	○	○		
Google (2)	○	○	●	○	○	○		
Mullvad (6)	–	–	–	–	–	–		
NextDNS (2)	–	–	–	–	–	–		
Quad9 (4)	○	○	●	○	○	○		
Quad9 (2)	○	○	●	○	○	○		
Wikimedia	–	–	–	–	–	–		
Yandex (5)	○	○	●	○	○	○		
Yandex (1)	○	○	●	○	○	○		
# Working	0	0	40	0	0	0		

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.

[1] Not working due to complete IP blocking via packet dropping.

Unencrypted Censorship Circumvention

	UDP		Last Resp.		TCP		TCP Seg.	
	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷
Adguard (6)	○	○	●	○	○	○	●	◐
Cisco (4)	○	○	●	○	○	○	●	◐
Cisco (2)	○	○	●	○	○	○	●	◐
Cisco Chromium	○	○	●	○	○	○	●	◐
CleanBrowsing (3)	○	○	●	○	○	○	●	◐
CleanBrowsing (2)	○	○	●	○	○	○	●	◐
CleanBrowsing (1)	○	○	●	○	○	○	●	◐
Cloudflare (5)	○	○	●	○	○	○	●	◐
Cloudflare (1)	○[1]	○	○[1]	○	○[1]	○	○[1]	◐
Gcore (2)	○	○	●	○	○	○	●	◐
Google (2)	○	○	●	○	○	○	●	◐
Mullvad (6)	–	–	–	–	–	–	–	–
NextDNS (2)	–	–	–	–	–	–	–	–
Quad9 (4)	○	○	●	○	○	○	●	◐
Quad9 (2)	○	○	●	○	○	○	●	◐
Wikimedia	–	–	–	–	–	–	–	–
Yandex (5)	○	○	●	○	○	○	●	◐
Yandex (1)	○	○	●	○	○	○	●	◐
# Working	0	0	40	0	0	0	40	–

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.

[1] Not working due to complete IP blocking via packet dropping.

Unencrypted Censorship Circumvention

	UDP		Last Resp.		TCP		TCP Seg.	
Adguard (6)	○	○	●	○	○	○	●	◐
Cisco (4)	○	○	●	○	○	○	●	◐
Cisco (2)	○	○	●	○	○	○	●	◐
Cisco Chr								
Cle ow								
Brow								
Browsing (1)	○	○	●	○	○	○	●	◐
dflare								
dflare								
ore (2)								
Google (2)								
Mullvad (6								
NextDNS (2)	–	–	–	–	–	–	–	–
Quad9 (4)	○	○	●	○	○	○	●	◐
Quad9 (2)	○	○	●	○	○	○	●	◐
Wikimedia	–	–	–	–	–	–	–	–
Yandex (5)	○	○	●	○	○	○	●	◐
Yandex (1)	○	○	●	○	○	○	●	◐
# Working	0	0	40	0	0	0	40	–

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.

[1] Not working due to complete IP blocking via packet dropping.

UDP and TCP censored

Last Response and TCP Seg. Effective in China

Encrypted Censorship Circumvention

	DoT		DoH		DoH3		DoQ	
	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷
Adguard (6)	–	–	–	–	–	–	–	–
Cisco (4)	–	–	–	–	–	–	–	–
Cisco (2)	–	–	–	–	–	–	–	–
Cisco Chromium	–	–	–	–	–	–	–	–
CleanBrowsing (3)	–	–	–	–	–	–	–	–
CleanBrowsing (2)	–	–	–	–	–	–	–	–
CleanBrowsing (1)	–	–	–	–	–	–	–	–
Cloudflare (5)	–	–	–	–	–	–	–	–
Cloudflare (1)	–	–	–	–	–	–	–	–
Gcore (2)	–	–	–	–	–	–	–	–
Google (2)	–	–	–	–	–	–	–	–
Mullvad (6)	–	–	–	–	–	–	–	–
NextDNS (2)	–	–	–	–	–	–	–	–
Quad9 (4)	–	–	–	–	–	–	–	–
Quad9 (2)	–	–	–	–	–	–	–	–
Wikimedia	–	–	–	–	–	–	–	–
Yandex (5)	–	–	–	–	–	–	–	–
Yandex (1)	–	–	–	–	–	–	–	–
# Working	0	0	0	0	0	0	0	0

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.
-SNI = Works only when omitting the SNI extension.
[1] Not working due to complete IP blocking via packet dropping.

Encrypted Censorship Circumvention

	DoT		DoH		DoH3		DoQ	
	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷
Adguard (6)	○	● -SNI						
Cisco (4)	○	●						
Cisco (2)	○	○						
Cisco Chromium	–	–						
CleanBrowsing (3)	○	○						
CleanBrowsing (2)	○	● -SNI						
CleanBrowsing (1)	○	● -SNI						
Cloudflare (5)	○	○						
Cloudflare (1)	○	○						
Gcore (2)	–	–						
Google (2)	○	● -SNI						
Mullvad (6)	●	○						
NextDNS (2)	●	● -SNI						
Quad9 (4)	○	○						
Quad9 (2)	○	● -SNI						
Wikimedia	●	●						
Yandex (5)	○	○						
Yandex (1)	○	●						
# Working	9	21						

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.
-SNI = Works only when omitting the SNI extension.
[1] Not working due to complete IP blocking via packet dropping.

Encrypted Censorship Circumvention

	DoT		DoH		DoH3		DoQ	
								
Adguard (6)	○	●-SNI	○	●-SNI				
Cisco (4)	○	●	○	●				
Cisco (2)	○	○	○	●				
Cisco Chromium	–	–	●-SNI	●-SNI				
CleanBrowsing (3)	○	○	●	●-SNI				
CleanBrowsing (2)	○	●-SNI	●	●-SNI				
CleanBrowsing (1)	○	●-SNI	–	–				
Cloudflare (5)	○	○	○	○				
Cloudflare (1)	○	○	○	○				
Gcore (2)	–	–	–	–				
Google (2)	○	●-SNI	○	●-SNI				
Mullvad (6)	●	○	●	○				
NextDNS (2)	●	●-SNI	●	●-SNI				
Quad9 (4)	○	○	○	●-SNI				
Quad9 (2)	○	●-SNI	○	●-SNI				
Wikimedia	●	●	●	○				
Yandex (5)	○	○	●-SNI	●				
Yandex (1)	○	●	●-SNI	●				
# Working	9	21	21	34				

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.
-SNI = Works only when omitting the SNI extension.
[1] Not working due to complete IP blocking via packet dropping.

Encrypted Censorship Circumvention

	DoT		DoH		DoH3		DoQ	
	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷	🇨🇳	🇮🇷
Adguard (6)	○	●-SNI	○	●-SNI	○	○	○	●
Cisco (4)	○	●	○	●	–	–	–	–
Cisco (2)	○	○	○	●	–	–	–	–
Cisco Chromium	–	–	●-SNI	●-SNI	–	–	–	–
CleanBrowsing (3)	○	○	●	●-SNI	–	–	–	–
CleanBrowsing (2)	○	●-SNI	●	●-SNI	–	–	–	–
CleanBrowsing (1)	○	●-SNI	–	–	–	–	–	–
Cloudflare (5)	○	○	○	○	○	●	–	–
Cloudflare (1)	○	○	○	○	○	●	–	–
Gcore (2)	–	–	–	–	–	–	–	–
Google (2)	○	●-SNI	○	●-SNI	○	○	–	–
Mullvad (6)	●	○	●	○	–	–	–	–
NextDNS (2)	●	●-SNI	●	●-SNI	●	●	●	●
Quad9 (4)	○	○	○	●-SNI	–	–	–	–
Quad9 (2)	○	●-SNI	○	●-SNI	–	–	–	–
Wikimedia	●	●	●	○	–	–	–	–
Yandex (5)	○	○	●-SNI	●	–	–	–	–
Yandex (1)	○	●	●-SNI	●	–	–	–	–
# Working	9	21	21	34	2	8	2	8

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.
-SNI = Works only when omitting the SNI extension.
[1] Not working due to complete IP blocking via packet dropping.

Encrypted Censorship Circumvention

China censors more resolvers

Many censored based on SNI

Easy circumventions

	DoT		DoH		DoH3		DoQ	
Adguard (6)	○	● -SNI	○	● -SNI	○	○	○	●
Cisco (4)	○	●	○	●	–	–	–	–
Cisco (2)	○	○	○	●	–	–	–	–
Cisco CI	○	○	○	●	–	–	–	–
CleanBr	○	○	○	●	–	–	–	–
CleanBr	○	○	○	●	–	–	–	–
CleanBrowsing (1)	○	● -SNI	○	●	–	–	–	–
Cloudfla	○	○	○	●	–	–	–	–
Cloudfla	○	○	○	●	–	–	–	–
Gcore (2)	–	–	–	–	–	–	–	–
Google	○	○	○	●	–	–	–	–
Mullvac	○	○	○	●	–	–	–	–
NextDN	○	○	○	●	–	–	–	–
Quad9 (4)	○	○	○	● -SNI	–	–	–	–
Quad9 (2)	○	● -SNI	○	● -SNI	–	–	–	–
Wikimedia	●	●	●	○	–	–	–	–
Yandex (5)	○	○	● -SNI	●	–	–	–	–
Yandex (1)	○	●	● -SNI	●	–	–	–	–
# Working	9	21	21	34	2	8	2	8

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-SNI = Works only when omitting the SNI extension.
[1] Not working due to complete IP blocking via packet dropping.

Encrypted DNS in Browsers Usable?

	Domain Resolvable?	
		
Adguard (6)	●	○
Cisco (4)	●	●
Cisco (2)	●	●
Cisco Chromium	●	○
CleanBrowsing (3)	●	○
CleanBrowsing (2)	●	○
CleanBrowsing (1)	●	○
Cloudflare (5)	●	○
Cloudflare (1)	●	○
Gcore (2)	–	–
Google (2)	●	○
Mullvad (6)	○	○
NextDNS (2)	●	○
Quad9 (4)	●	○
Quad9 (2)	●	○
Wikimedia	●	●
Yandex (5)	●	●
Yandex (1)	●	●
# Working	42	13

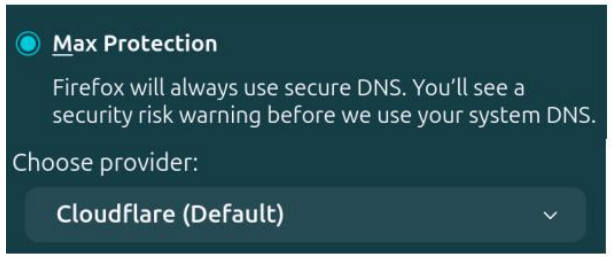
– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.

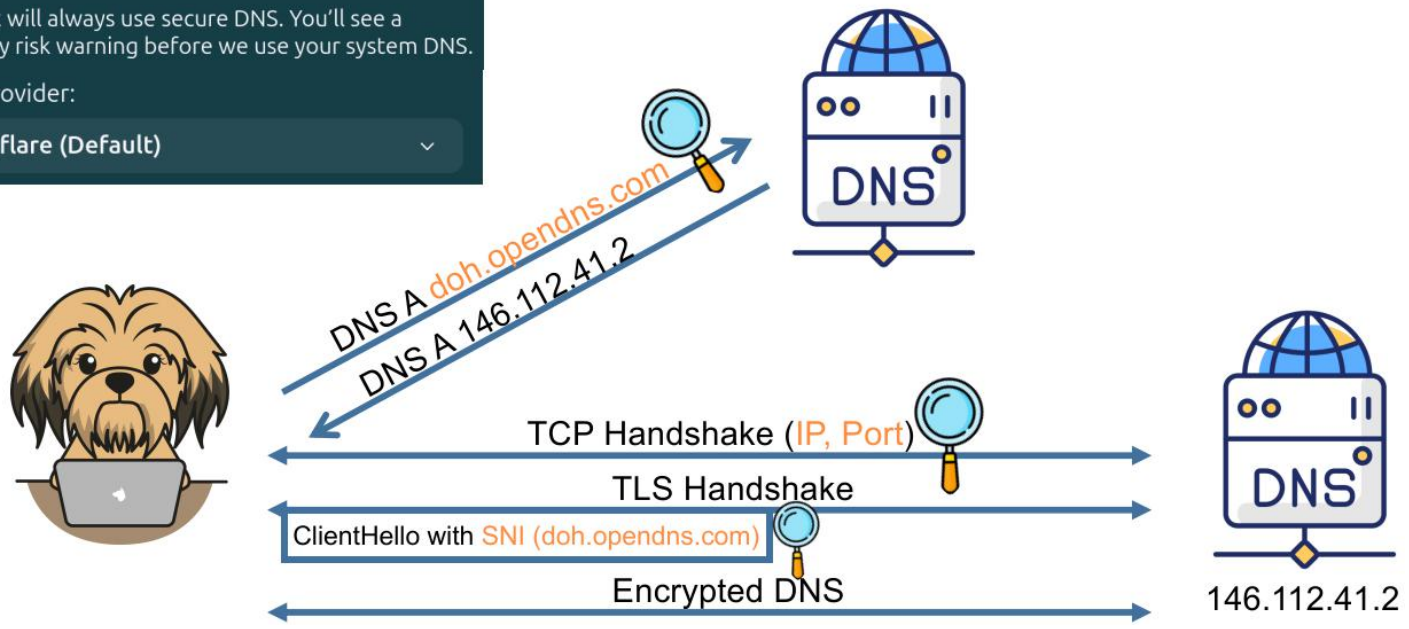
Encrypted DNS in Browsers Usable?

	Domain Resolvable?	
		
Adguard (6)	●	○
Cisco (4)	●	●
Cisco (2)	●	●
Cisco Chromium	●	○
CleanBrowsing (3)	●	○
CleanBrowsing (2)	●	○
CleanBrowsing (1)	●	○
Cloudflare (5)	●	○
Cloudflare (1)	●	○
Gcore (2)	–	–
Google (2)	●	○
Mullvad (6)	○	○
NextDNS (2)	●	○
Quad9 (4)	●	○
Quad9 (2)	●	○
Wikimedia	●	●
Yandex (5)	●	●
Yandex (1)	●	●
# Working	42	13

– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.

Encrypted DNS in Browsers ~~to the Rescue?~~



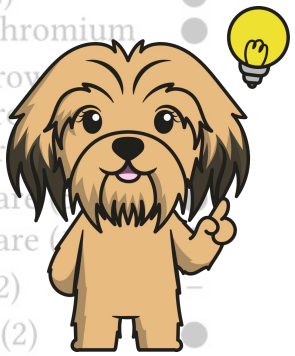


Encrypted DNS in Browsers Usable?

	Domain Resolvable?	
Adguard (6)	●	○
Cisco (4)	●	●
Cisco (2)	●	●
Cisco Chromium	●	○
CleanBrow	●	○
CleanBr	●	○
CleanBr	●	○
Cloudflar	●	○
Cloudflare	●	○
Gcore (2)	–	–
Google (2)	●	○
Mullvad (6)	○	○
NextDNS (2)	●	○
Quad9 (4)	●	○
Quad9 (2)	●	○
Wikimedia	●	●
Yandex (5)	●	●
Yandex (1)	●	●
# Working	42	13

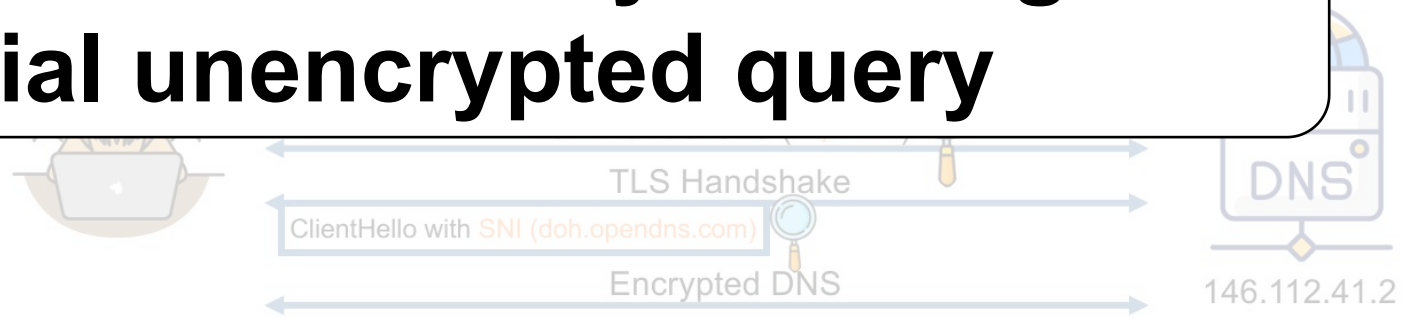
– = Unsupported, ○ = Supported but censored, ◐ = Works inconsistently, ● = Works.

Encrypted DNS in Browsers ~~to the Rescue?~~



Iran censors encrypted DNS with unencrypted DNS

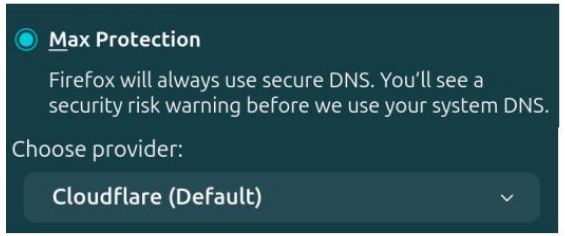
Circumvention by omitting initial unencrypted query

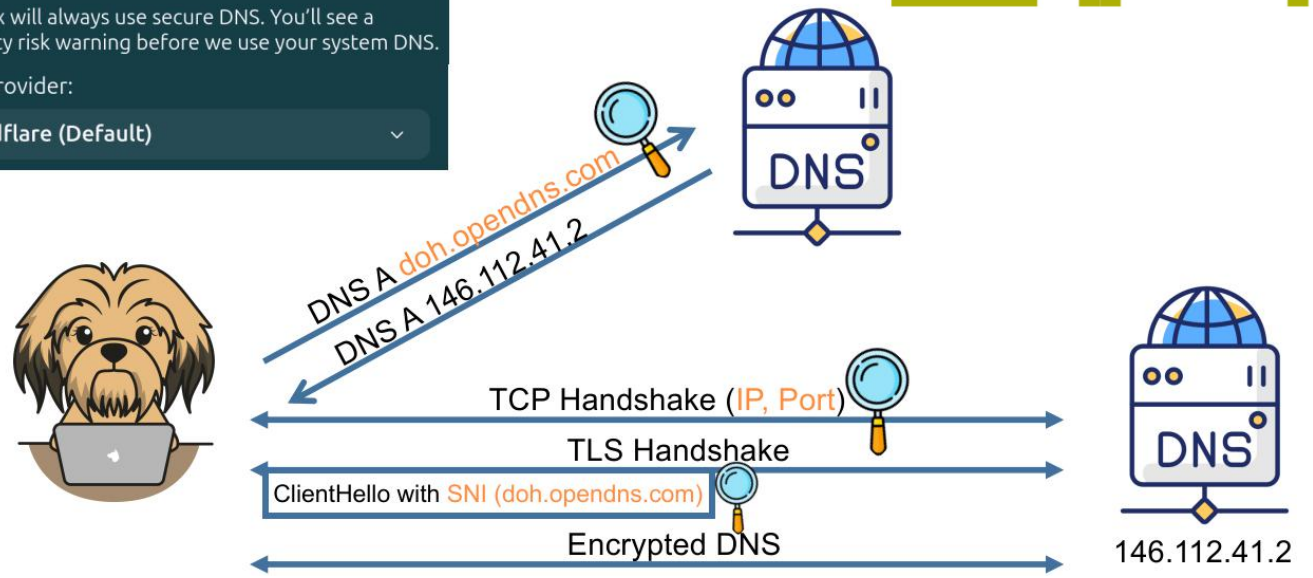


Takeaways

- DPYProxy-DNS publicly available
- Automatic DNS censorship circumvention

- Browsers need improvements!
  - Remove initial query **Encrypted DNS in Browsers ~~to th~~**
  - Do not send SNI





Backup Slides

Which Resolvers?

dnsprivacy.org
wikipedia

Layer Overview

A Layer Overview of Analyzed Encrypted DNS Protocols

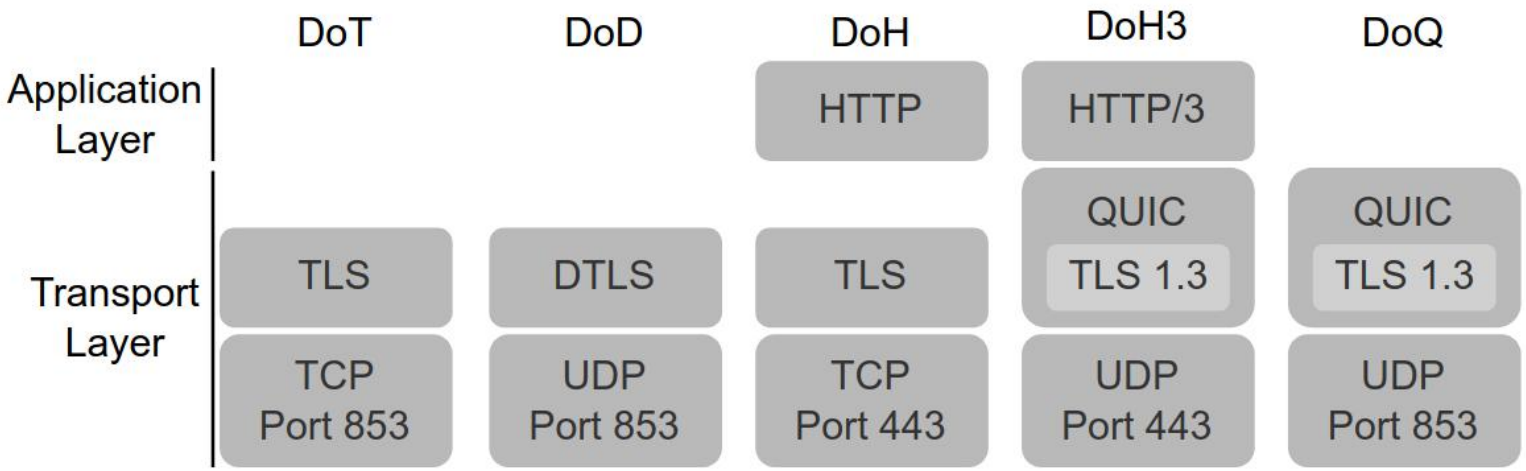


Figure 3: Layer overview of DoT, DoD, DoH, DoH3, and DoQ with additional port information.

In-Path vs. On-Path

B In-Path and On-Path Example

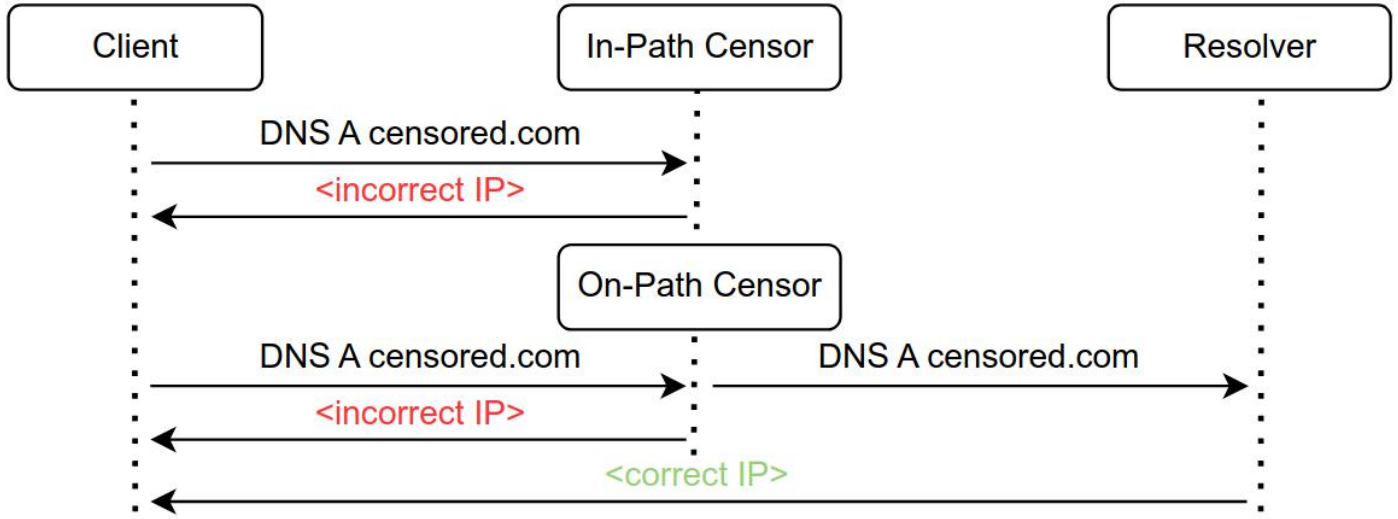


Figure 4: Example of an in-path and an on-path censor. The in-path censor can directly block the packet and inject its own response, while the on-path censor injects a response with the requirement to be faster than the intended response.

Last Response Mode

C Last Response Mode Example

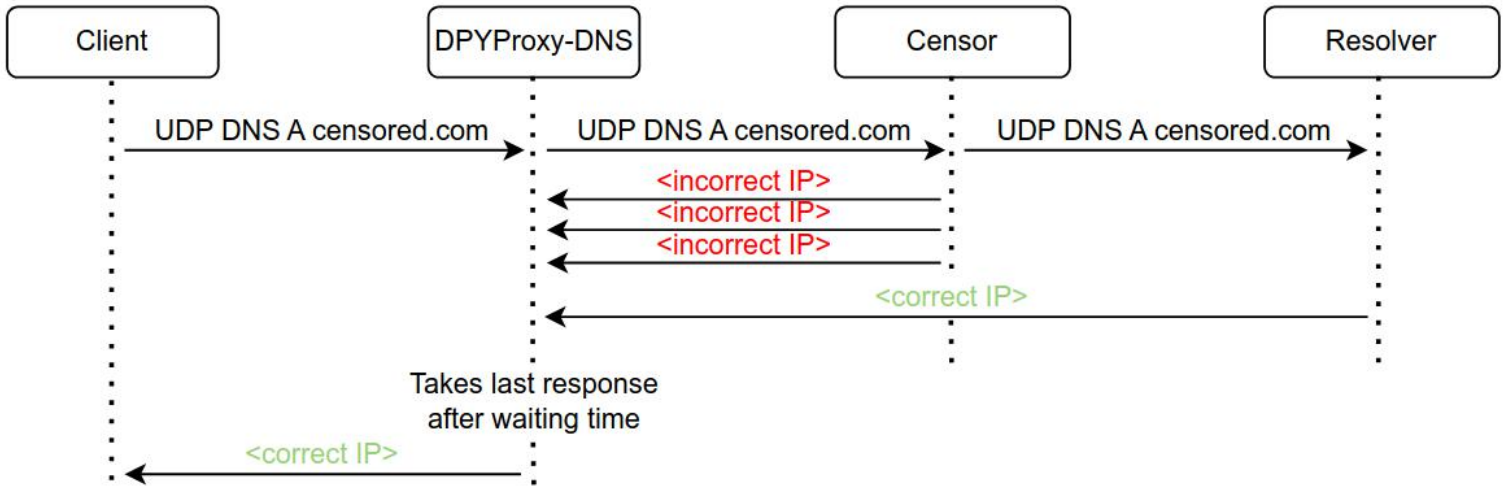


Figure 5: Example of DPYProxy-DNS's Last Response mode. The tool waits for a fixed waiting time and then chooses the last received message, which, in this example, is the correct IP.

Server Specifications

Table 3: Specification of our Vantage Point in Iran.

Country:	Mashhad, Iran
Autonomous System Number:	201295
Vendor:	Avanetco
URL:	https://www.avanetco.com/
Internet Service Provider:	Shabakeh Ertebatat Artak Towseeh PJSC (private)

Table 4: Specification of our Vantage Point in China.

Country:	Zhengzhou, China
Autonomous System Number:	4837
Vendor:	China VPS Hosting
URL:	https://chinavpshosting.com/
Internet Service Provider:	CHINA UNICOM (state-owned)