Blind In/On-Path Attacks
and Applications to VPNs

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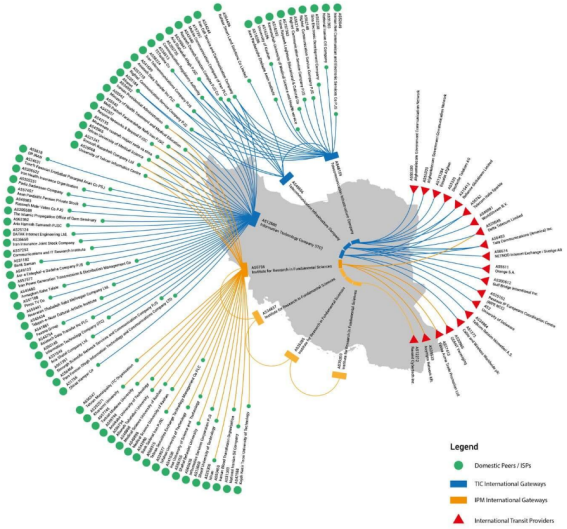
Research question

Do VPNs (and related technologies such as Psiphon, Orbot, *etc.*) protect the connections tunneled through them from inference, interference, and hijacking?

- Public Wifi
- State-controlled cell tower
- In-path state-controlled ISP

In-path state-controlled ISP



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Attacker with *.facebook.com SSL/TLS cert: 2009 vs. today

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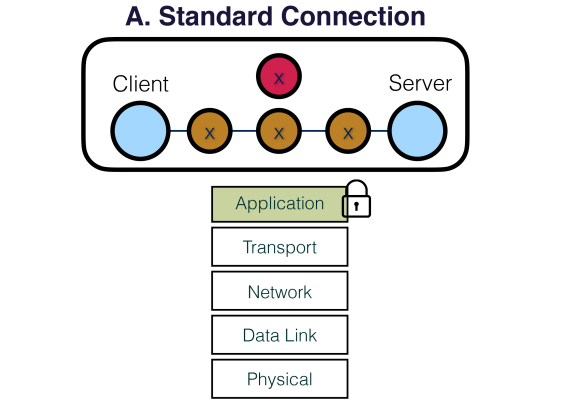
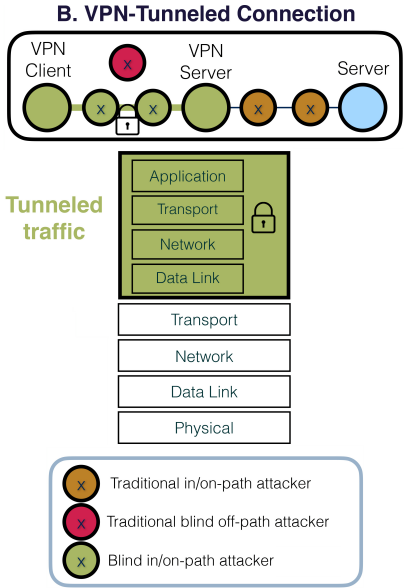
What if the Facebook users in Iran in 2009 had all used a VPN?

E.g., the latest version of WireGuard from May, 2021

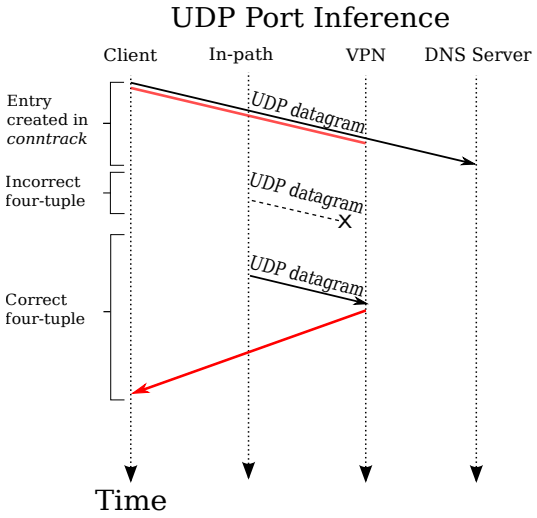
Need for new terminology



New terminology: *Blind In/On-Path Attacker*



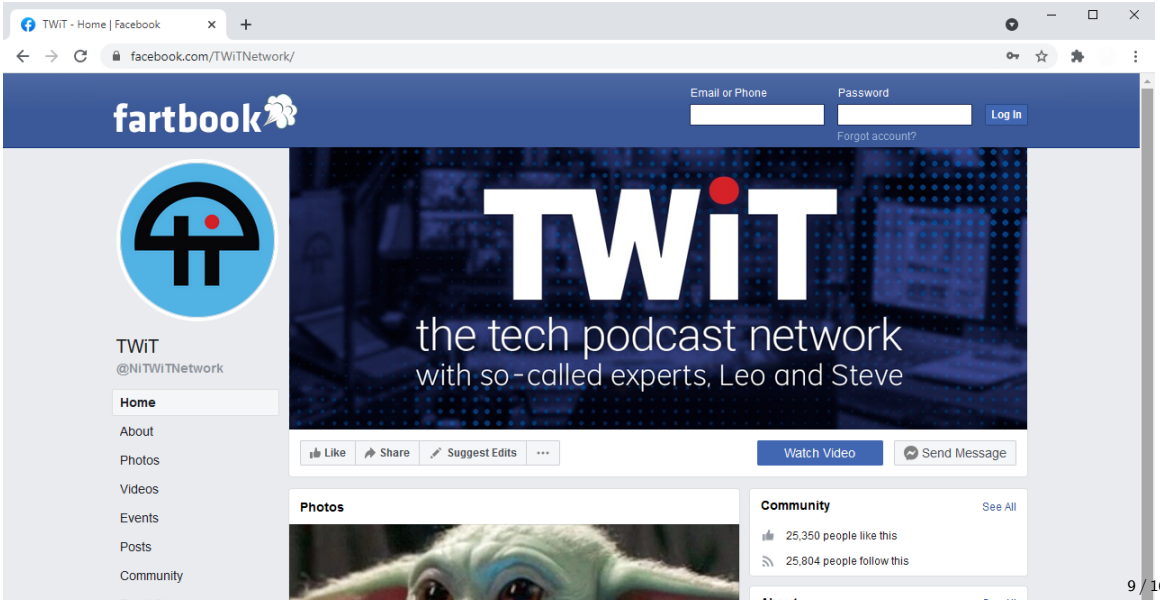
Server-side attack on DNS over UDP



IP	UDP			DNS		
...	...	dst port	...	...	TXID	...

- Off-path attacker
  - $2^{16} \times 2^{16} = 2^{32}$, ☹
- In/On-path attacker
  - $2^{16} + 2^{16} = 2^{17}$
  - 32,768× faster than 2^{32} ☺

Man-in-the-middle despite TLS and VPN



Is hijacking DNS practical?

Tested for different DNS timeouts:

- 15 seconds (*e.g.*, Android 11): 75.3% succuessful
- 10 seconds (*e.g.*, Ubuntu 20.04): 48.1% succuessful
- 5 seconds (*e.g.*, Firefox 80.0.1): 11.6% succuessful

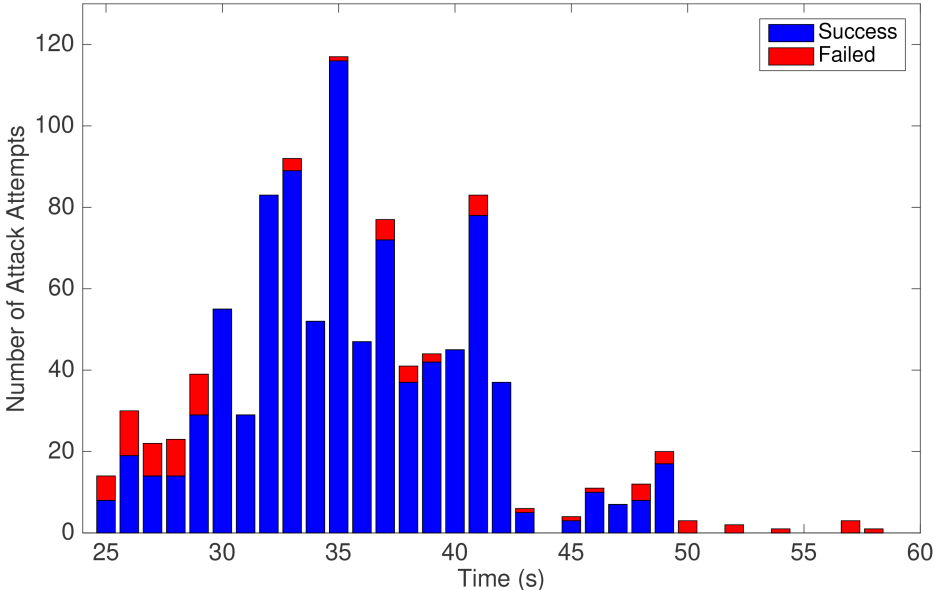
Client- *vs.* server-side attacks

- We also did *client-side attacks*
  - Can infer that a client is connected to a VPN, infer the existence of TCP connections in the VPN tunnel, and then reset or even hijack those connections
- The DNS over UDP attack you just saw is *server-side*
  - Interface and all packet fields are identical for attack *vs.* legitimate traffic
  - It's also possible to do any of our TCP attacks above server-side

Disclosure and mitigation

- Ethical Disclosure
  - CVE-2019-9461
  - CVE-2019-14899
  - Correspondence with Linux kernel developers
- Mitigation
  - *Client-side **mitigated** by many vendors by distinguishing the interface*
  - *Server-side totally **unmitigated** by any vendor despite ethical disclosure*

Client-side results



Future work

- Have client-side attacks actually been mitigated by vendors?
- How practical are server-side attacks for a real ISP?
- Can we detect and prevent server-side attacks?
- What about things like Shadowsocks?
- What about padding, *etc.*?
  - *e.g.*, obsfproxy
- What else can go wrong when you stack layers of abstraction on top of each other and encrypt them?

Conclusion

- You can encrypt your packets, but you can't hide their existence, timing, or size
- Blind in/on-path attackers should be considered when designing any protocols that might be tunneled (*e.g.*, in a VPN)

Thank you!

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