The Dark Web
Tor and the Dark Web

- There are ways to use the Internet (almost) untraceably
- This can be used for good purposes or bad purposes
- Two technologies are necessary, communication and payment
- Let’s look at the technologies first
Payment System Requirements

- Untraceable (i.e., cash, not credit cards)
- Decentralized, to avoid a single point of monitoring and control
Digital Cash Requirements

- Prevent counterfeiting
- Prevent double-spending
- If these can’t be prevented, make sure that violators are identified
- There have been schemes for this since the 1980s, but they all required a “bank”
Digital Currencies

(photos from Wikipedia)
Bitcoin

• Bitcoin was the first truly decentralized digital cash system
• It was invented by the pseudonymous “Satoshi Nakamoto”
• Bitcoins are “mined” by solving a hard cryptographic problem
  The only way to “solve” it is brute force
• Double-spending is prevented by recording transactions in the “block chain”, a distributed database updated via a peer-to-peer network
• People generally buy and store Bitcoin via exchanges
The Block Chain

- A distributed, publicly verifiable, ledger
- Bitcoin transactions are sent to block chain nodes
- They work (i.e., do lots of calculations) to solve a cryptographic problem; when they succeed, they add a new block to the chain
- (Each block points to the previous block)
- In case of ties, the longest block wins
- Eventually, all nodes agree on the sequence of transactions
- Since each transaction is recorded, you can’t double-spend a Bitcoin
- Important note: block chains have other uses besides cryptocurrencies
Status of Bitcoin

- Bitcoin had been used legitimately (even in the Microsoft App Store), but its volatility and high transactions costs have made that much less common.

- Its value fluctuates quite a bit, and there have been scandals in the Bitcoin industry.

- Mining has become uneconomical; it costs more in electricity than the resulting Bitcoins are worth.

- Hackers are using web browsers to mine for them. Salon wants you to allow them to do this if you use an ad-blocker (https://arstechnica.com/information-technology/2018/02/salon-to-ad-blockers-can-we-use-your-browser-to-mine-cryptocurrency/).

- Bitcoin doesn’t scale well—it was never properly engineered for high-volume use.
It Isn’t Completely Anonymous

- Because all transactions are publicly recorded in the block chain, it’s possible to link together various transactions
- If the user’s private files are compromised, all transactions by that user are revealed
- There are variants of Bitcoin that solve that
- There are also “tumblers”—sites that mix together various bitcoin transactions, to disguise who has received what from whom (though they don’t work all that well)
Ethereum

- Ethereum: embed programs—“smart contracts”—into the coins
- Will those programs be correct?
- The DAO incident: a bug in an Ethereum contract let someone loot a lot of Ethers
- (Other bugs, too)
- But: cryptokitties!
Initial Coin Offerings

- Instead of selling stock, sell cryptocoins—usually by payment in Bitcoin or Ethers
- In theory—or at least, according to some theories—these are currency, not stocks, and therefore not subject to Securities and Exchange Commission regulations
- Some can, in principle, be used later to buy services from the companies
- The SEC doesn’t always agree with the issuers...
Current Status

- There are very many cryptocurrencies
- Most have relatively low acceptability, i.e., you can’t easily sell or spend them
- Most economists think that Bitcoin is a bubble (but that’s been said for years)
- A lot of work to improve scalability
- Many legal concerns: fraud by the exchanges, hacking of them, money laundering, use by criminals, and more
- But—major financial firms are seriously interested
Crypto Kitties

115,376 Kitties

Kitty 565955 - Gen 0 - Fast
Kitty 565891 - Gen 0 - Fast
Kitty 565854 - Gen 7 - Snappy
Kitty 565825 - Gen 0 - Fast
Kitty 566387 - Gen 0 - Fast
Kitty 565894 - Gen 0 - Fast
Kitty 565853 - Gen 7 - Snappy
Kitty 565826 - Gen 0 - Fast
Kitty 565827 - Gen 0 - Fast
Tracking

- There are many ways to identify users and servers on the Internet
- One is IP address—every computer that talks on the net needs an IP address
- ISPs know who owns an IP address at a given time
- Governments can obtain that information if they wish to harass users
- The IP addresses are public, for governments that want to block certain sites
- Is there a solution?
Solutions

• Forward traffic through some other node
• Will the trace stop at the forwarding node?
• What are the attackers’ powers?
Virtual Private Network

- All nodes forward traffic to a VPN node
- It sends the traffic to desired destinations
- Destination nodes see the IP address of the VPN node, not that of the actual clients
- However...
Hiding the Source Address with a VPN
Powerful Attackers

- Suppose the attacker can wiretap the link to the VPN
- Match the input packets with the output packets
- Who are the attackers? Destination nodes can’t identify the source, but a government can
An Encrypted VPN
Metadata

• Using the IPsec VPN protocol, the length of encrypted packets is (usually) $42 + |P| + ((14 - |P|) \mod 16)$, where $|P|$ is the length of the plaintext packet.

• An eavesdropper who monitors packet lengths can still identify the real source.

• It’s possible to add padding—but that doesn’t hide timing: who sent a packet just before one was forwarded?

• Or—look for packet size distribution.
Monitoring Packet Size Patterns
Requirements for a Solution

- Mix traffic from multiple sources
- Defend against local eavesdroppers
- Avoid easy-to-detect patterns
Tor: The Onion Router

- Assumption: many clients
- Assumption: eavesdropping possible
- But—the adversary isn’t “global”
- That is, it can monitor many links but not all
- The NSA is not the all-seeing eye...
How it Works

- A client computer picks a set of 3–4 “relay nodes” and an “exit node”
- (All of these nodes are volunteers)
- The client sends the traffic to the first node, which sends it to the second, etc.; the exit node forwards it to the real destination
- The set of Tor nodes used, including the exit node, is changed frequently
- In other words, the source IP address is short-lived
Multiple Hops
Onion Routing

- G thinks that both connections are coming from D
- The real sources—A and B — are hidden
- On subsequent visits, C and Z may be the exit nodes
- Intuitive understanding: nested envelopes
Why Multiple Hops?

- If someone is spying on D or its links, they’ll see where traffic is coming from.
- Here, though, traffic is coming from E and C — which is which?
- Can the same attacker spy on E and C?
- Remember that the path will switch soon.
Change Paths Frequently
Using Cryptography
What is Known

- Each node knows only the previous and next hops
- Nodes do not know where on the path they are
- Only the exit nodes knows the destination
- Only the entrance node knows the source
- Intuitive understanding: nested sealed envelopes; each hop adds its own return address
Anonymous Browsing

- With Tor, it is possible to browse the web without being identified
- It’s great for dissidents in oppressive countries
- It’s also great for spies, law enforcement investigations, etc.
- (Tor was invented at the Naval Research Lab—the military understands the need for this sort of anonymity for their communications)
- No accountability...
What About Servers?

- Servers traditionally live at a known IP address
- But Tor is designed to hide IP addresses—even the exit nodes don’t know the user’s real IP address
- Even if we solve that problem, what about authenticity? How does the Tor network know which is the real claimant to some service?
Tor Hidden Services

- The server operator picks some set of Tor nodes as *introduction points*
- These nodes are registered in a distributed directory
- A client node opens a Tor service to some random Tor node, and uses it as a *rendezvous point*
- The client sends the address of its rendezvous point to the server’s introduction point
- The server opens a Tor circuit to the rendezvous point
- The rendezvous node forwards traffic between the two Tor services
Creating an Introduction Point
Creating an Rendezvous Point
Notifying the Introduction Point
Authenticating Hidden Services

- The server generates a key pair
- The private key is used to sign all of its announcements, e.g., of the introduction points
- The server’s name is formed from a hash of the public key
- In other words, you cannot have arbitrary “.onion” names—but you can keep generating keys until you get one you like
Generating .Onion Names

- Generate a key pair
- Take the SHA-1 hash of the public key, and truncate it to 80 bits
- Represent the truncated hash in base 32, using 26 letters and 6 digits
- If you don’t like the result, try again
Facebook’s Hidden Service Certificate

Certificate:
Data:
  Version: 3 (0x2)
  Serial Number:
  Signature Algorithm: sha256WithRSAEncryption
  Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert SHA2 Extended Validation Server CA
Validity
  Not Before: Sep 25 00:00:00 2015 GMT
  Not After : Nov 28 12:00:00 2016 GMT
Subject: businessCategory=Private Organization/1.3.6.1.4.1.311.60.2.1.3=US/1.3.6.1.4.1.311.60.2.1.2=Delaware/serialNumber=3835815/street=1601 Willow Rd./postalCode=94025, C=US, ST=CA, L=Menlo Park, O=Facebook, Inc., CN=*.facebookcorewwwwi.onion
Subject Public Key Info:
How Did They Get facebookcorewwwi.onion?

- The prefix ‘facebook’ is 8 characters—40 bits, if a base 32 number
- Generating a key whose hash has the first 40 bits of that string takes $O(2^{40})$ tries
- They then looked at the candidate names for one that had a suffix—“corewwwi”—for which they could construct a plausible story
- Facebook has *lots* of computers…
Why Does Facebook Use Tor?

- Facebook, of course, wants to learn lots about its users
- Why should it like Tor?
- Some countries, notably Iran, were blocking Facebook—but not Tor
- They noticed that many of their Iranian users were connecting over Tor, so they decided to make it work properly
The Dark Web

- There are other services that use Tor hidden services as well
- Some of them are rather less benign than Facebook
The Silk Road

- An online drug, etc., market place
- Created by “Dread Pirate Roberts” (DPR), later shown to be Ross Ulbricht
- More of an EBay than an Amazon—the site hosted independent sellers
- Payment was in Bitcoin; delivery was by UPS, FedEx, etc.
- DPR also solicited murders of former lieutenants he thought had betrayed him
The Fall of the Silk Road

- The FBI—somehow!—located the physical server, in Iceland
- Assorted Federal agents wormed their way into DPR’s confidence—after all, it was all online, anonymous activity—and became assistant site admins
- Early on, Ulbricht had posted a query to Stack Overflow on setting up Tor services—and he used his own name
- He was arrested in a San Francisco library, while online as DPR
- To add to the fun, two of the Federal agents investigating the Silk Road were themselves corrupt...
Child Pornography

- Child pornography is also popular on the Dark Web
- It’s a natural fit—it’s all information-based; there’s no need to ship anything physical
- The FBI has had some success here, too
Hacking Tor

- Suppose you control a Tor hidden server
- Maybe you’ve found it and done something physical—or maybe you’ve hacked into it
- Plant malware on that server—and when other Tor users visit it, infect their machines
- All that software has to do is send the FBI the machine’s real IP address
- The FBI has done exactly that
Legal and Ethical Issues!

- Is it proper for the FBI to hack computers? There’s no explicit statutory authority, but most lawyers say it’s OK if they have a search warrant.
- Do judges understand the warrants they’re signing?
- Is it OK for the FBI to run a child porn server for a while?
- Is it OK to hack a machine in another country, or one where you don’t even know what country it’s in?
- Is it OK to hack hundreds or thousands of machines with a single warrant?
- Do judges understand those warrants?
SecureDrop

- A Tor hidden service for whistleblowers
- News organizations run Tor SecureDrop services—to send information anonymously to such an organization, connect via Tor

(See https://theintercept.com/securedrop/ or https://securedrop.propublica.org/)

- Note well: procedural security matters, too
Risks of Tor

- Exit nodes have been seized or searched by the police
- What if the exit node is corrupt? That has happened.
- There are various statistical attacks on Tor links
- (The FBI apparently subpoenaed the results of some experiments at CMU)
The Bomb Threat During Finals

- At one school, a bomb threat was email in during finals
- It was sent over Tor
- The network folks found that only one person at that school was using Tor at that time...
User Errors

- Tor protects the IP address, but not anything else
- Higher-level data is not anonymized—it can often reveal identity or at least continuity (e.g., login names or tracking cookies)
- If you don’t patch your system, you can be hacked
- Never use Tor except through the official Tor Browser Bundle or the Tails bootable USB stick
Is Tor Worth It?

- Evading censorship is good
- Talking freely to news agencies is good
- Child pornography is not good
- Soliciting murders for hire is even worse
- Should Tor exist? What about Tor hidden services?