ECE560
Computer and Information Security

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Cryptocurrencies: the Short Version

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Structure of this talk based on
[“But how does bitcoin actually work?” by 3Blue1Brown on YouTube]

Cryptocurrency: Origins

- **Regular currency**: Money managed by a central authority. E.g., created by government, non-cash spending tracked by banks.
  - Want to send some money? Record a row into a database. Easy.

But wait! I want a form of money with <u>no central authority</u>!

Also, I want to waste as much electricity as possible,
and I don’t mind if I enable tons of crime.

- Satoshi Nakamoto, probably

Inventing BitCoin

- **BitCoin**: First cryptocurrency, invented by “Satoshi Nakamoto” (pseudonym, identity unknown) in 2008
  - Key innovation: solves the double-spend problem
- Many follow-on cryptocurrencies that make different design decisions
- Key properties in common:
  - **Ledger-based**: The transaction history *is* the currency
  - **Digital signatures on transactions**: Establish identity
  - **Peer-to-peer network:** Decentralizes it
  - **Proof-of-work system**: Miners accept transactions and turn them into blocks in exchange for bonus currency
  - **Block chain**: Prevent double-spend in the long term

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Ledger-based with digital signatures

- A ledger is a list of transactions, e.g. "Alice pays Bob $20, Charlie pays Denise $35, etc."
- Anyone can append lines, except:
  - Spender must author the transaction
  - Spender can't spend more than they have
  - Transaction must have a **digital signature** from spender
- Others will verify these properties (covered soon)

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Peer-to-peer network

- **Peer-to-peer network**: A network with no clear client/server relationship; all participants are **peers** and can talk to one another
  - Some complexity in finding fellow peers with no central authority to organize, but this is solvable
- Don't want a central authority to own the ledger, so **everyone keeps their own copy of the ledger.**
- Have to **broadcast** transactions to peer network, get them to record it into their ledgers

- Big problem: How to get rest of the world to agree on the same sequence of transactions? This is what BitCoin solved.

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Proof-of-work system

- Each client trusts whatever version of the ledger has the most computational work put into it.
  - Goal: Make it computationally infeasible for fraudulent transactions to survive
- Method:
  - Gather many transactions that are being broadcast into a **block**
  - Find a piece of data that, when appended to the block, causes the hash of that data to be ***special*** (e.g., to start with a N zero-bits)
    - Have to try 2^N tries on average to find one! Also, N is configurable.
  - Others can verify this is true quickly; this is a **proof of work**
    - Others also verify all signatures and that nobody overspent

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Block chain

- For those **blocks** from before, each must also contain the hash of the previous block
  - This puts them into an order, or *chain* of blocks: the **block chain**
  - Can't change earlier transaction without re-computing *all* the subsequent proofs of work
- Peers trust the *longest* chain
  - Breaks ties, ensures that network trends toward consensus
- Thanks to nodes doing *tons* of computation, 99.999999% of which is wasted, the network arrives at consensus on a single view of the ledger or **block chain**

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Motivating the waste: Mining

- Wait, why would someone bother doing hours of computation just to validate other peoples' transactions?
  - **We bribe them**: whatever node successfully gets its proof of work accepted is awarded a free transaction that *creates* some Bitcoin for them
  - This is where Bitcoins come from, and it's why they call it "mining" (could really be called "validating other peoples' spending for cash")
  - Miners also earn transaction fees too: **bribes** to include one transaction in an attempt versus another
    - If you try to spend Bitcoin but include too little of a bribe, no miners will include it and the spend will never happen. But it's probabilistic, so you just see it "waiting to go through" for a long time before giving up.
- **Sliding difficulty**: BitCoin protocol sets the difficulty of the proof of work (number of zeroes at the front of the hash) so the average time is ~10 minutes (no matter how many people are mining)
  - Exponentially increasing computation → exponentially increasing cost

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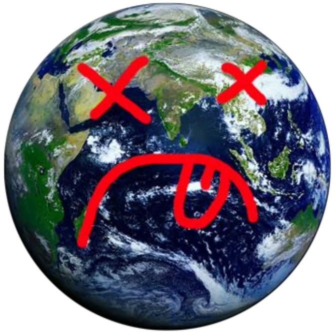
Why I hate Bitcoin and think it harms the world: #1. WASTE

- To record a transaction in a traditional system, a database might use 10ms of computation on a 500 W server: 5 J of energy/transaction
- BitCoin: does 4.6 transactions per second (src), uses ~7 GW of power worldwide (src):
  (1/4.6) * 7 GW = 1.5 **G**J of energy/transaction
- The energy use per transaction of BitCoin is
  300 MILLION TIMES WORSE
  - I literally can't think of anything less efficient than this on earth.
- 0.21% of all electricity generated by our species goes into this!
  ¯\_(ツ)_/¯



Why I hate Bitcoin and think it harms the world:
#2. CRIME

- BitCoin is the single reason **ransomware** exists
  - Before, there was safe no way for criminals to charge “customers” (victims)
  - Now, cryptocurrency allows anonymous payments in an automated way
  - Greatly increased motivation of criminal black-hat hackers – new path to revenue!
- Cryptocurrency gives rise to **electronic black markets**
  - Want to charge for your botnet, attack services, child pornography, assassination, fake credentials, or cocaine? BitCoin is for you!
- **Forensic accounting** (tracking money) used to be a top method of law enforcement against cyber criminals. Now it’s not. ¯_(ツ)_/¯

Why I hate Bitcoin and think it harms the world:
#3. WALLET SECURITY

- Your private key ("wallet.dat") ***is*** the money,
  if it's stolen, nobody can help you.
  - In traditional currency

    Victim: "My card was stolen, freeze it immediately and reverse the charges!"
    Bank: "Of course, and we'll cover the losses."
  - In cryptocurrency

    Victim: "Hello, computer programs! My wallet.dat was stolen!"
    Nobody: ¯_(ツ)_/¯
  - $1.1 BILLION in cryptocurrency was stolen in 2018 (src).
  - Not just individuals, **currency exchanges** are frequent targets, as "remote shell" now equals "direct access to millions of dollars"
- Also, if you lose that file, you lose the money irrevocably
  - In fact, 20% of all BitCoin mined is eventually lost forever (src)

Conclusion

- Cryptocurrency:
  - Interesting application of cryptography to solve a hard problem:
    a decentralized tamper-resistant public ledger system
  - Downsides: garbage efficiency, garbage security, incentivizes crimes
- Blockchain in general:
  - A lot of interest in blockchain for other purposes (much of it stupid)
  - Do you need a globally writable public ledger where nobody is trusted, and you’re willing to have absolute garbage time and energy efficiency to do so?

    Then check out ~~block chain~~ revising your requirements to be less insane!