Blockhains and Distributed Ledgers
Lecture 10

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Lecture 10

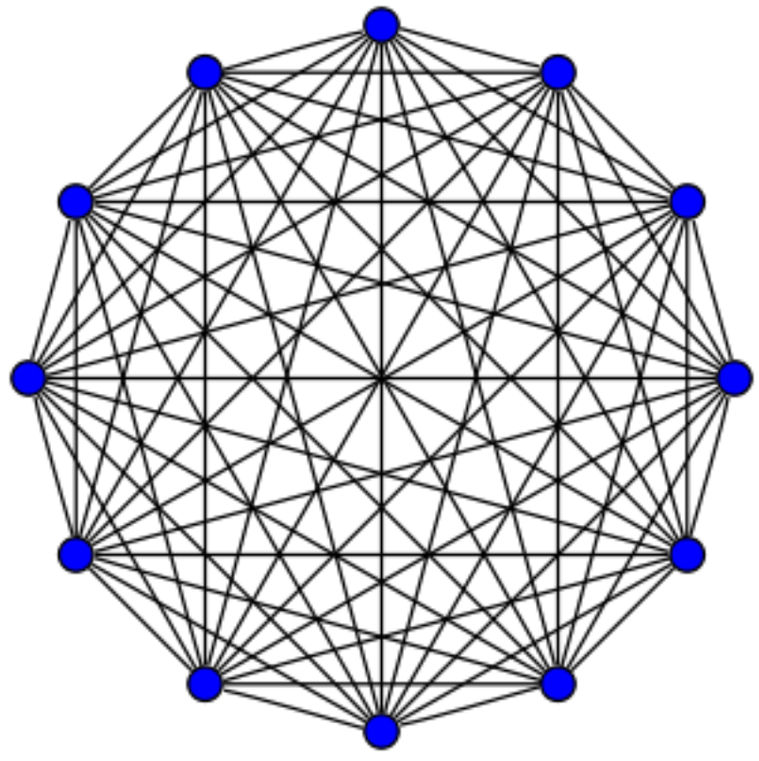
- The distributed ledger “ecosystem”, policy, real world and applications.
- Physical objects - colored coins.
- Namecoin.

Overlay networks, I

- A reliable network is critical for blockchains and distributed ledger protocols to operate.
- typically they utilize an overlay network.
- An overlay network, is a network built on top of another network.
- In an overlay network, virtual links connect the participating nodes.

Overlay networks, II

in a network
we would like
nodes to
be fully connected



relevant operations :

1. point-to-point communication
2. broadcast.

Network Requirements

- Synchronicity.
- Reliable message transmission.
- Broadcast.

Bitcoin’s P2P Network

- A **Peer to Peer** network over TCP/IP.
- Peers are identified by their IP address.
- Peers can diffuse messages that will be propagated to the whole network.
- Peers initiate a small number of outgoing connections.
- Peers receive a limited number of incoming connections.

Public and Private Networks

- Public networks vs. private networks.
  - A system with a public IP lives in the Internet.
  - A system with a private IP lives in a private network and communicates with the Internet via a router that performs Network Address Translation.

Connecting to a P2P network

- (In the case of Bitcoin) The requesting node contacts a **DNS Seeder** which is a node with a public IP address that can serve a list of IP addresses for Bitcoin nodes.
    - The seeder obtains those addresses via crawling.

- If the connection fails the node has a hardcoded set of IP addresses.

- Peers can exchange node IP addresses via **ADDR** messages that contain a selection of a peers address book.

Maintaining tables of peers

- Nodes maintain tables of peers that they have learned. Typically in two categories:
    - Nodes that have been contacted and are operational
    - Nodes for which the node has been informed about their existence but they have not been contacted yet.
- Tables are updated in a regular basis.
- Timestamp information is stored from the last connection attempt.

In Bitcoin

- Tables “new” and “tried.”
- A node with ω in {0,.., 7} outgoing connections will select the ω+1 connection from **tried** with probability:

$$= \frac{\sqrt{\rho}(9-\omega)}{(\omega+1)+\sqrt{\rho}(9-\omega)}$$

ρ = ratio between #(addresses in **tried**) and #(addresses in **new**)

Then choose from the table an address to connect, biasing towards addresses with **fresher** timestamps.

Heileman et al. Eclipse Attacks on Bitcoin’s Peer-to-Peer Network, Usenix Sec. 2015

Attacks against the Bitcoin communication layer

- Key Observations:
  - a node will add an address to the ‘tried' table if it receives an incoming connection from another node.
  - a node will accept unsolicited ADDR messages. These will be added to the ‘new’ table.
  - nodes rarely will solicit information from DNS seeders and other nodes.

Eclipse attacks, I

- In the eclipse attack the victim is a node with a public IP.
    - attacker makes outgoing connection to the node using adversarial nodes. => ‘tried’ table gets full with fresh adversarial IP’s.
    - attacker uses ADDR messages to insert “**trash**” IP’s into the ‘new’ table of the victim.
    - finally, the attacker needs to wait for the victim node to restart (as nodes themselves will maintain exiting outgoing connections). Restarts can happen because of a software update or even deliberately by the attacker (via a “denial of services” (DOS) attack).

Eclipse attacks, II

- The attacker can repetitively connect to victim node to ensure timestamps of adversarial nodes are fresh.
- If a ‘new’ address is selected the injection of trash IP’s ensures that with some probability the new node will not be responsive. As a result another coin flip will be attempted for the connection which can result to an adversarial IP.

Eclipse Attack, III

- Attacker now saturates the incoming connection of the victim.
  - The protocol allows for the same IP to occupy all 117 incoming TCP/IP connections.
- In this way it is impossible for other nodes to connect to the victim.
- Given the maximum number of connections is reached the victim will deny any other incoming connections.

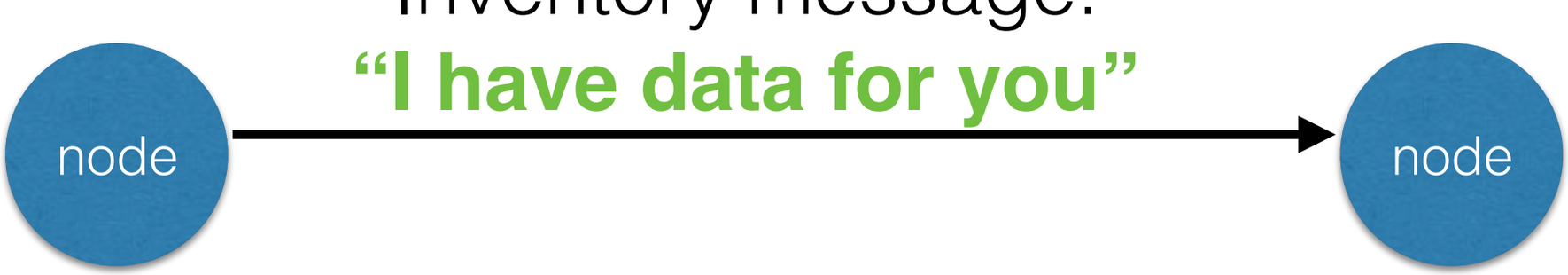
Eclipse Attack, IV

- Once the eclipse takes place, all communication of the victim (incoming/outgoing) will be routed via the attacker nodes.
  - victim's transactions may be censored.
  - victim's blocks can be dropped.
  - victim's blockchain may be populated almost entirely by adversarial blocks!
- Moreover: the rest of the network will eventually completely forget about the victim node (a function **isTerrible** is executed periodically on the tables that will remove any node that has an over 30 days old timestamp and too many failed connection attempts).

Countermeasures against Eclipse attacks

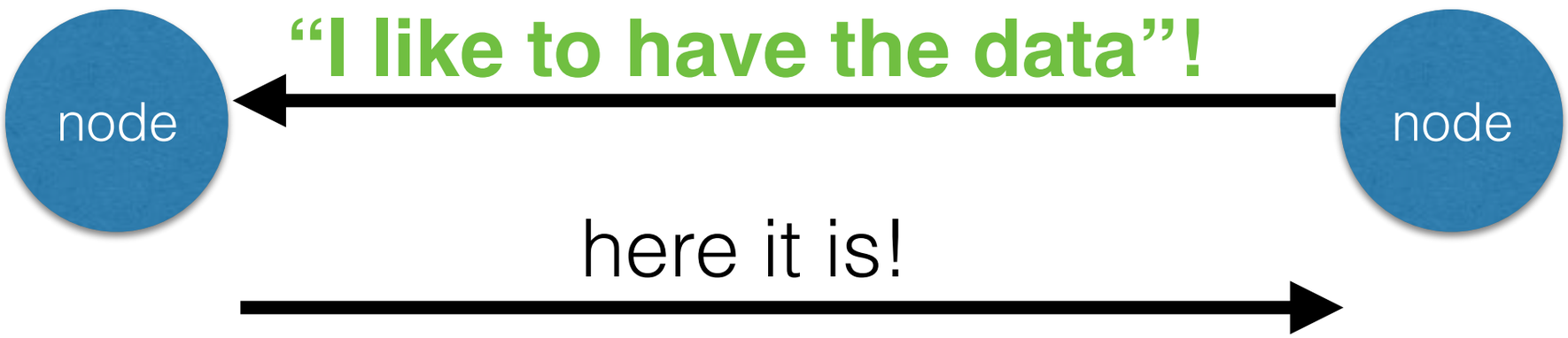
- Many mitigation techniques can be used:
  - ban unsolicited ADDR messages.
  - diversify incoming connections.
  - test before evicting addresses from the tried table.
- Nevertheless: the possibility of an attack cannot be zeroed.

Information Propagation in Bitcoin, I



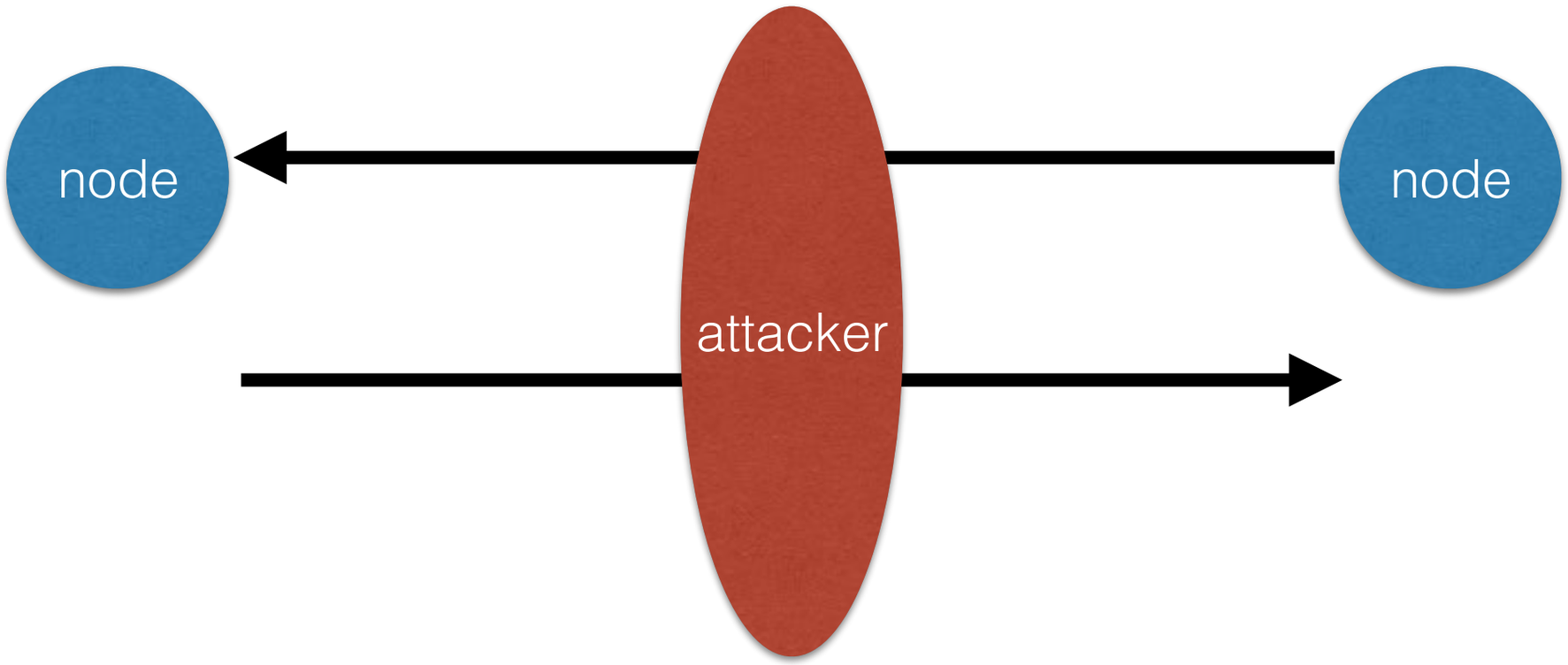
Field Size	Description	Data type	Comments
4	type	uint32_t	Identifies the object type linked to this inventory
32	hash	char[32]	Hash of the object

Information Propagation in Bitcoin, II



20 minute window
before connection dropped

Man-in-the-middle Attacks in information propagation



if attacker manipulate
message contents on either direction
it can delay information propagation by 20 minutes.

such delays can be extremely detrimental for security

Network Partitioning Attacks

- Internet traffic is routed via the Border Gateway Protocol (BGP).
    - BGP is the primary interdomain routing protocol.
    - Paths between networks need to be updated constantly as the Internet is an evolving infrastructure.
    - BGP is run by Internet Service Providers and other large networks that are connected. The participating nodes are called **autonomous systems** (AS).

BGP Highjack

- An attacker running an AS, can announce that it can route a certain network path.
    - There is no actual validation performed of such announcements. Thus a malicious AS can even advertise a non-existent path.

- Subsequently Bitcoin traffic can be filtered by the malicious AS.

Network Partitioning Effects

- In the case of Bitcoin (and conceivably in any other global deployment of a distributed ledger) a network partitioning can be **devastating**:
  - The protocol is designed to adapt and will allow the co-existence of two independent ledgers.
  - The ledgers will proceed independently.
- The attacker (sitting in the middle) will effectively double its balance and can selectively filter activity from each partition to be distributed to the other.

Network Partitioning due to Software Error

- A software upgrade causes upgraded clients to drop old blocks and vice versa.

- example: bitcoin version 0.8 in March 2013, older clients were forced into their own chain.

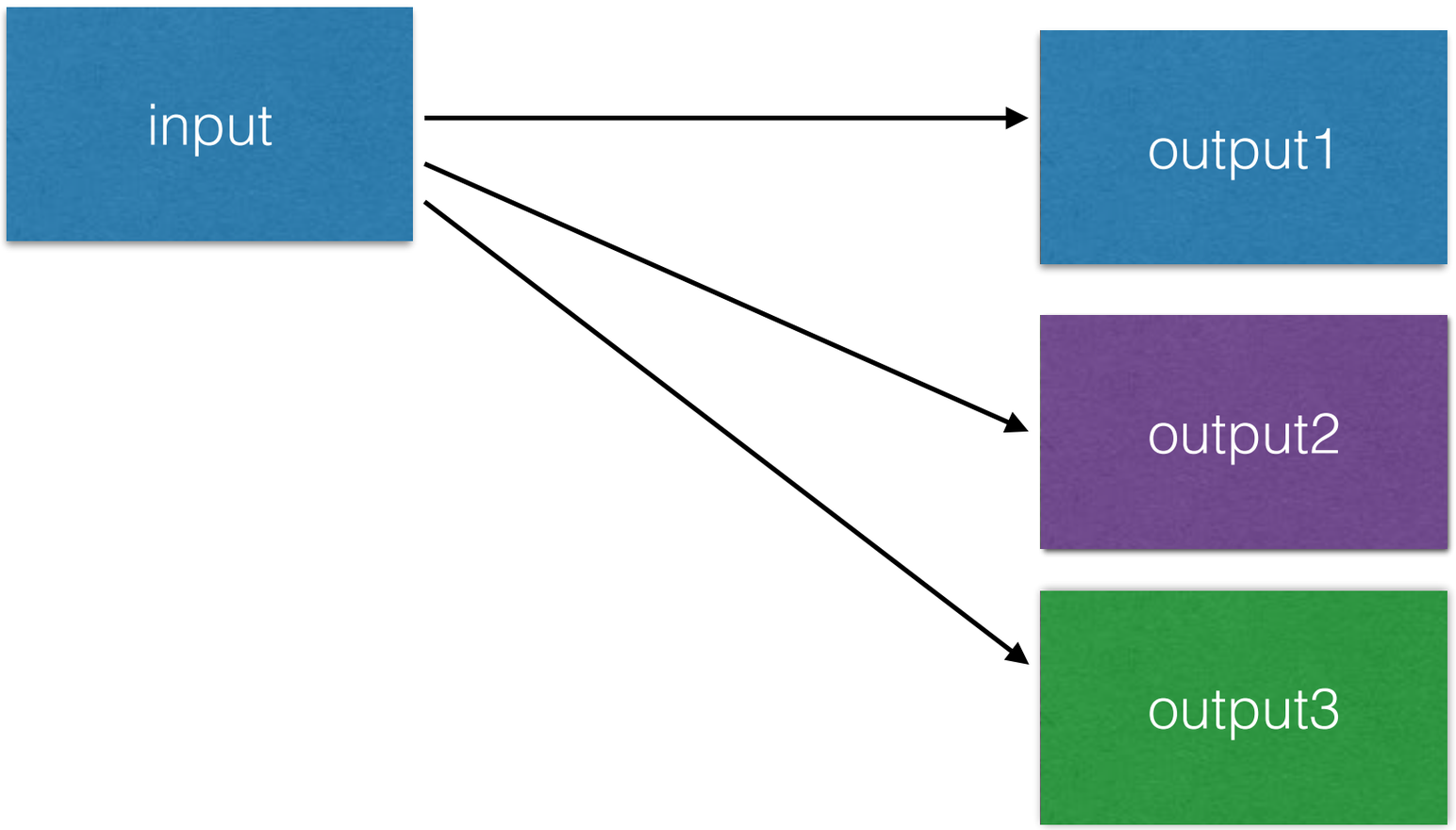
Fungibility and Bitcoin

- Even though bitcoin can be treated as being fungible, it is not:

- the smallest denomination in the Bitcoin blockchain, “Satoshi”, can be tracked from account to account following some convention.

Colored Coins, 1

- “Coloring" outputs so they represent specific assets.



Colored Coins, 2

- Use of the OP_RETURN opcode (allowed to be followed by 80 bytes of data).
    - OP_RETURN will be treated to signify that a transaction output is invalid.
    - Paying to an OP_RETURN enables storing personal data on the blockchain.
- “sacrifice” one output to contain coloring information for the transaction.

Colored Coins,3

- Bitcoin transaction fees still apply (as transactions are necessary to be formed with OP_RETURN and the modicum of storage permitted).
- The secret-key of the account that is colored controls asset ownership.
- Marker outputs (using OP_RETURN) can be used to further specify quantities transferred etc.
- Accounts should hold a balance to ensure the ability to transfer them onwards.

Bitcoin Colored Coins

- Bitcoin miners do not enforce proper rules of colouring.
    - coloured transactions are treated as regular transactions by “colour-blind” miners.
- It is conceivable that colouring rules might not be respected by a miner acting maliciously.
- Parsing algorithms for colours should take this into account.

Land registries

- Using colored coins:
  - issue a new asset linked to land title.
  - store information in the asset that links to an information resource (e.g., one can insert a URL or an identifier for a **Torrent** file).
  - subsequently proof of ownership and transfer can be performed.

Item Registries

- As an example: everledger.io stores diamond certificate data in a blockchain.

- **Issue** how do you create a link between a physical object and a digital “thumbprint” ?

Name Registries

- Use a blockchain to register names. Useful in the context of DNS (domain name system) and Public-key directories.

- Example **namecoin** (separate blockchain based on Bitcoin protocol), **blockstack** (piggybacking on the bitcoin blockchain as in the case of colored coins).

Separate Blockchain vs. Piggybacking on existing?

Scheme	**Advantage**	**Disadvantage**
Piggybacking	Potential for higher assurance	Have to engineer the protocol rules into existing protocol
Separate	Ability to customise protocol & enforce individual properties.	Might attract a small set of initial nodes. Less trustworthy at the onset.

Prediction Markets

- A prediction market enables trading on future events.
  - Simple example: “we will colonise Mars by 2040”.
  - participants bet in favour or against the event.
  - Market share of **YES** = α and **NO** = 1-α. Total investment = X.
  - Consider probability of event happening is *p.* Then expected Profit of YES = pX - αX.

Prediction Markets in the Blockchain

- How is it possible to issue smart contracts, that control such outcomes.

- **Main challenge**: how to ensure that the blockchain can detect the outcome of an event.
    - Use an external trusted party that will vouch for the outcome.
    - Use a voting process from blockchain stakeholders that will vote that the outcome will take place.
        - (e.g., a proof-of-stake can back up that a certain event has been reached).

Financial Instrument Registries

- Any type of financial instrument (assets that can be traded) can be tracked by a blockchain using the colored coin approach or via a dedicated blockchain.

What is a Security

- a fungible, negotiable, financial instrument that has some value. examples:
  - a stock (representing ownership of a public company) — **equity security**.
  - a bond (representing a creditor relationship with a government), —- **debt security**.

Howey Test

- In the US, following, Securities and Exchange Commission (SEC) v. W.J. Howey Co, a security is
  - a contract, transaction or scheme whereby a person **invests** his money in a **common enterprise**.
  - .. and is led to **expect** profits solely from the efforts of the promoter or a third party.

Common Enterprise

- When does a venture constitute a common enterprise?
  - Horizontal approach. Investors' assets are joined and they shared the risks and benefits of the enterprise.
  - Vertical approach. The fortunes of the investors are linked and dependent upon the efforts of those seeking the investment.
    - **narrow** (investors' profits rise and fall together with promoter's) vs. **broad** (investors' profits depend on promoter's expertise and performance).

Blockchain and Securities law

- From the financial instruments we have seen:
  - decentralised cryptocurrencies like bitcoin, ether etc. are less likely to qualify as securities (think: vertical commonality).
  - closed cryptocurrencies, ICOs, DAO tokens etc. will likely qualify as securities (e.g., the SEC has advised that this is the positioha).

Securities related obligations

- Become registered.
- File reports.
- Follow account and record keeping procedures.

Celebrity Endorsements

- Any promoter of a security has obligations.

> *Looking forward to participating in the new @LydianCoinLtd Token! #ThisIsNotAnAd #CryptoCurrency #BitCoin #ETH #BlockChain pic.twitter.com/a8kT9eHEko*
>
> *— Paris Hilton (@ParisHilton) September 3, 2017*

SEC: ”Celebrities and others are using social media networks to encourage the public to purchase stocks and other investments. These endorsements may be unlawful if they do not disclose the nature, source, and amount of any compensation paid, directly or indirectly, by the company in exchange for the endorsement."

Criminal Activity Summary

- Ponzi schemes and securities fraud.
- Sales of prohibited items.
- Ransomware.
- Money laundering.
- Theft.
- Kidnapping.

End of lecture 10

- This is the last lecture.

- Thanks for attending Blockchains and Distributed Ledgers.