WELCOME!

attendance form:

tinyurl.com/fun-decal-1

code word: **consensus**

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discussion preference form:

tinyurl.com/decal-dis

BITCOIN PROTOCOL AND CONSENSUS:
A HIGH LEVEL OVERVIEW

Nadir Akhtar
Aparna Krishnan
Gloria Zhao

EXPECTATIONS

Expect from us:

- A fundamental understanding of blockchain technology and its applications
- High level theory and low level technical details of bitcoin and blockchain
- Guidance and abstraction for code, CS jargon, and difficult mathematical concepts
- The best bang for your time and 2 units

We expect from you:

- Dedication -- treat this course as a 2-unit class
- Attention and readiness to learn (attendance = 40% grade)
- Participation in discussion, office hours, and on Piazza to master the material
- No CS background or coding experience -- open to all majors and backgrounds

EXPECTATIONS

This class is 2 units: Attend any 1 lecture and your 1 assigned discussion

Lectures:

Tuesdays 2 - 3pm in 306 Soda

Tuesdays 5 - 6pm in 155 Donner

max. 2 lecture absences

and 2 discussion absences

Discussions:

Wednesday 2-3pm in Moffit 150D

Thursday 1-2pm in Moffit 150D

Thursday 2-3pm in Moffit 150D

Thursday 5-6pm in Moffit 150D

Friday 2-3pm in Soda 310

tinyurl.com/decal-dis

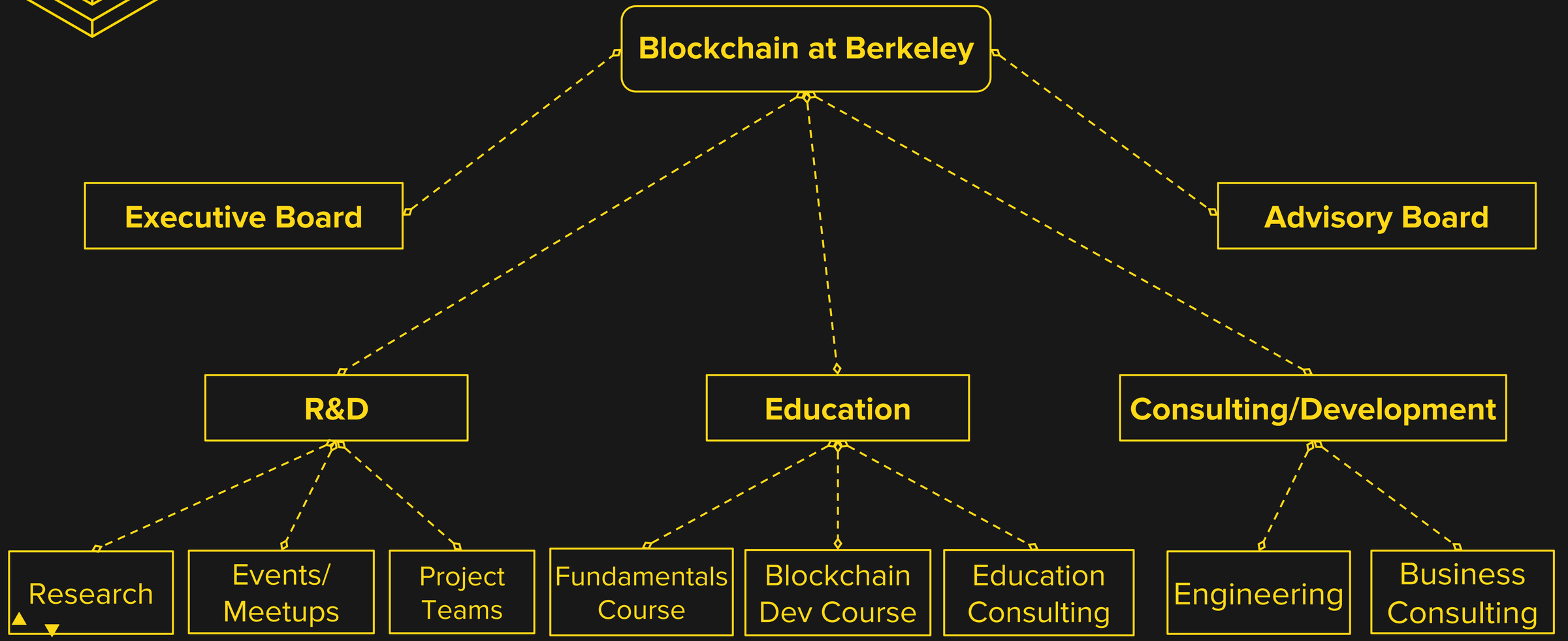
You will be assigned a discussion section TONIGHT

Enrollment codes will be handed out in discussion section THIS WEEK

WHO ARE WE?

BLOCKCHAIN
AT BERKELEY

WHO ARE WE?



BLOCKCHAIN AT BERKELEY

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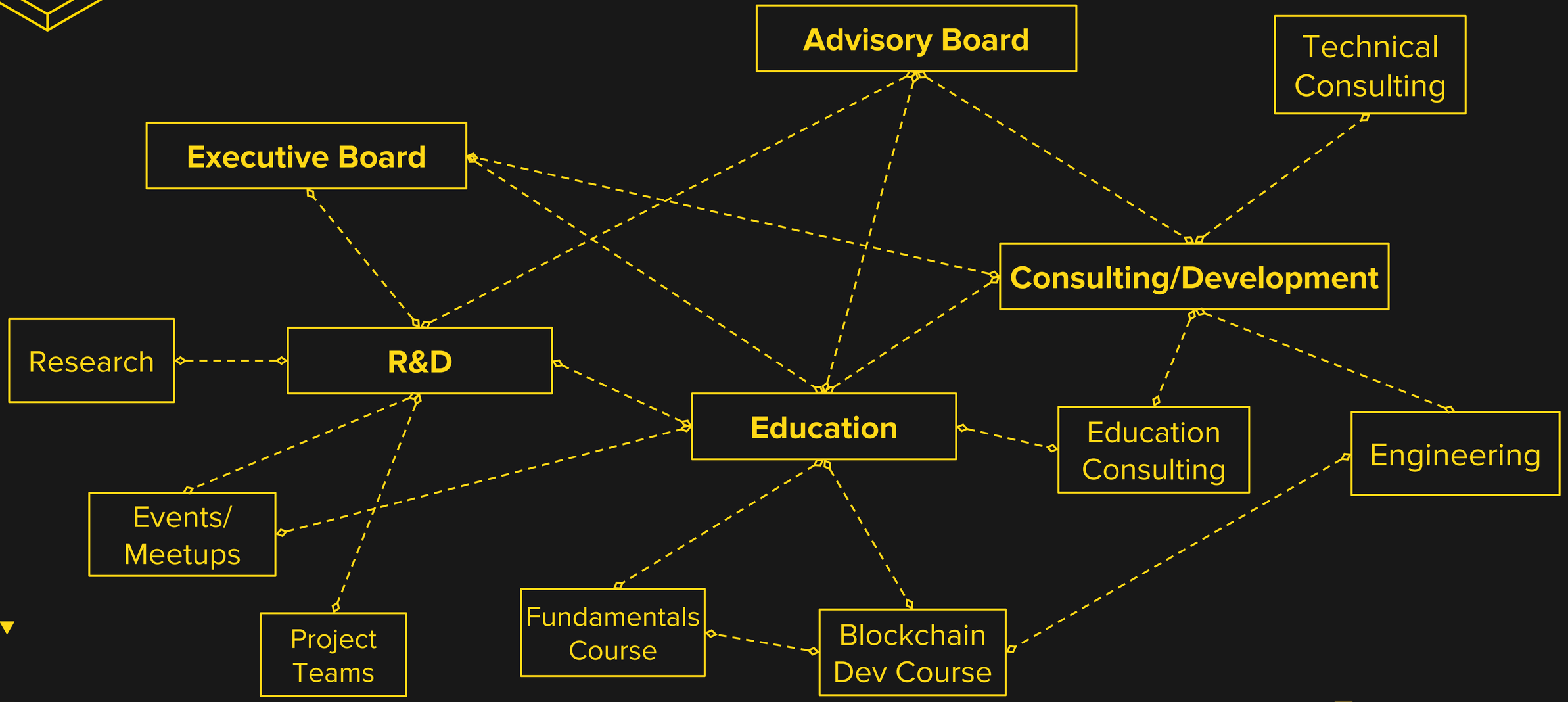
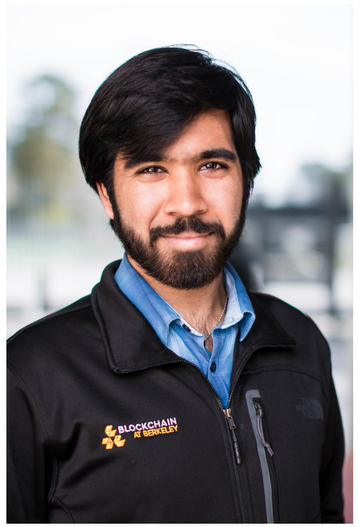


BLOCKCHAIN AT BERKELEY

Course site: blockchain.berkeley.edu/decal/fa17/fund



Nadir Akhtar

nadir@blockchain.berkeley.edu

Office Hours:

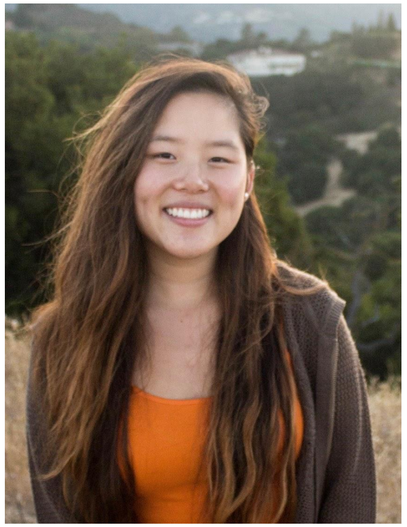
- Fridays 320 Soda 1 - 2
- By appt

Aparna Krishnan

aparna@blockchain.berkeley.edu

Office Hours:

- TBD
- By appt



Gloria Zhao

gloria@blockchain.berkeley.edu

Office Hours:

- Wednesdays 1 - 2pm
- By appt

BLOCKCHAIN AT BERKELEY

BITCOIN PROTOCOL AND CONSENSUS:
A HIGH LEVEL OVERVIEW

Nadir Akhtar
Aparna Krishnan
Gloria Zhao

LECTURE OVERVIEW

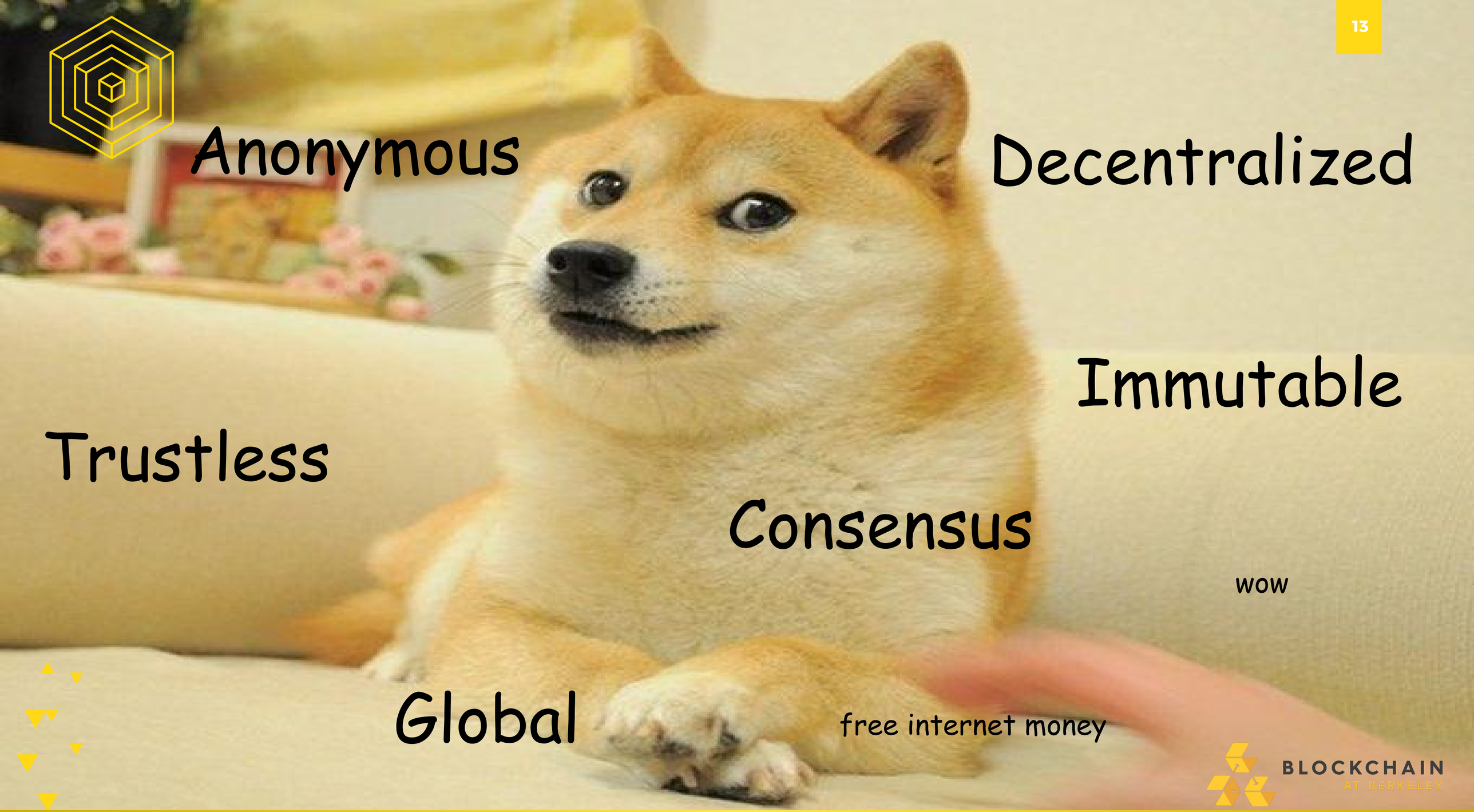
1. WHAT IS BITCOIN?
2. IDENTITY
3. TRANSACTIONS
4. RECORD-KEEPING (THE BLOCKCHAIN)
5. CONSENSUS (PROOF-OF-WORK)

1 WHAT IS BITCOIN?

WHAT IS BITCOIN?

BITCOIN'S GENESIS

- Bitcoin is a cryptocurrency, existing purely in the digital realm, first deployed in 2009.
  - **Cryptocurrency:** a currency built upon computer science, cryptography, and economics
- Born out of the Cypherpunk movement, a libertarian fight for privacy and self-governance.
- The inspiration for the invention of the blockchain.
- Created by Satoshi Nakamoto, an anonymous identity.


Anonymous
Decentralized
Immutable
Trustless
Consensus
wow
Global
free internet money

CURRENCY

“IN BANKS WE DISTRUST”

What does a bank provide?

- Account and identity management: Storage of your personal information and your account balances
- Services: Transferring and redeeming money
- Record management: Tracking account history, particularly for audits
- Trust: Verified professionals regulated by gov’t

How do we make a decentralized system that does everything that a bank does?

CURRENCY

“IN BITCOIN WE TRUST”

What does Bitcoin provide?

- Account and identity management: Addresses for every user, each associated with amounts of currency
- Services: Transactions between users
- Record management: Redundant information stored between thousands of users via a **blockchain**
- Trust: Personal incentive aligning with community goals

But how does this all happen?

Image source:
https://s3.amazonaws.com/kd4/byob

2 IDENTITY

IDENTITY

IDENTITY IN BITCOIN

- What's the role of identity in the context of currencies?
  - Authentication
    - *Receiving money*
    - *Claiming/Spending money*
    - *Blame*
  - Integrity
- Identity in daily life:
  - Houses have addresses and mailbox keys
  - Emails have aliases and passwords
  - Bitcoin has public keys and private keys

IDENTITY

PUBLIC AND PRIVATE KEYS

- Each entity is represented with a unique **public key**
  - A corresponding **private key** acts as a key to “unlock” the public key, the proverbial chest containing your money
- Private key chosen at random, public key generated from private key
  - **Public key** for *receiving*, **private key** for *redeeming*

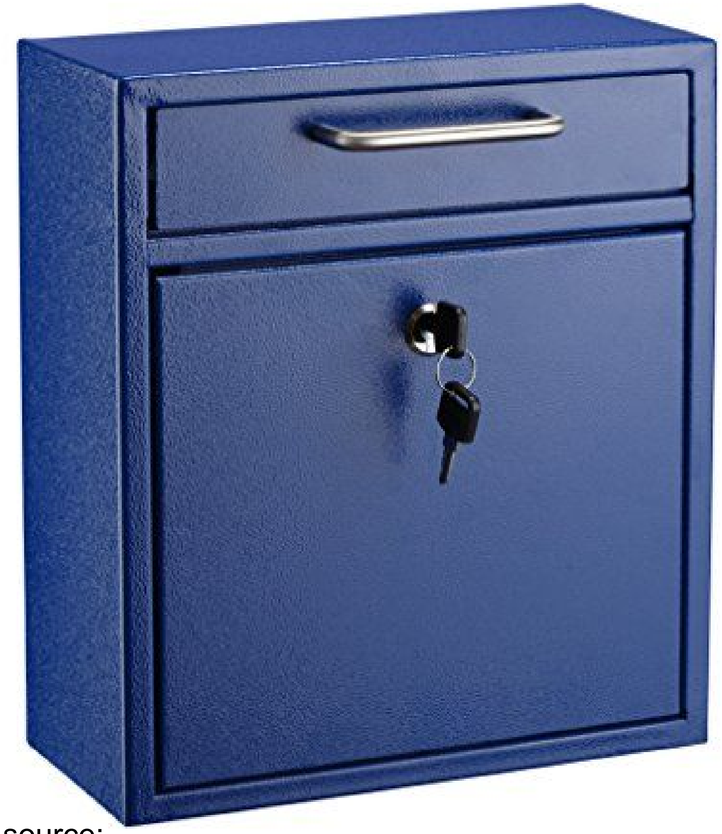


Image source: https://images-na.ssl-images-amazon.com/images/I/51rh0s9VdyL.jpg

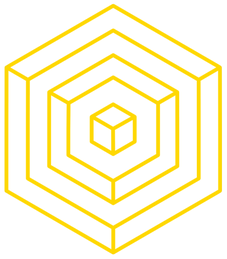
IDENTITY

SECURITY: HIDDEN IN PLAIN SIGHT

“What if someone guesses my private key?!”

- Bitcoin is hidden in the large amount of public keys
  - 2^{160} (1,461,501,637,330,902,918,203,684,832,716,283,019,655,932,542,97) possible addresses
- Practically impossible for anyone to overlap
  - For reference:
    - Grains of sand on earth: 2^{63}
    - With 2^{63} earths, each with 2^{63} grains of sand: 2^{126} total grains of sand
    - 2^{126} is only **0.0000000058%** of 2^{160}
  - Population of world: 7.5 billion in April 2017
    - Every person could have about 2^{127} addresses *all to themselves*

3 TRANSACTIONS



TRANSACTIONS

VALIDITY

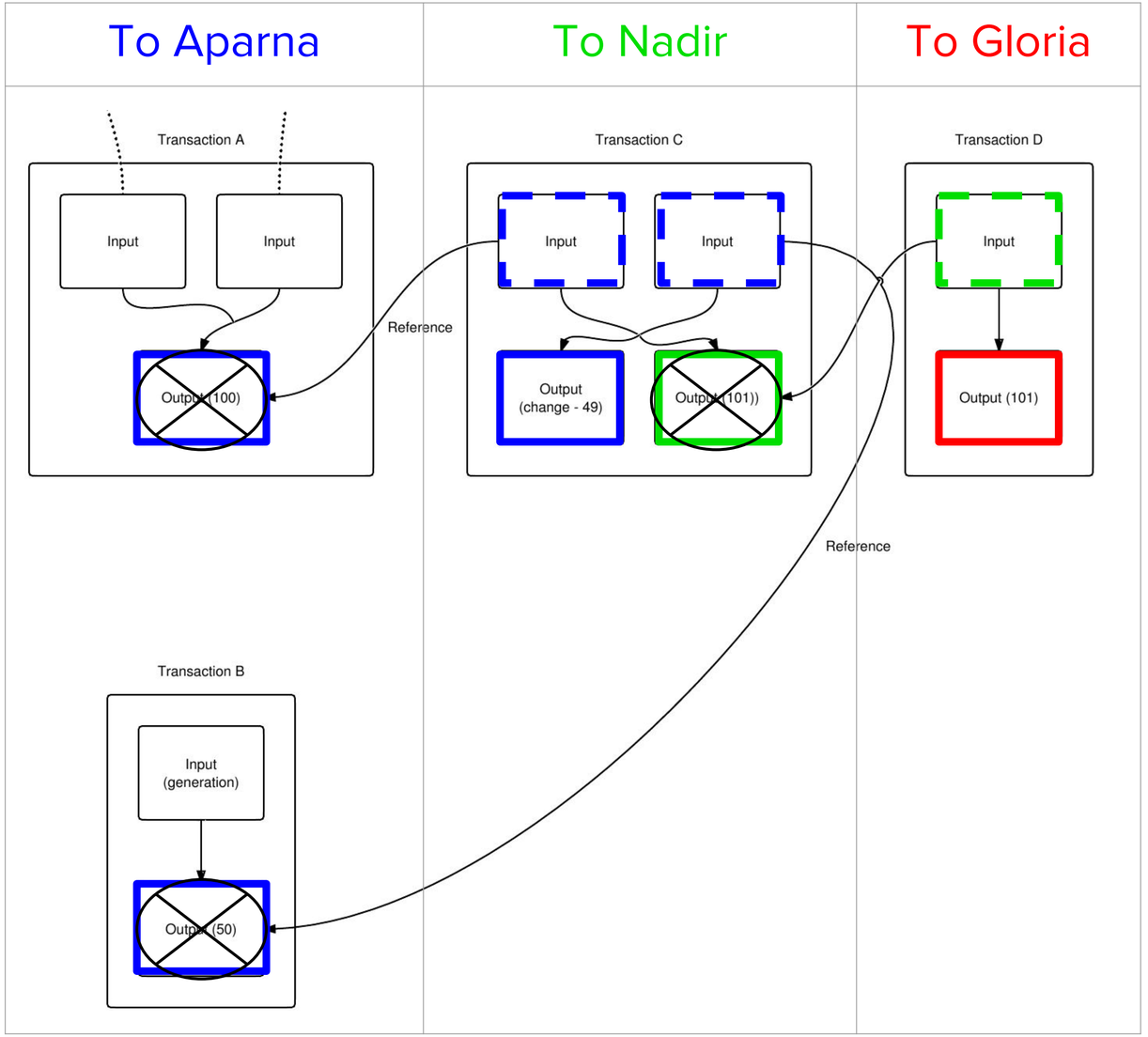
- What makes a transaction valid?
  - Proof of ownership (a signature)
  - Available funds
  - No other transactions using the same funds

Instead of accounts like one might expect, Bitcoin uses an Unspent Transaction Output (UTXO) model to ensure that funds are used only once

TRANSACTIONS

UTXO MODEL

- Instead of keeping all your cash in one chest, each received payment goes into a new piggy bank
  - Every time you need to make a transaction, you break one or more piggy banks
- All bitcoins have a “serial number,” the reference number when using UTXOs as inputs for other transactions
- **Note:** Bitcoins are divisible, smallest unit is a “satoshi,” $10^{-8\text{th}}$ of a bitcoin

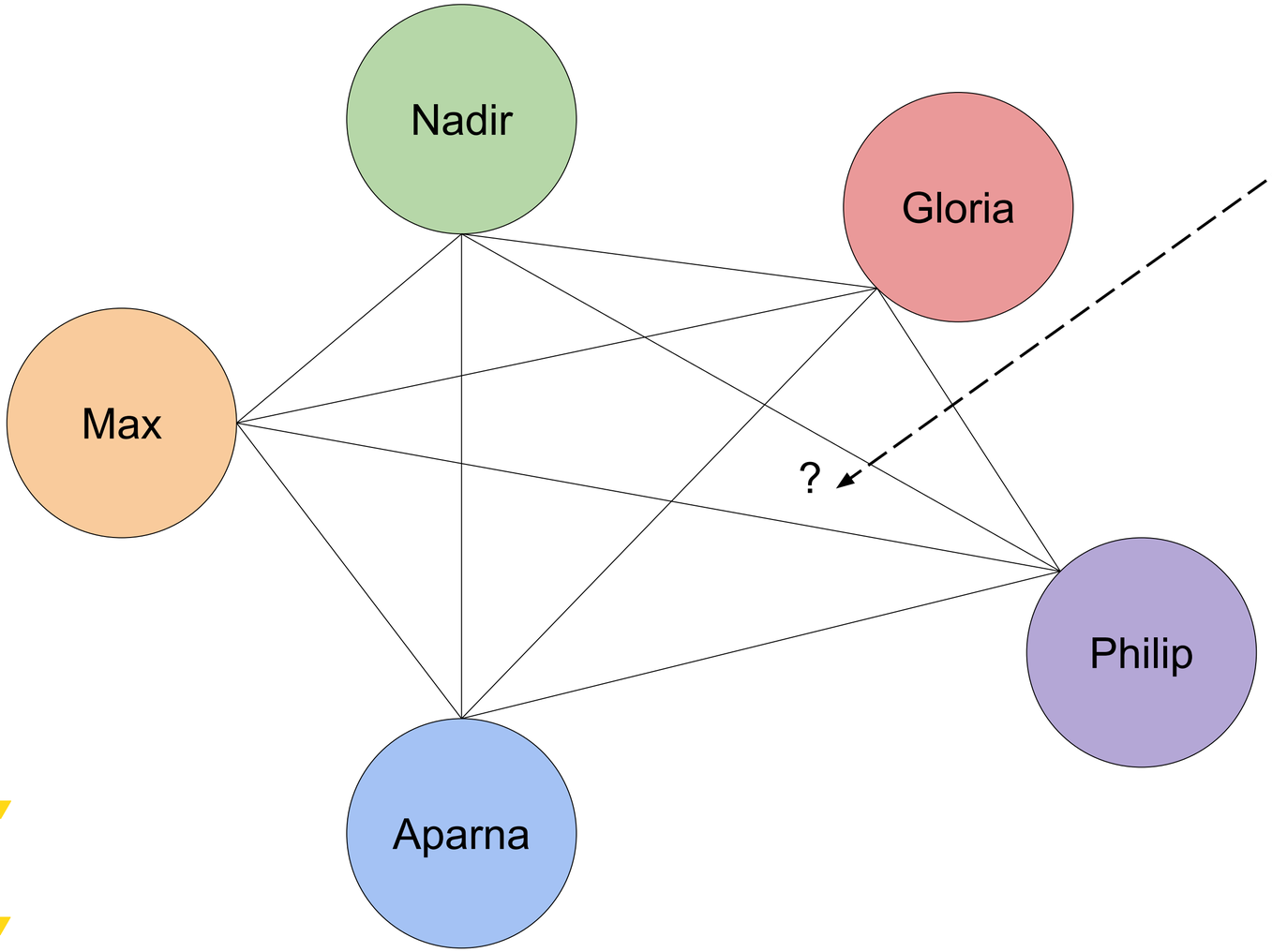


Source: https://en.bitcoin.it/wiki/File:Transaction.png

4 RECORD-KEEPING (THE BLOCKCHAIN)

RECORD-KEEPING

DISTRIBUTED DATABASES



Sender	Recipient	Amount (BTC)
Max	Nadir	0.5
Aparna	Gloria	4.2

We know how to represent identities and transactions---how do we store all that information? How do we keep track of this ledger of transactions?

⇒ With a **distributed database**

RECORD-KEEPING

EVERYONE'S THE BANK

Sender	Recipient	Amount (BTC)
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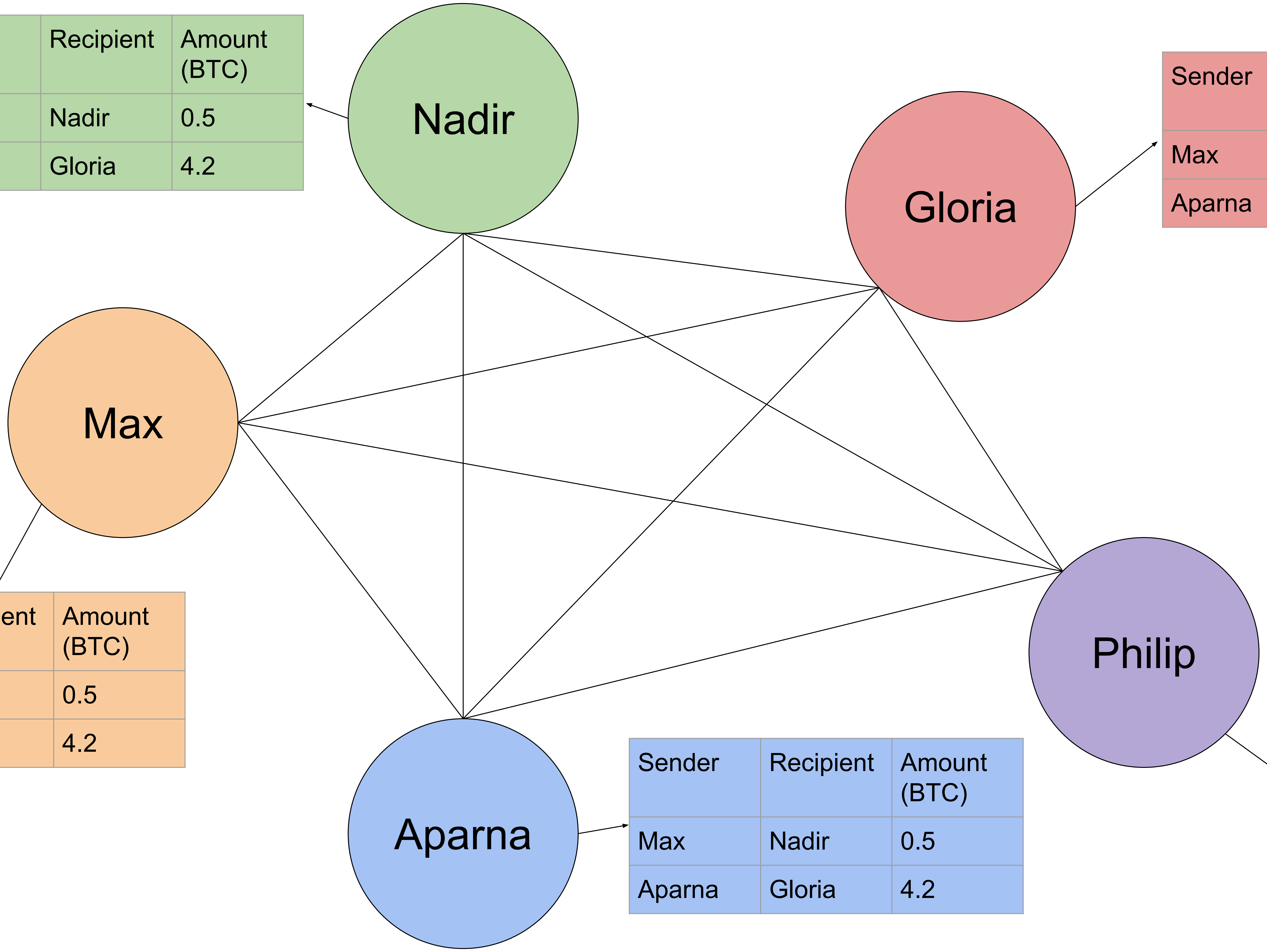
Aparna	Gloria	4.2



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Everyone stores the ledger

RECORD-KEEPING

THE BLOCKCHAIN

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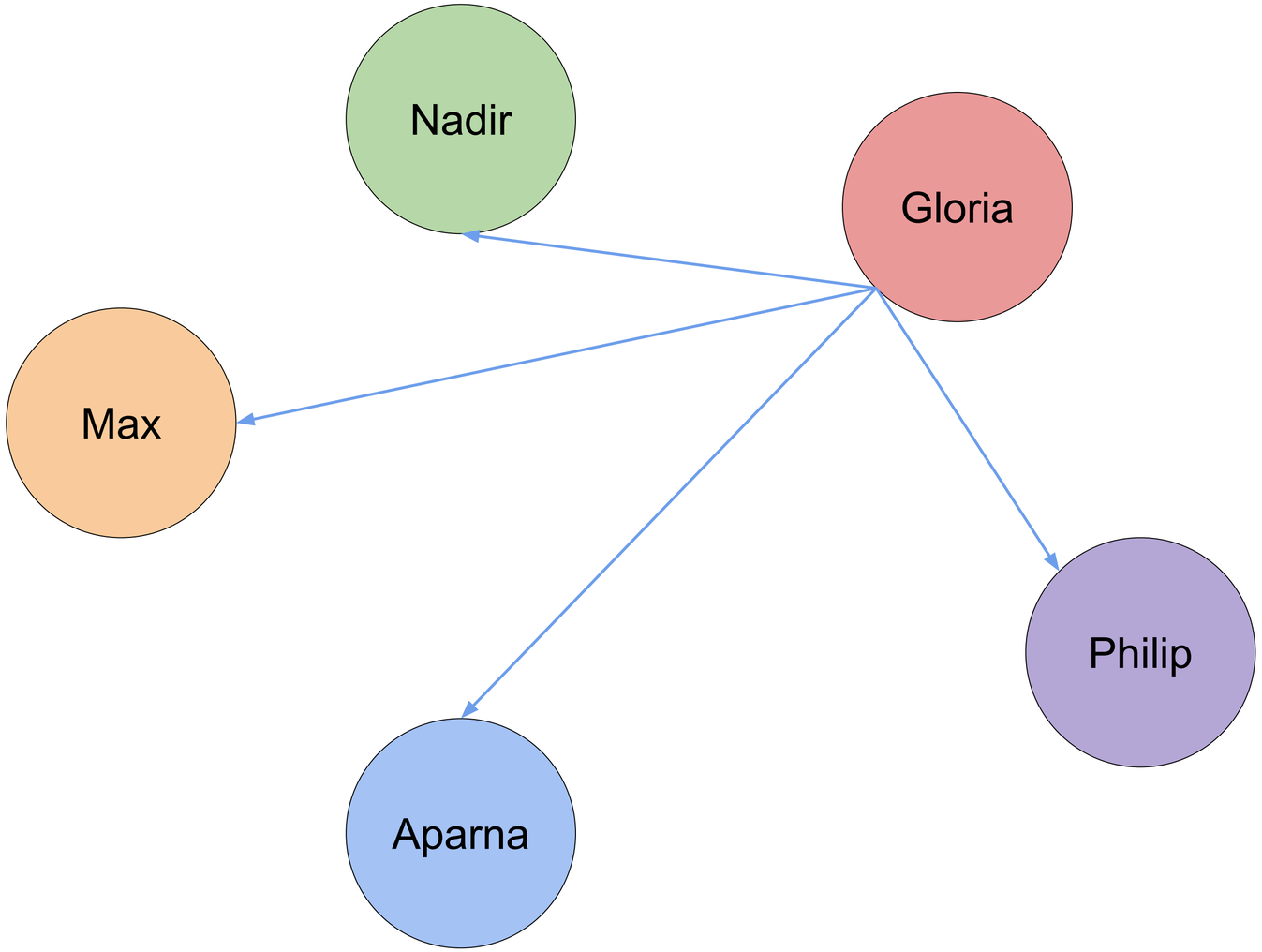
5

CONSENSUS (PROOF-OF-WORK)

CONSENSUS

STAYING ON THE SAME PAGE

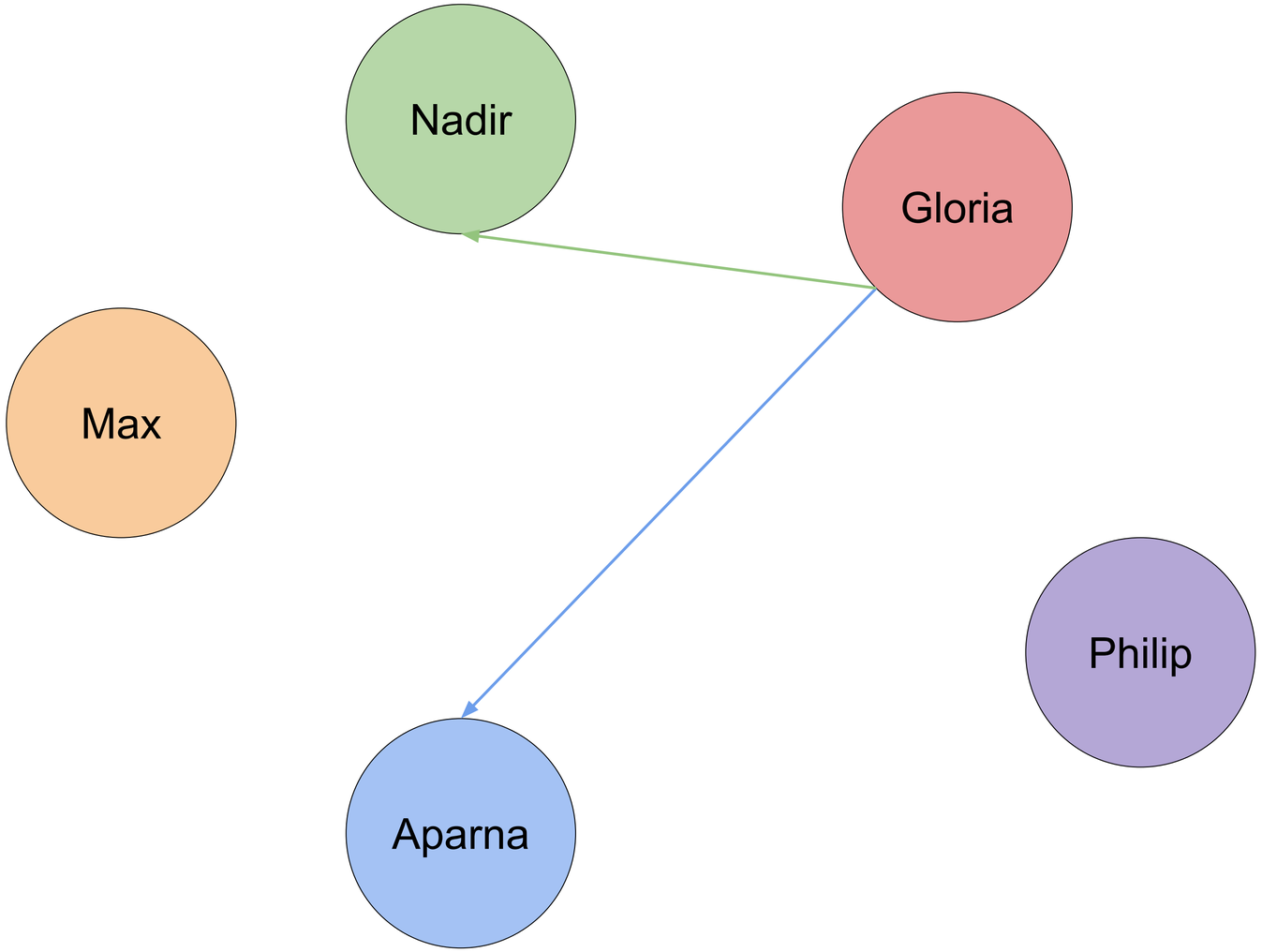


Everyone accepts valid transactions as they come around without “discussion”

- How do we ensure no one’s cheating if we make decisions alone?

CONSENSUS

DOUBLE SPEND ATTACK

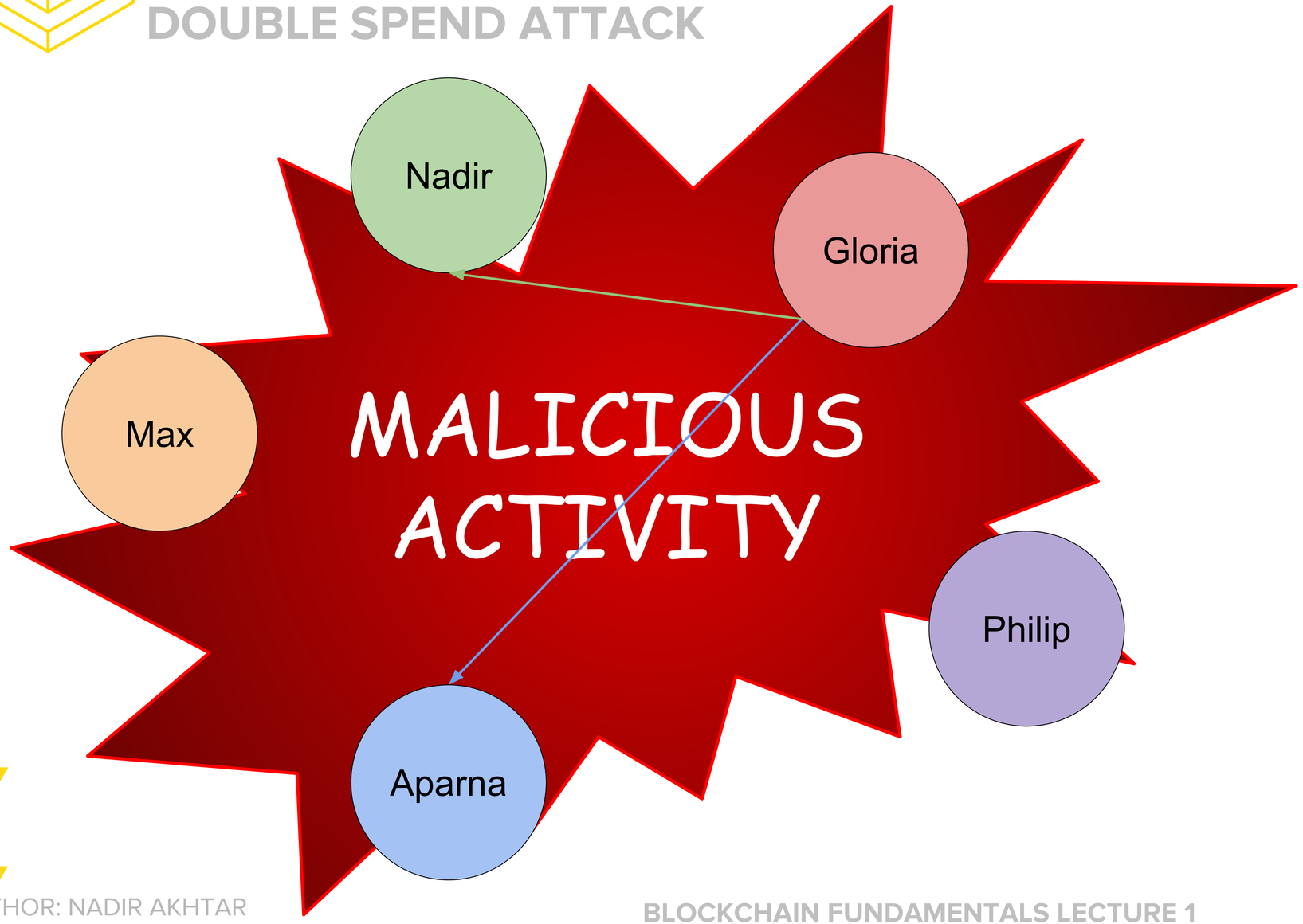


Gloria promises 10 BTC to Aparna in one transaction, and she promises 10 BTC to Nadir in another -- but she only has 10 BTC total!

- Gloria is performing a **double spend** attack

CONSENSUS

DOUBLE SPEND ATTACK



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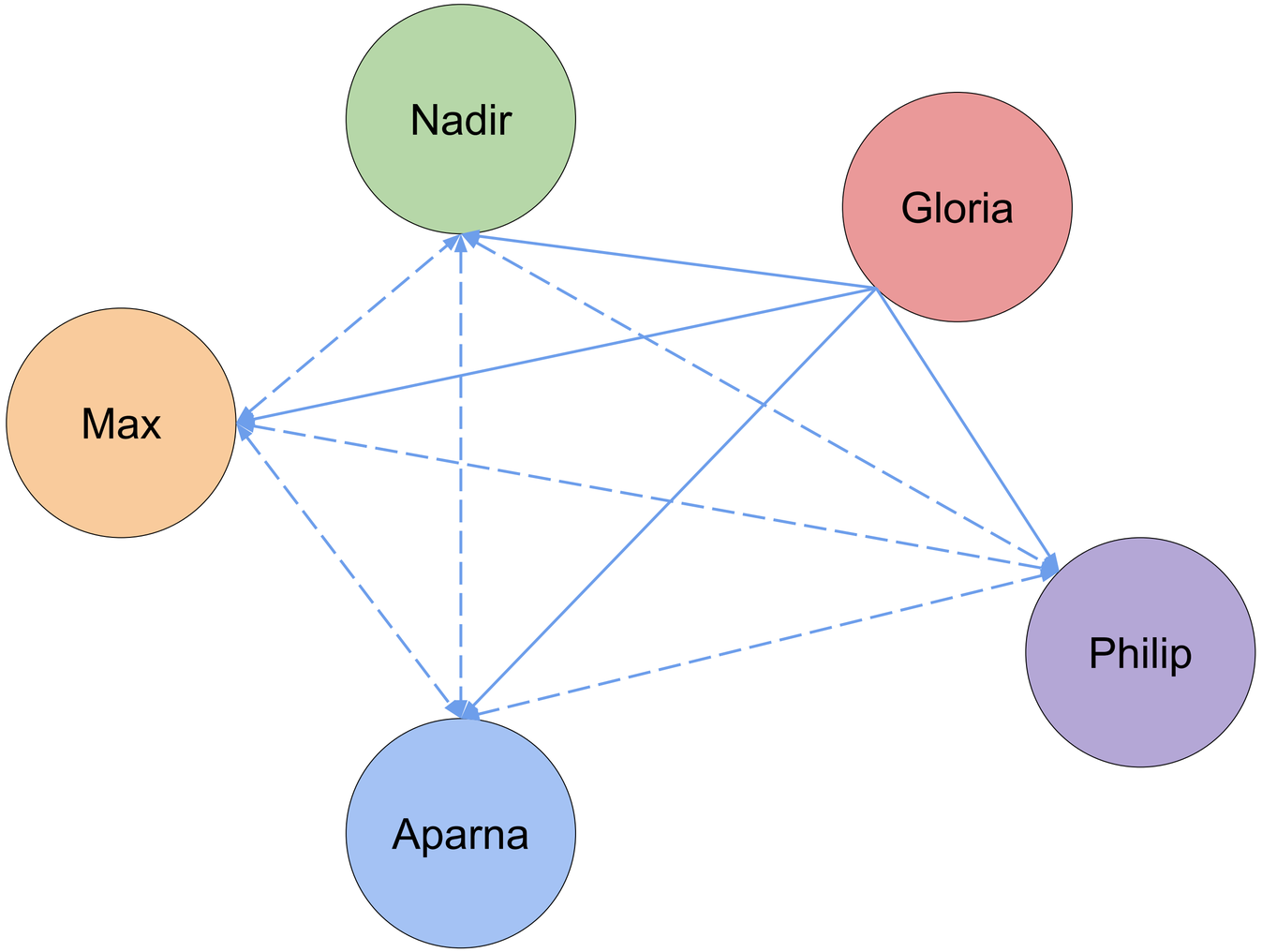
CONSENSUS

PEER VALIDATION

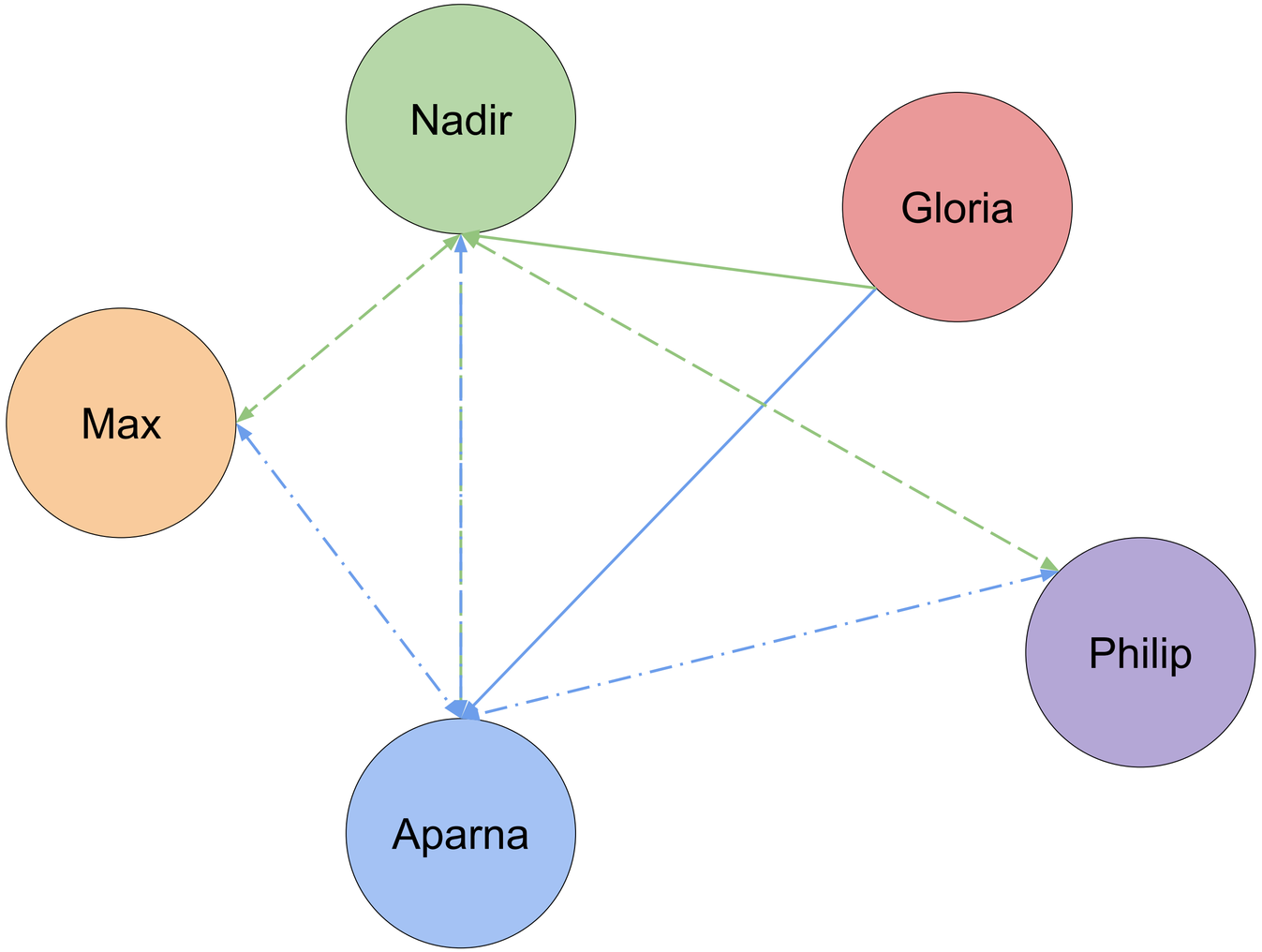


Instead of siloed decisions, let's have proposers and voters

- The proposer submits a transaction to everyone else
- Peers cast votes
- Only save after receiving a certain number of votes

CONSENSUS

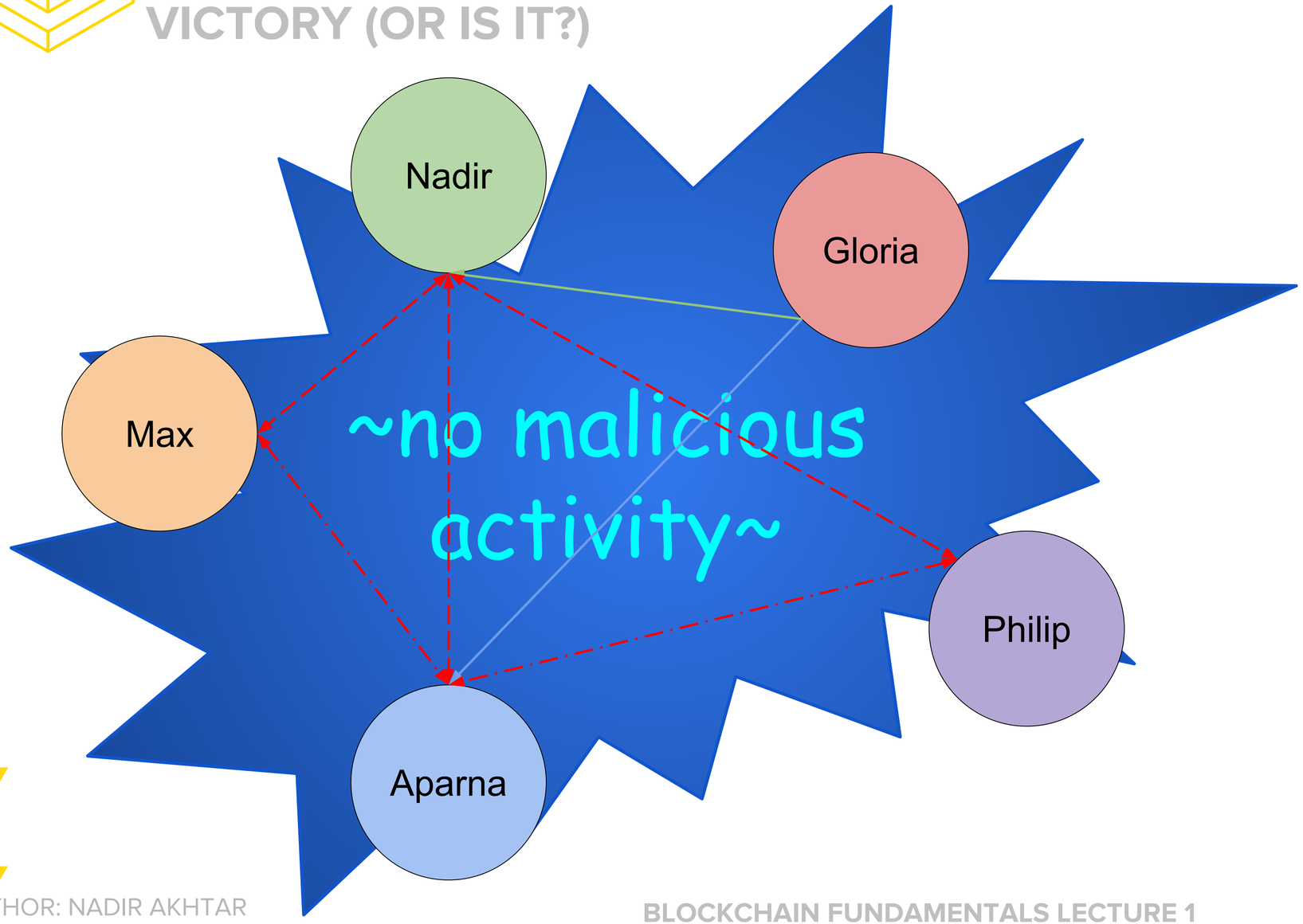
REJECTING THE DOUBLE SPEND



Now, when Gloria attempts to double spend, she will be rejected by observing peers.

CONSENSUS

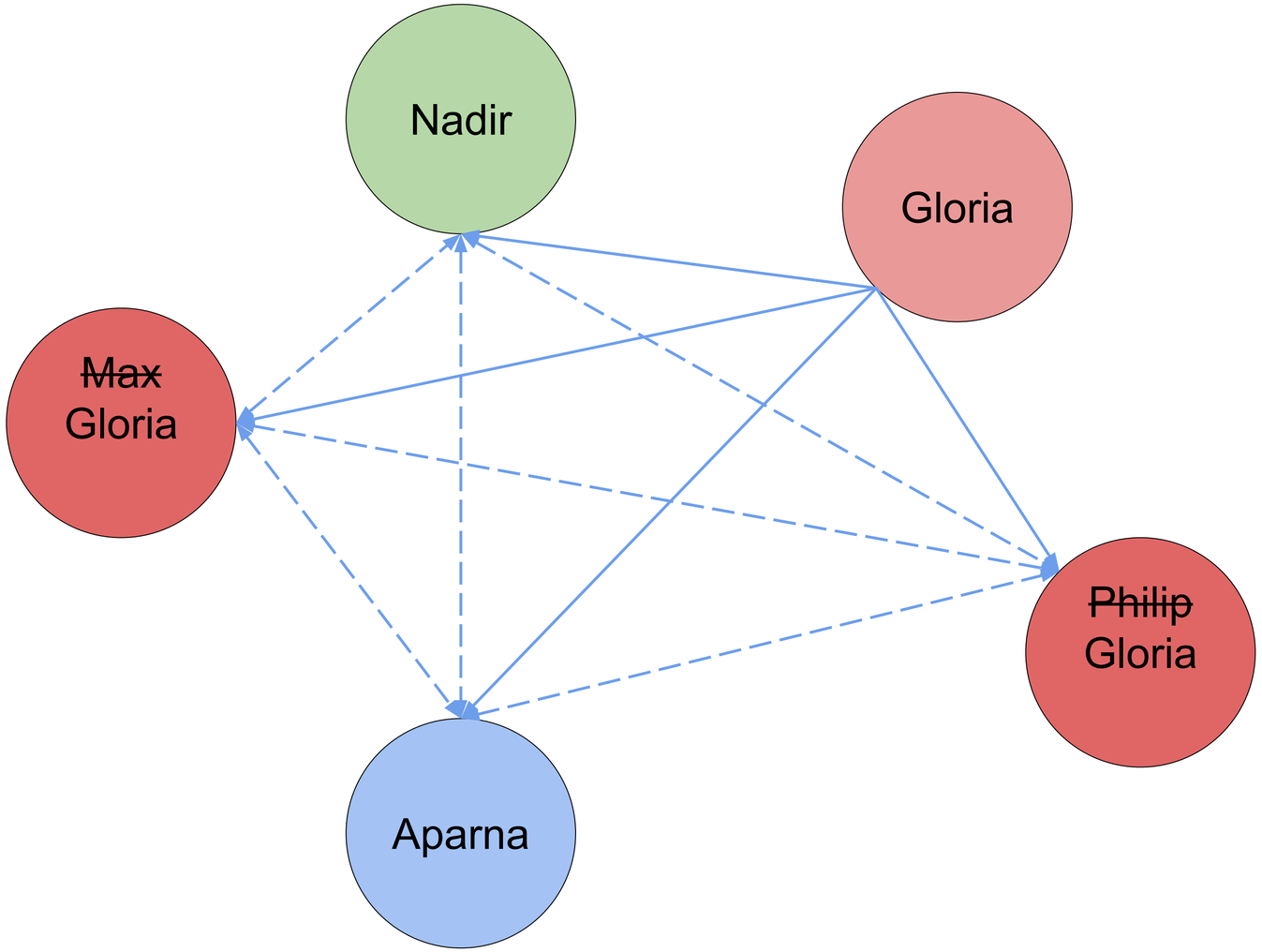
VICTORY (OR IS IT?)



Peers vote “no” on Gloria’s proposal, as they notice multiple transactions trying to spend the same funds.

CONSENSUS

A STRANGER AMONG US

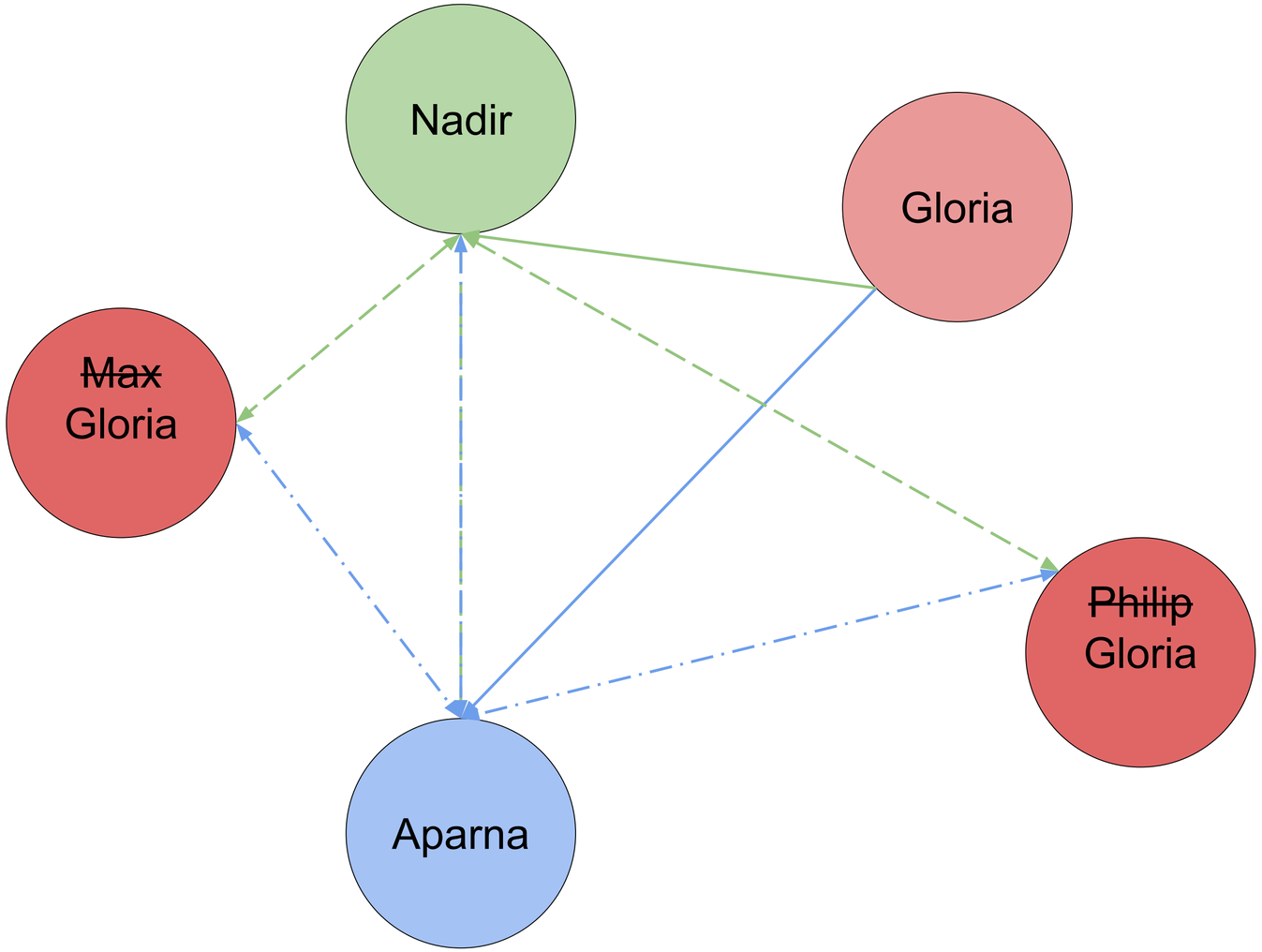


Keep in mind, Bitcoin is an anonymous service with no central registry

- Inexpensive to create multiple identities
- Multiple identities ⇒ multiple opportunities to cast votes

CONSENSUS

A STRANGER AMONG US



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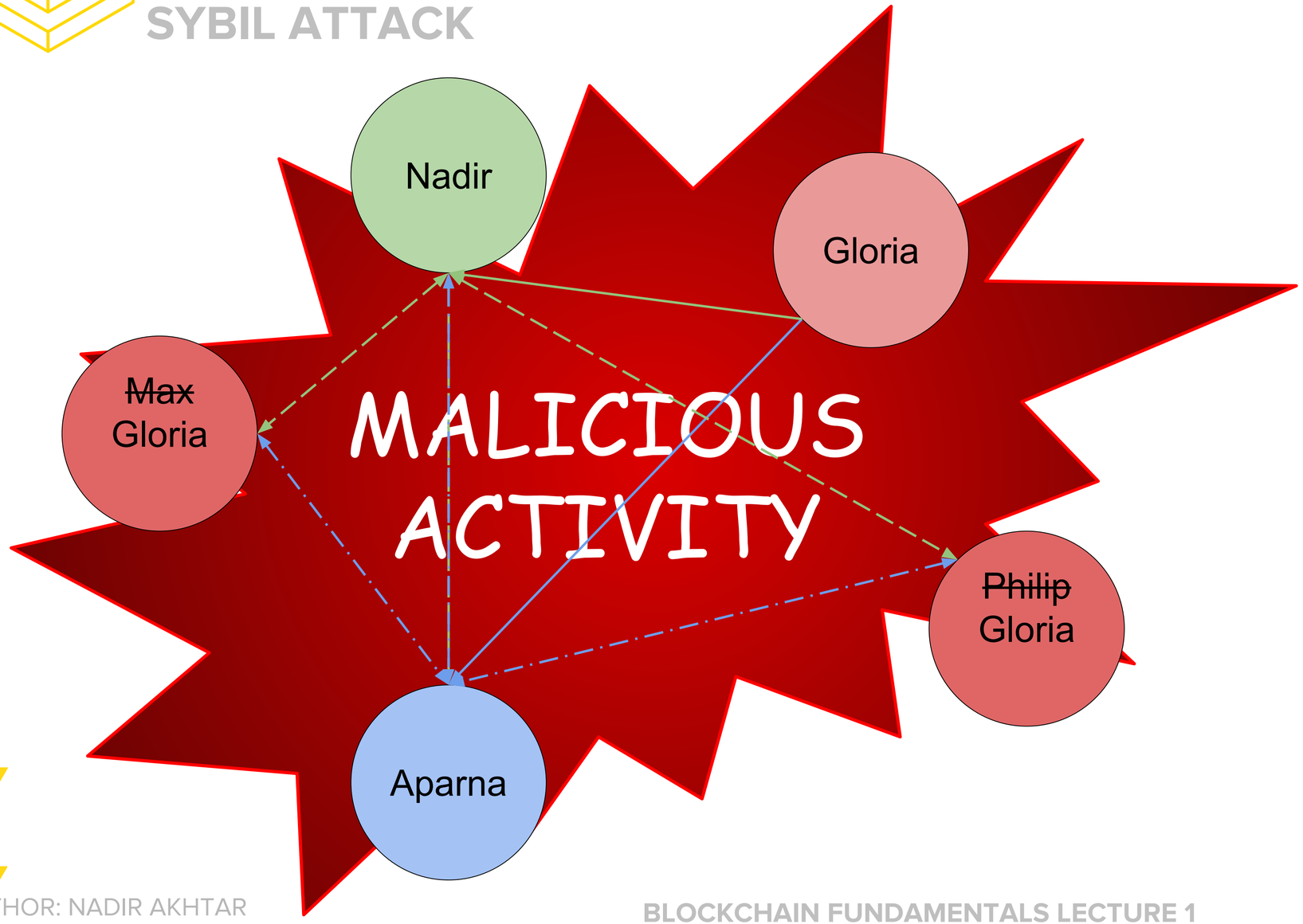
CONSENSUS

SYBIL ATTACK

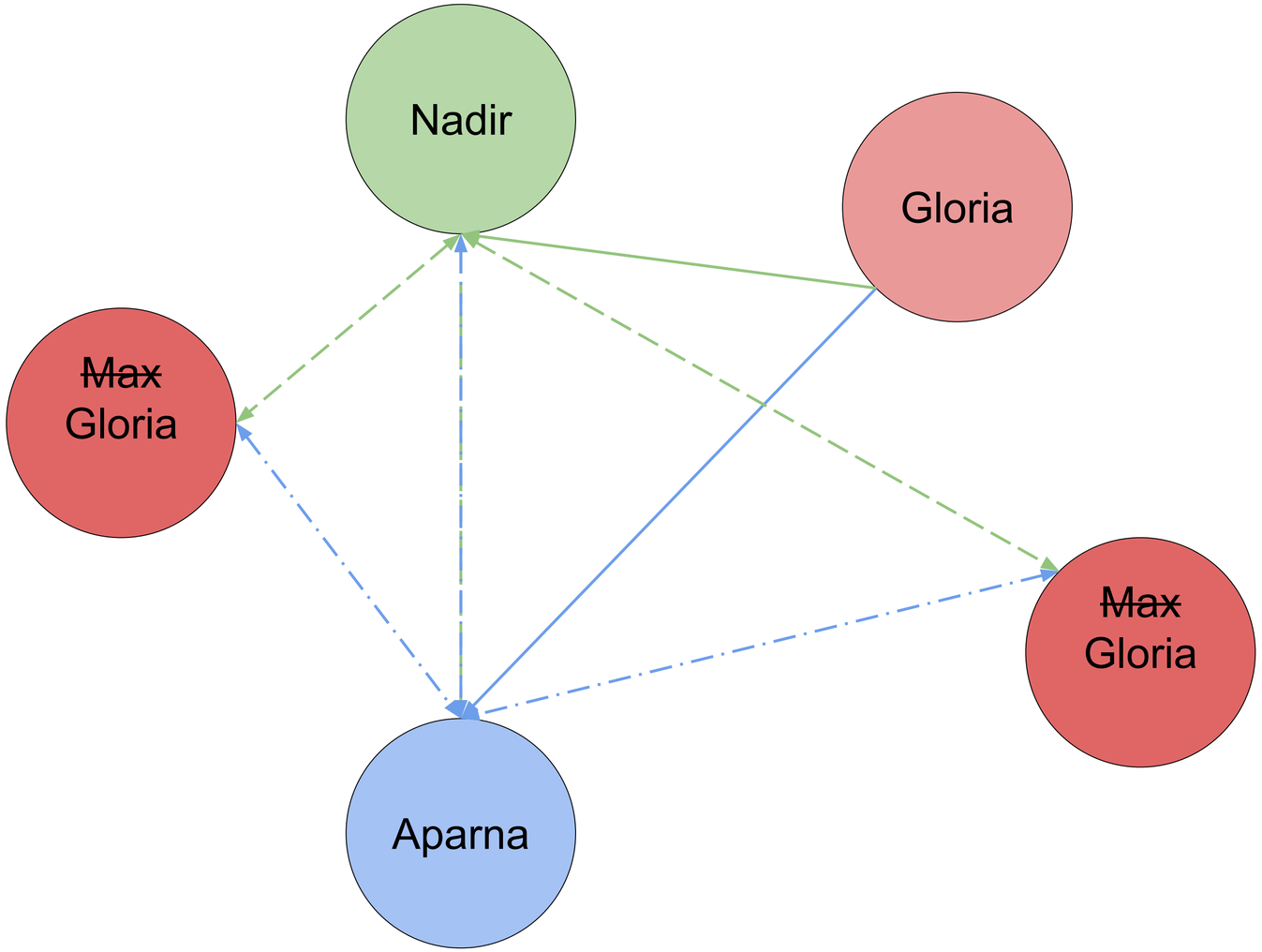


Keep in mind, Bitcoin is an anonymous service with no central registry

- Inexpensive to create multiple identities
- Multiple identities ⇒ multiple opportunities to cast votes
- Gloria can perform a **Sybil attack**, which will allow her to double spend

CONSENSUS

PAY TO PLAY



Instead of casting votes with *identities*, we cast votes with **resources**

CONSENSUS

PROOF-OF-WORK

Proof-of-Work

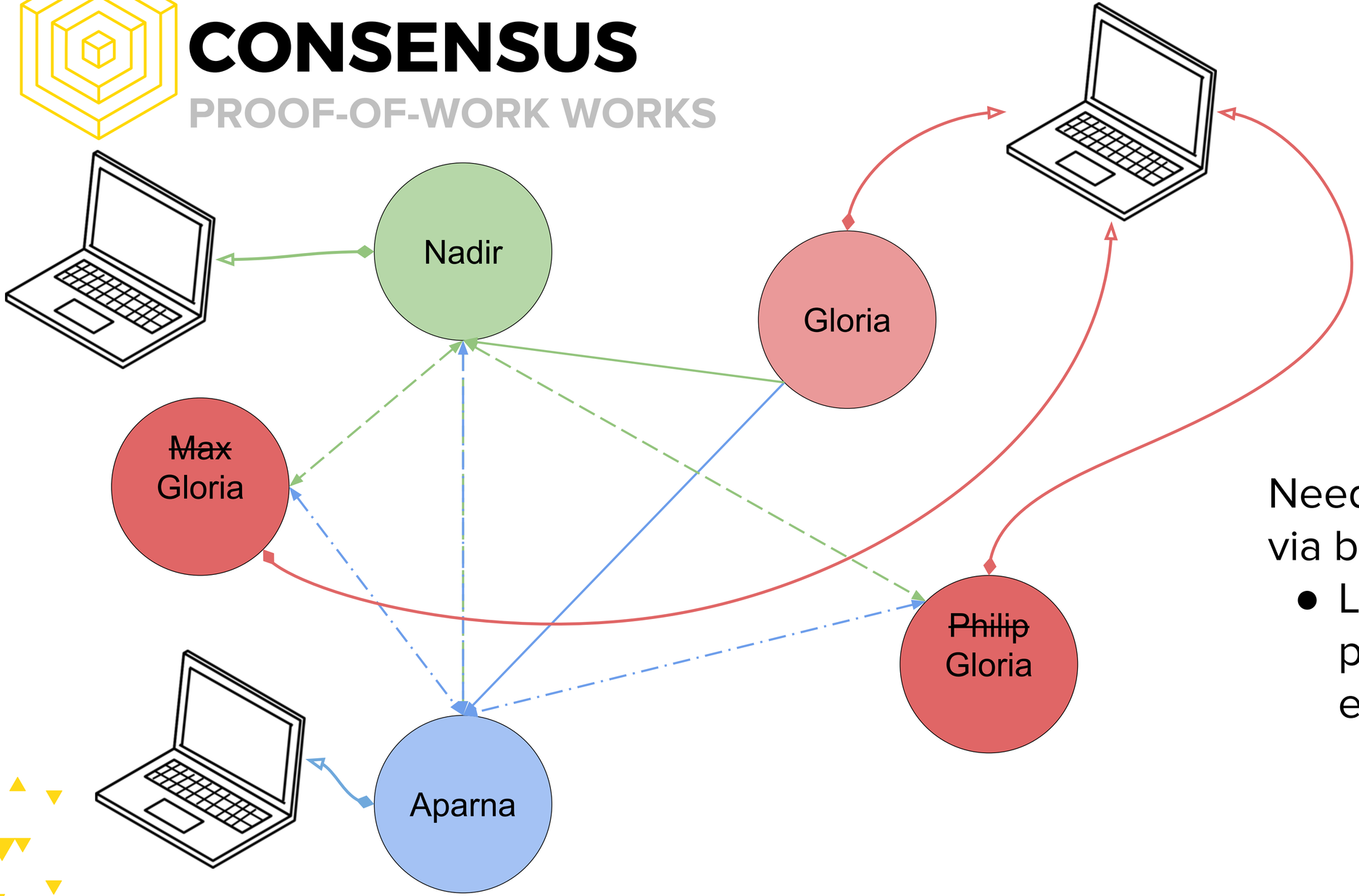
Evidence

Spent resources

AUTHOR: NADIR AKHTAR

CONSENSUS

PROOF-OF-WORK WORKS



Need to solve a problem via brute forcing

- Like brute forcing a password -- trial and error

CONSENSUS

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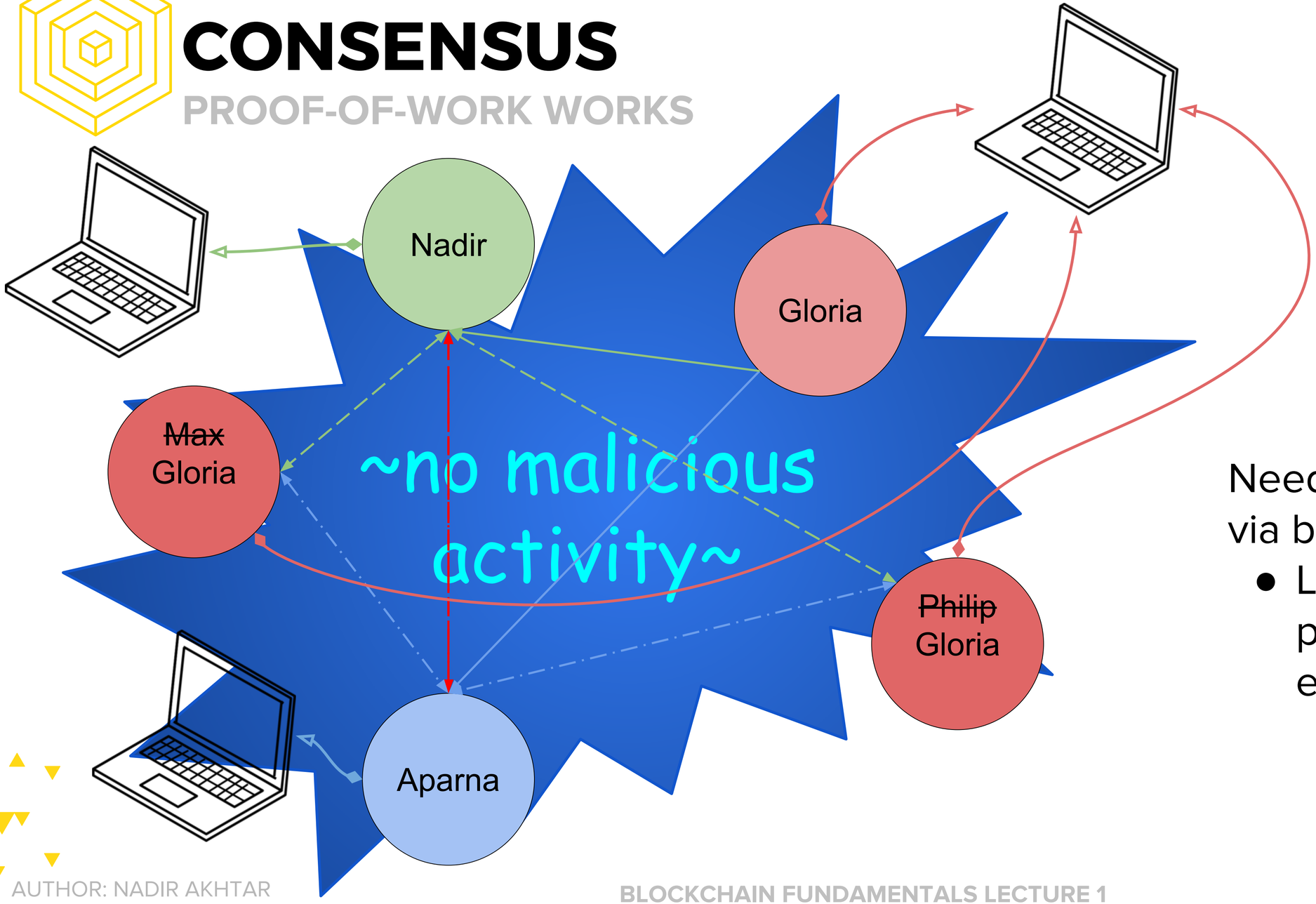

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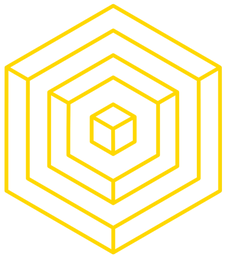

REVIEW

SUMMING UP BITCOIN

Identity: We share our public key to transfer Bitcoin and use our private key to redeem it.

Transactions: Under the UTXO model, balances are implicitly the summation of all unspent transaction outputs which you can redeem.

Record-keeping: Each entity keeps a copy of the blockchain, the distributed ledger.

Consensus: Peers cast proposals via Proof-of-Work, an expensive voting process, to deter double spend attacks.

REVIEW

GOALS OF CURRENCY

Source: https://eleventhirthypm.wordpress.com/2013/11/10/the-five-properties-of-currency-not-money/

Currency aims to provide:

- Scarcity: finite units, for maintaining value
- Fungibility: interchangeable and identical units, for preserving equal value between all units
- Divisibility: subunits for every major unit, for ease and precision of payments
- Durability: long-lasting units, for longevity of each unit
- Transferability: liquidity, for ease in transacting

But most importantly, **legitimacy** -- we've demonstrated how we can trust Bitcoin, the mathematical accumulation of several years of research, without trusting individuals.

EXTRA: FORKING

A LITTLE DIFFERENT FROM SPOONING

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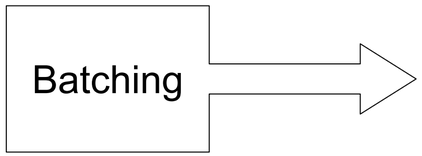

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?

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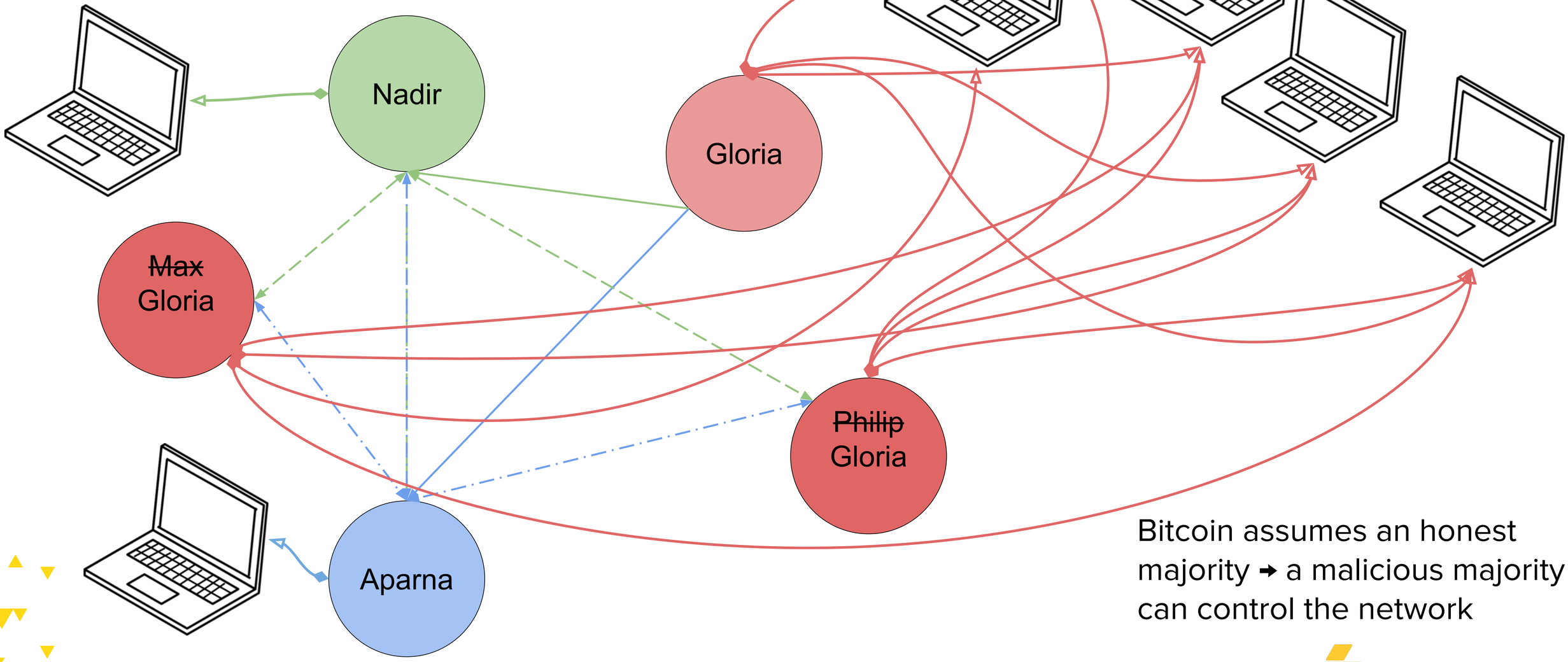
EXTRA: 51% ATTACK

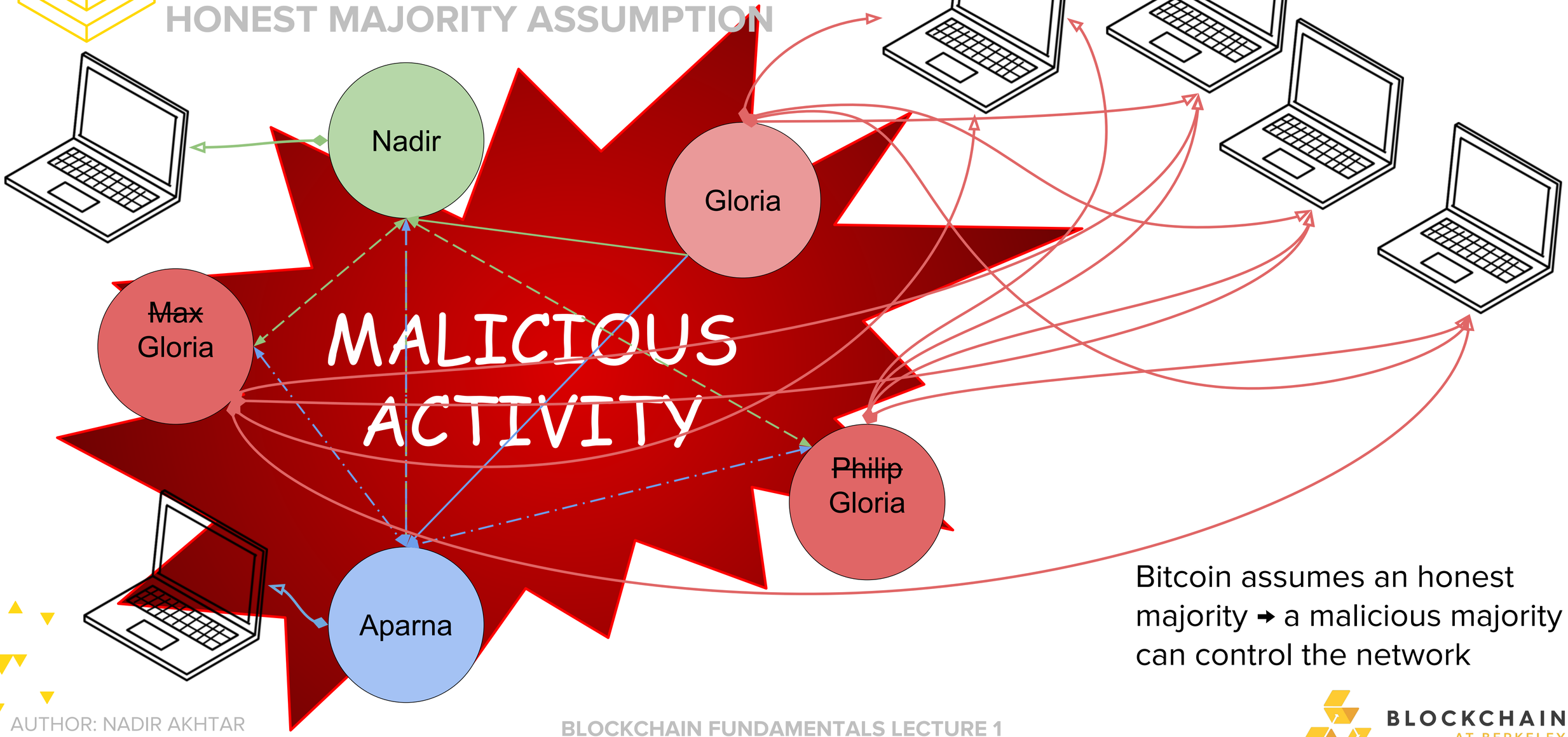
HONEST MAJORITY ASSUMPTION



Bitcoin assumes an honest majority ➔ a malicious majority can control the network

EXTRA: 51% ATTACK

HONEST MAJORITY ASSUMPTION



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EXTRA: 51% ATTACK

THE ROAD NOT TAKEN

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HOMEWORK

- **sign up** for Piazza: piazza.com/berkeley/fall2017/cs19878
- **attend** discussion section and use your code to enroll in the right class
  - your code is single-use only and will expire on September 22
- **read** assigned readings on Piazza