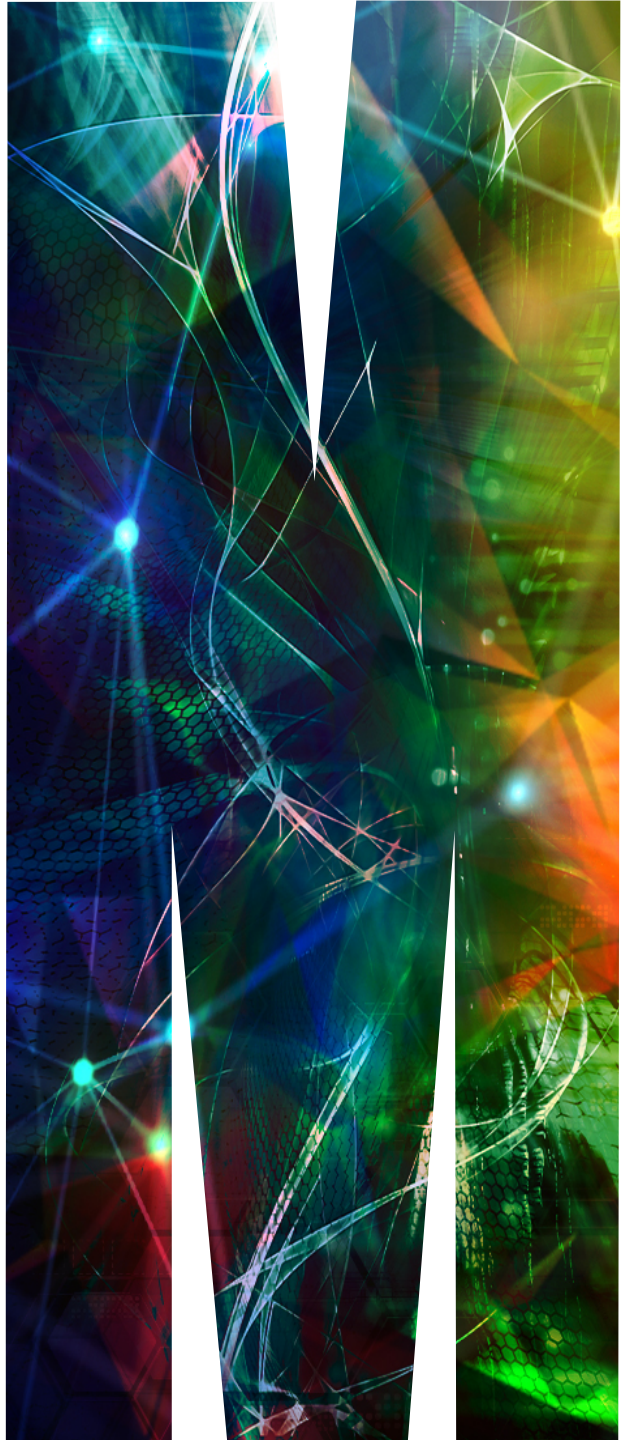
MONASH University

FIT5214: Blockchain

Lecture 10: Algorand



Lecturer: Rafael Dowsley

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Unit Structure

- Lecture 1: Introduction to Blockchain
- Lecture 2: Bitcoin
- Lecture 3: Ethereum and Smart Contracts
- Lecture 4: Proof-of-Work (PoW)
- Lecture 5: Attacks on Blockchains
- Lecture 6: Class Test/Alternatives to PoW
- Lecture 7: Proof-of-Stake (PoS)
- Lecture 8: Privacy
- Lecture 9: Byzantine Agreement
- Lecture 10: Algorand
- Lecture 11: Blockchain Network
- Lecture 12: Payment Channels

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Recap: Proof-of-Stake (PoS)

- PoW has the following disadvantages:
  - Control of the network is very centralised in a few mining pools.
  - A huge amount of energy is wasted computing useless hash outputs.
  - Migration of hash power to do 51% attacks in platforms with smaller amounts of total hash power.

- To solve some of PoW weakness, PoS uses the number of controlled coins (instead of hashing power) in order to determine the voting power.

Recap: Proof-of-Stake (PoS)

There are different types of PoS, depending on the "things" put at stake:

- Proof-of-Lock/Deposit
- Balance-based
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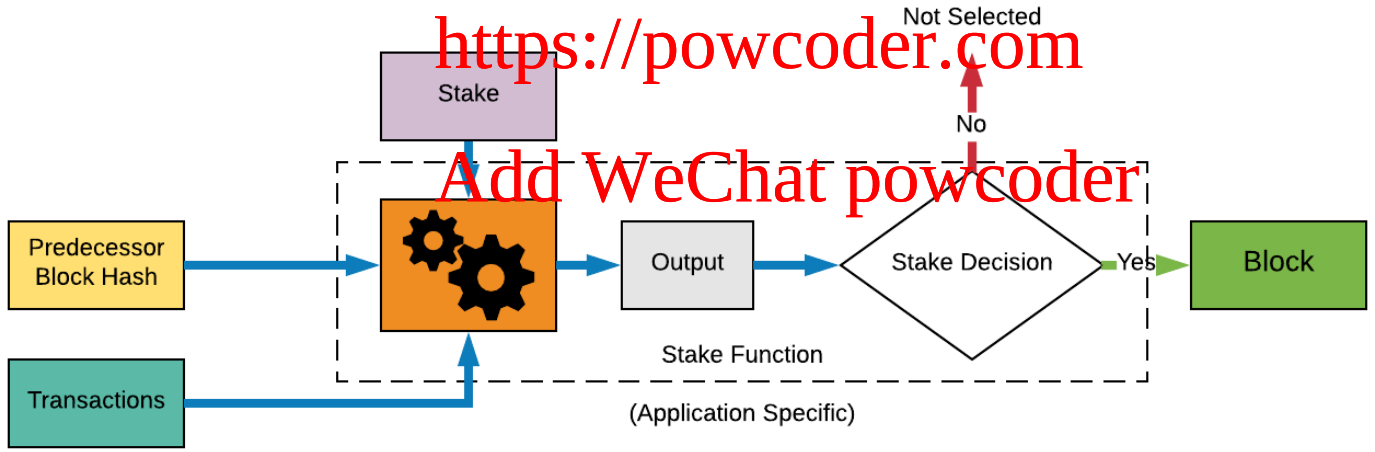


Nakamoto-style consensus: e.g., Ouroboros
BFT-style consensus: e.g., Algorand

Recap: Ouroboros Praos PoS

Nakamoto-style consensus dividing the time into slots. For each slot, select leader to create the block corresponding to that slot.

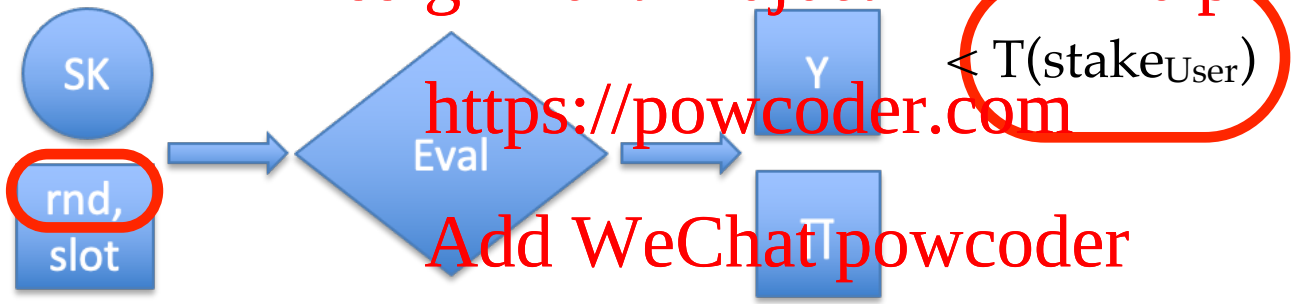
Lottery: the slot leader is randomly selected with the users probabilities of being selected proportional to their stake.

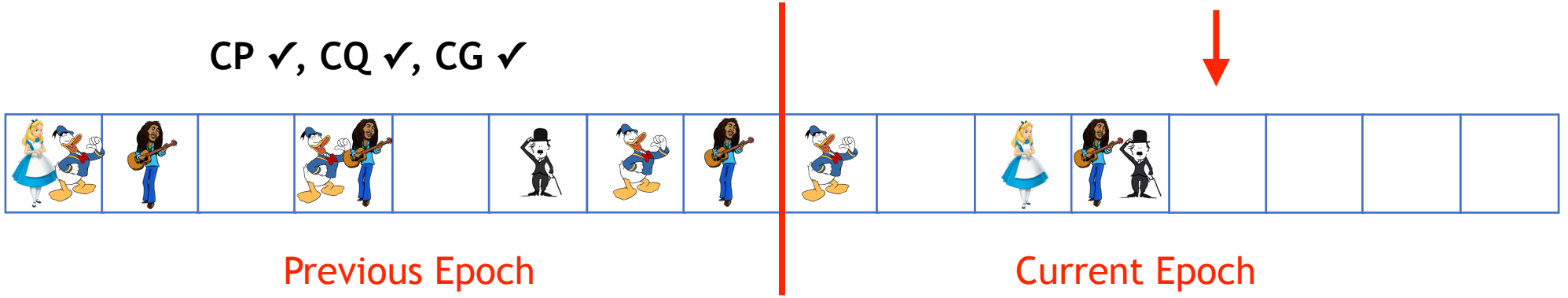
More than 50% of the coins should be controlled by users that behave honestly.

Recap: Ouroboros Praos PoS

The protocols works in epochs. Each epoch contains a fixed number of slots.

The parties need to agree on the random nonce rnd and stake distribution that is used to select leaders in the current epoch.





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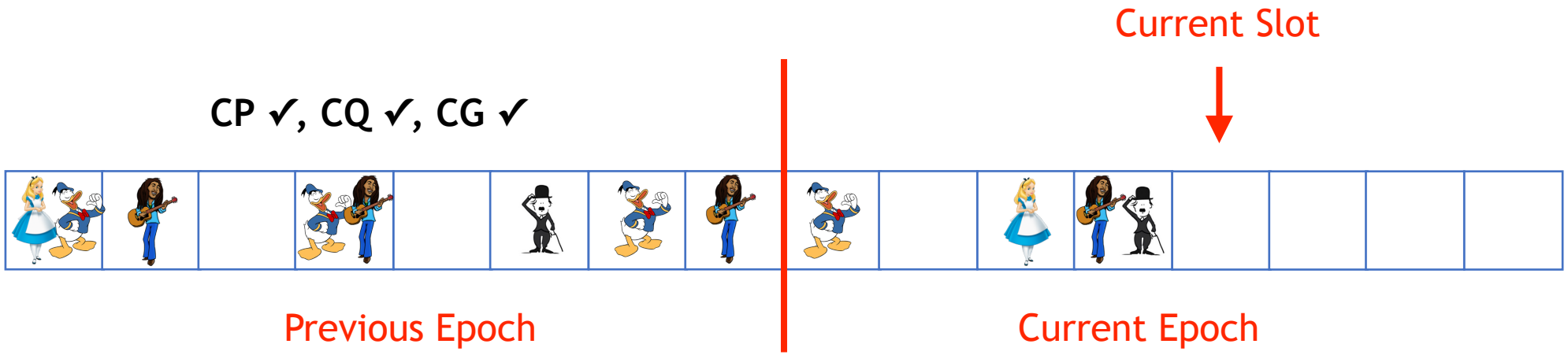
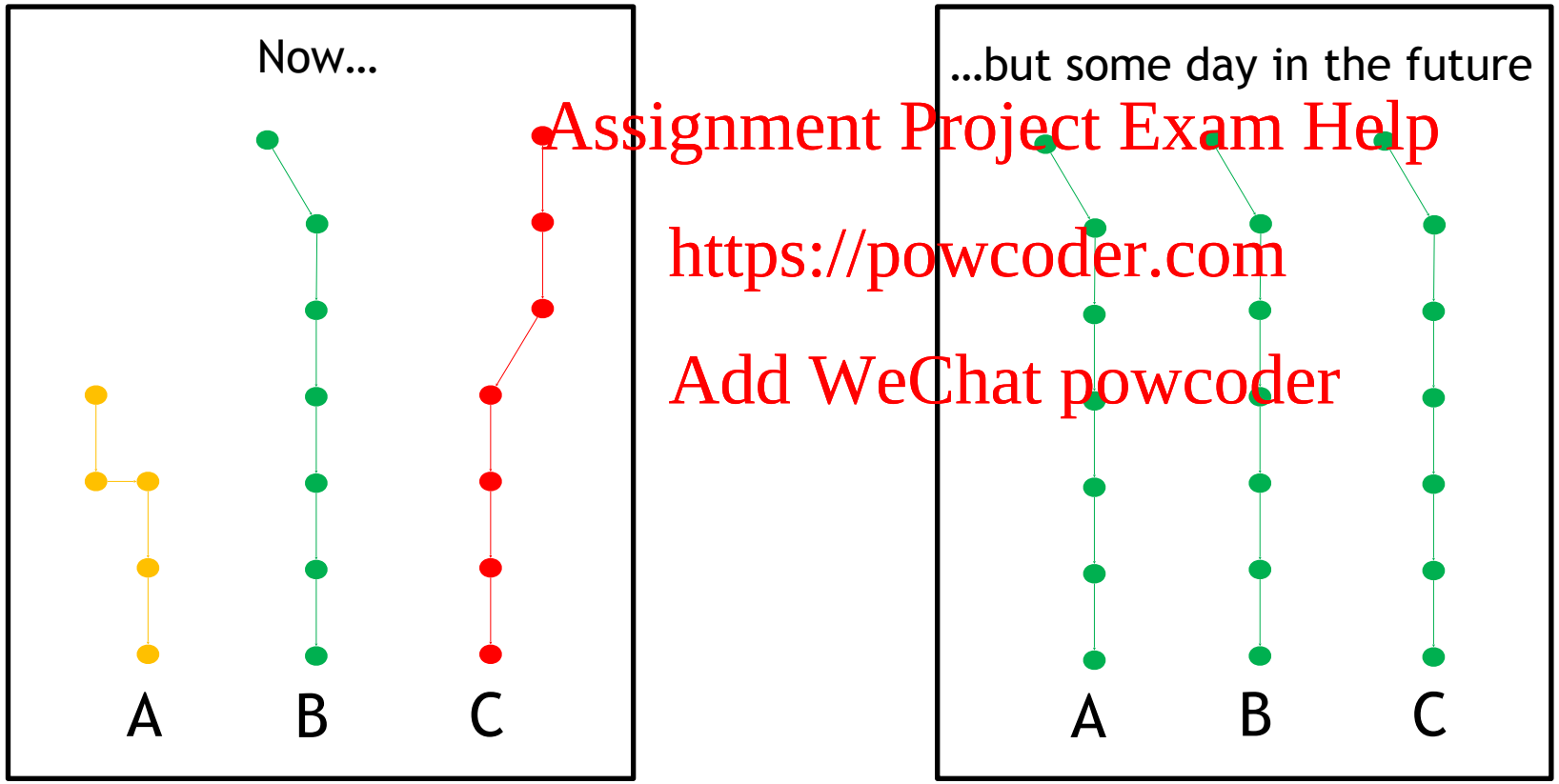
Agreement on the stake distribution is done in the previous epoch and fixed for the current epoch.

Similarly, an agreement on the new random nonce is achieved on the previous epoch by hashing verifiable random values from the chain to obtain the new nonce. And this nonce is affected by honest blocks.



Recap: Eventual Consistency

Eventually, all the nodes will agree on the same blockchain



Recap: T-Consistency

T-consistency **is used to quantify the quality of the Nakamoto-style consensus — after cutting down the last T blocks, all nodes should agree on the rest of the blockchain.**

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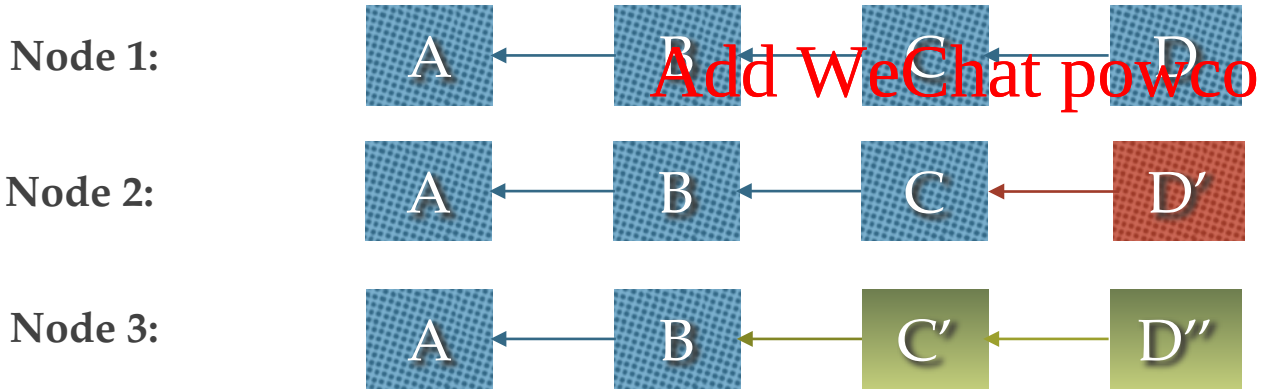

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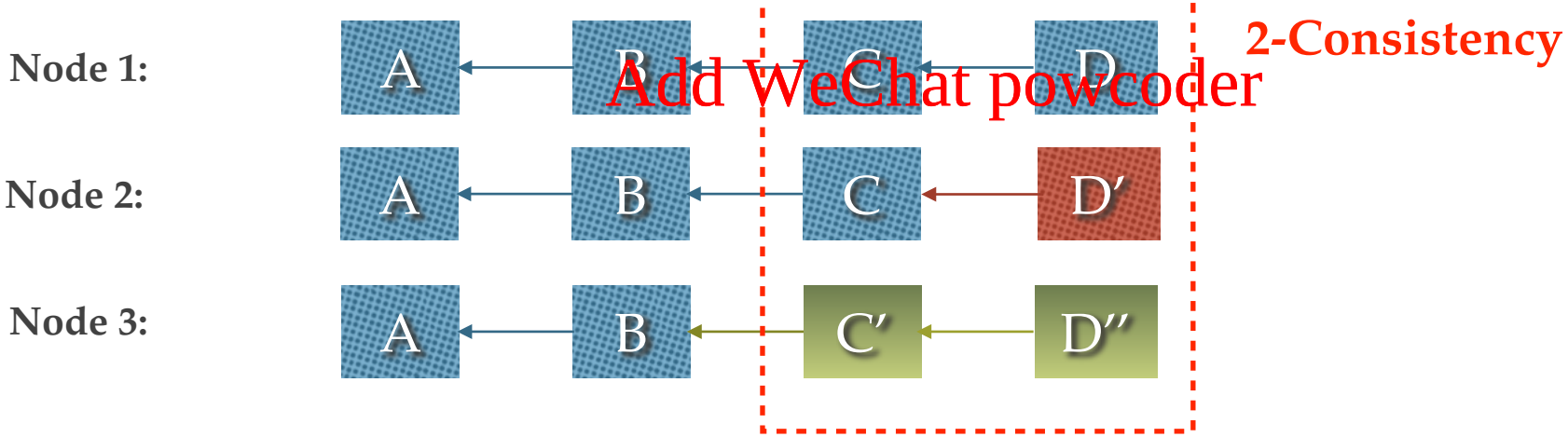

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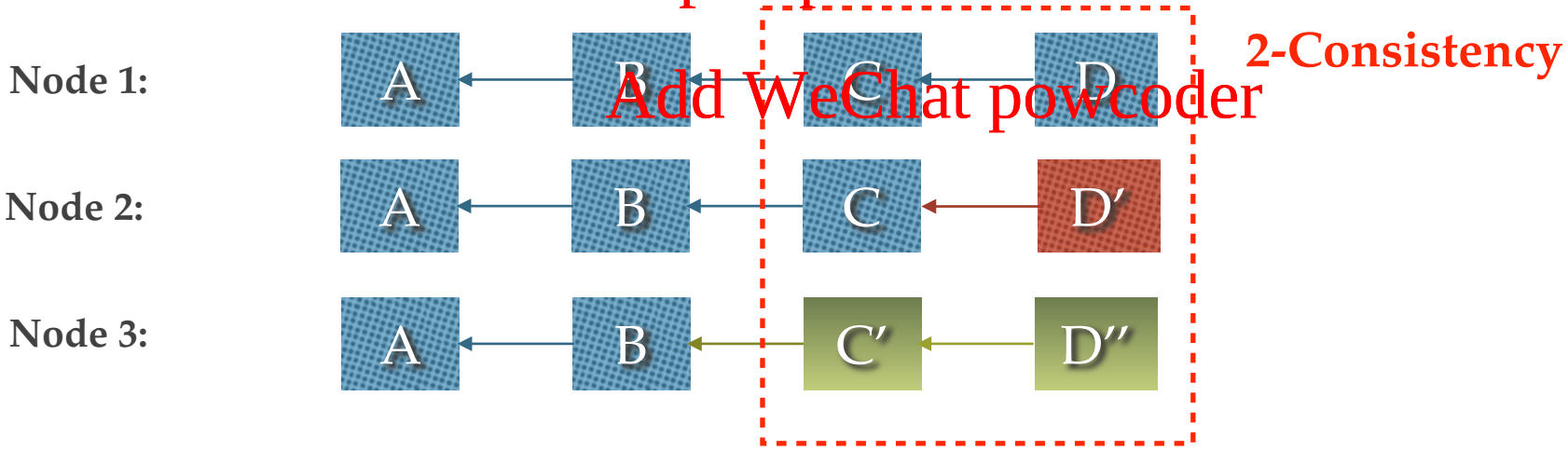

The best consistency is 0-consistency, which can be provided by traditional consensus protocols

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- *But this is bad for the usability of the system in many realistic situations.*

- **Ideally, we would like to guarantee that a transaction would not be reverted as soon as the block containing it is accepted as part of the blockchain.**

Recap: consensus

Definition 1. (Consensus.) There are n nodes, of which at most f can be malicious, i.e., at least $n - f$ nodes are correct. For all $i \in [1, n]$, node i starts with an input value v_i. The nodes must decide for one of those values, satisfying the following properties:

- **Agreement:** All correct nodes decide for the same value.

- **Termination:** All correct nodes terminate in finite time.
- **Validity:** The decision value must be the input value of a node.

Recap: safety and liveness

- The **safety** of the global state is ensured by the consensus
  - The entire *valid* transaction history can be *agreed by all* correct nodes. Agreed values cannot be changed later on. (Agreement & Validity)
- The **liveness** of the system is ensured by the consensus
  - All nodes can *terminate* their process and reach a conclusion. (Termination)

Recap: Byzantine agreement (BA)

Byzantine agreement (BA) systems, also known as Byzantine fault tolerant (BFT) systems, provide solutions to the Byzantine generals problem.

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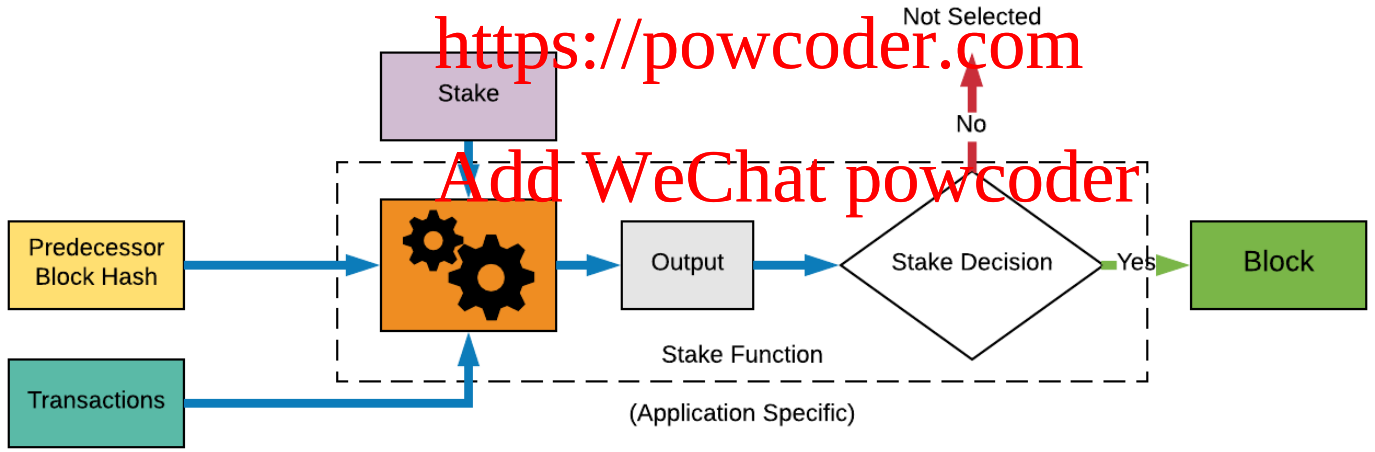

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- BFT solutions can only tolerate less than 1/3 of the participants being malicious.

- **This translates into Algorand only being able to tolerate less than 1/3 of the coins being controlled by the adversary.**

Scalability

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- **Consensus by committee: use a representative committee (with thousands of votes) for reaching consensus.**
- Users are randomly selected to participate in the committee, with their expected number of votes in the committee proportional to the amount of coins that they control.
- Challenge: relying on a committee creates the possibility of targeted attacks against the chosen committee members.

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- BA⋆ is executed to reach consensus among participants on the next set of transactions.
- Reach consensus on a new block with low latency and without the possibility of forks.

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- Scalability: mechanism based on VRFs allows users to privately and non-interactively check whether they are selected to participate in BA⋆ and to include a proof of their selection in their network messages.

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- Having no private state makes all users equally capable of participating. Elect new committee members for each step of BA⋆.

Model

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- Algorand achieves safety with a “weak synchrony” assumption: the network can be asynchronous (i.e., entirely controlled by the adversary) for a long but bounded period of time (e.g., at most 1 day or 1 week). After an asynchrony period, the network must be strongly synchronous for a reasonably long period again.

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- Loosely synchronised clocks across all users in order to recover liveness after weak synchrony.

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- The transactions in Algorand can be confirmed much faster due to the properties of BFT protocols.
- Both Algorand and Ouroboros use VRFs as an essential building block.

Recap: Verifiable Random Function (VRF)

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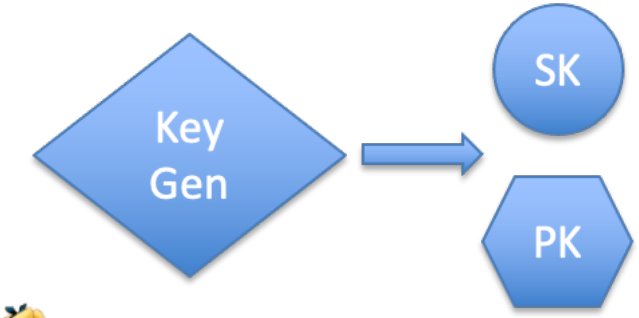

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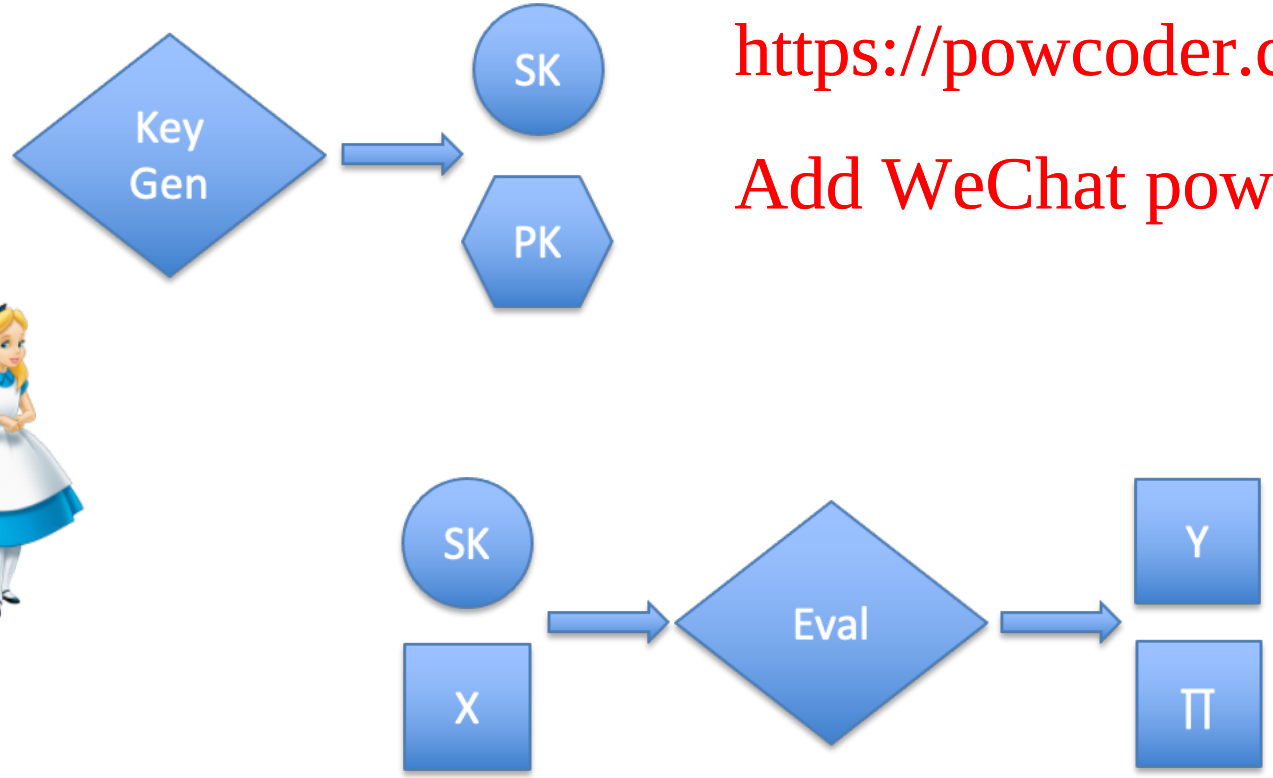

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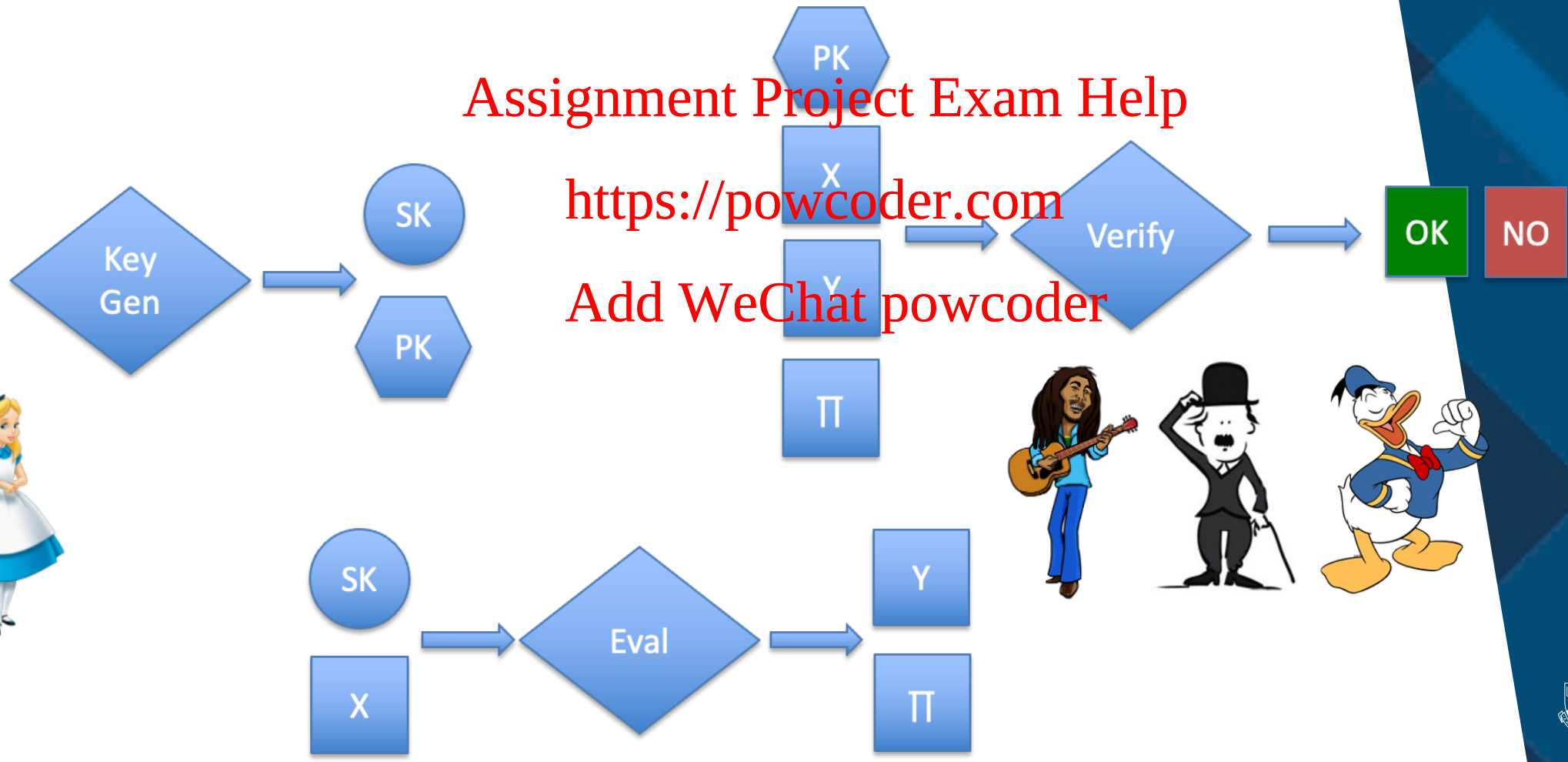
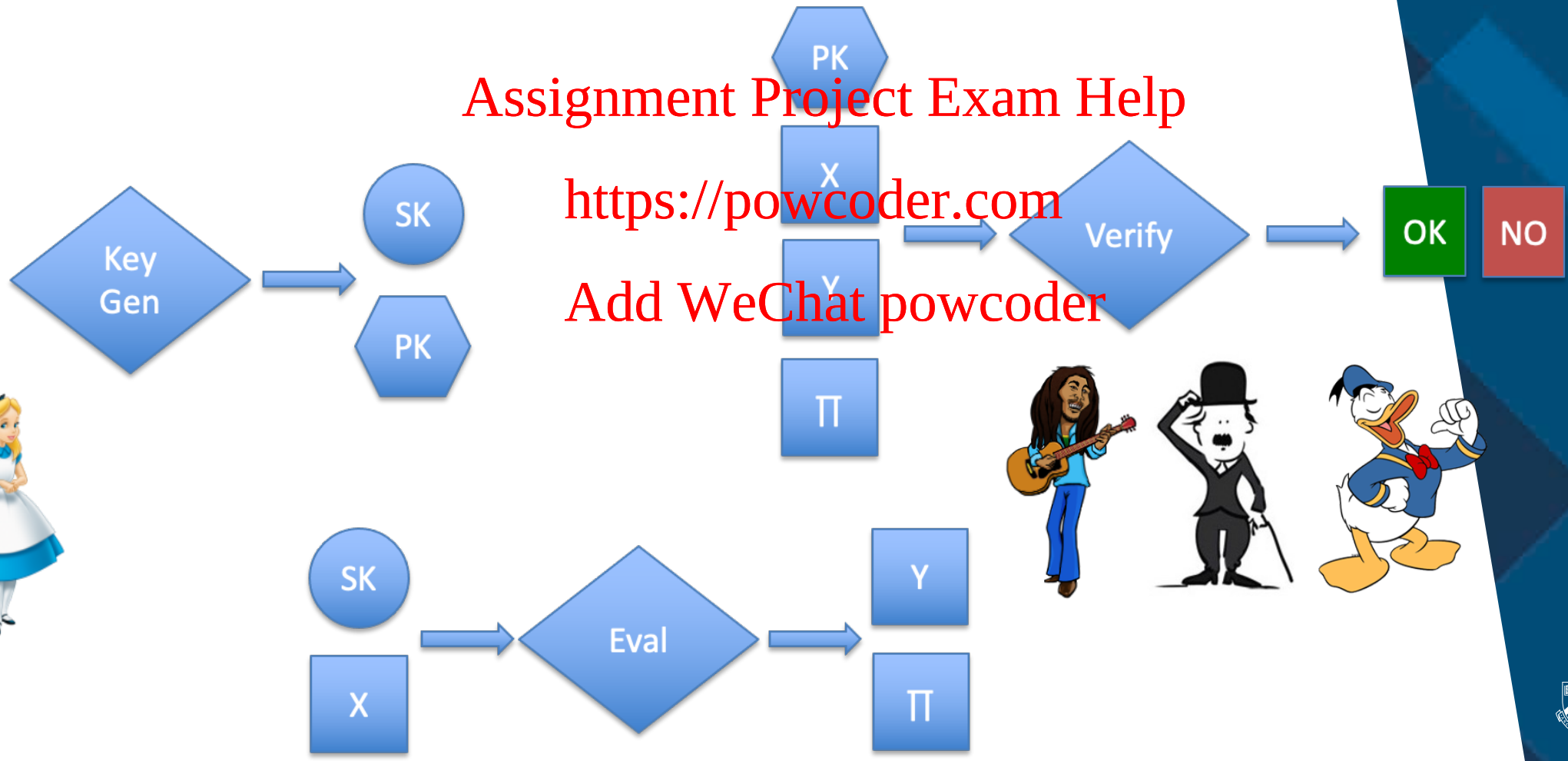


Recap: Verifiable Random Function (VRF)

- Security properties of VRF: pseudorandomness, provability and uniqueness.



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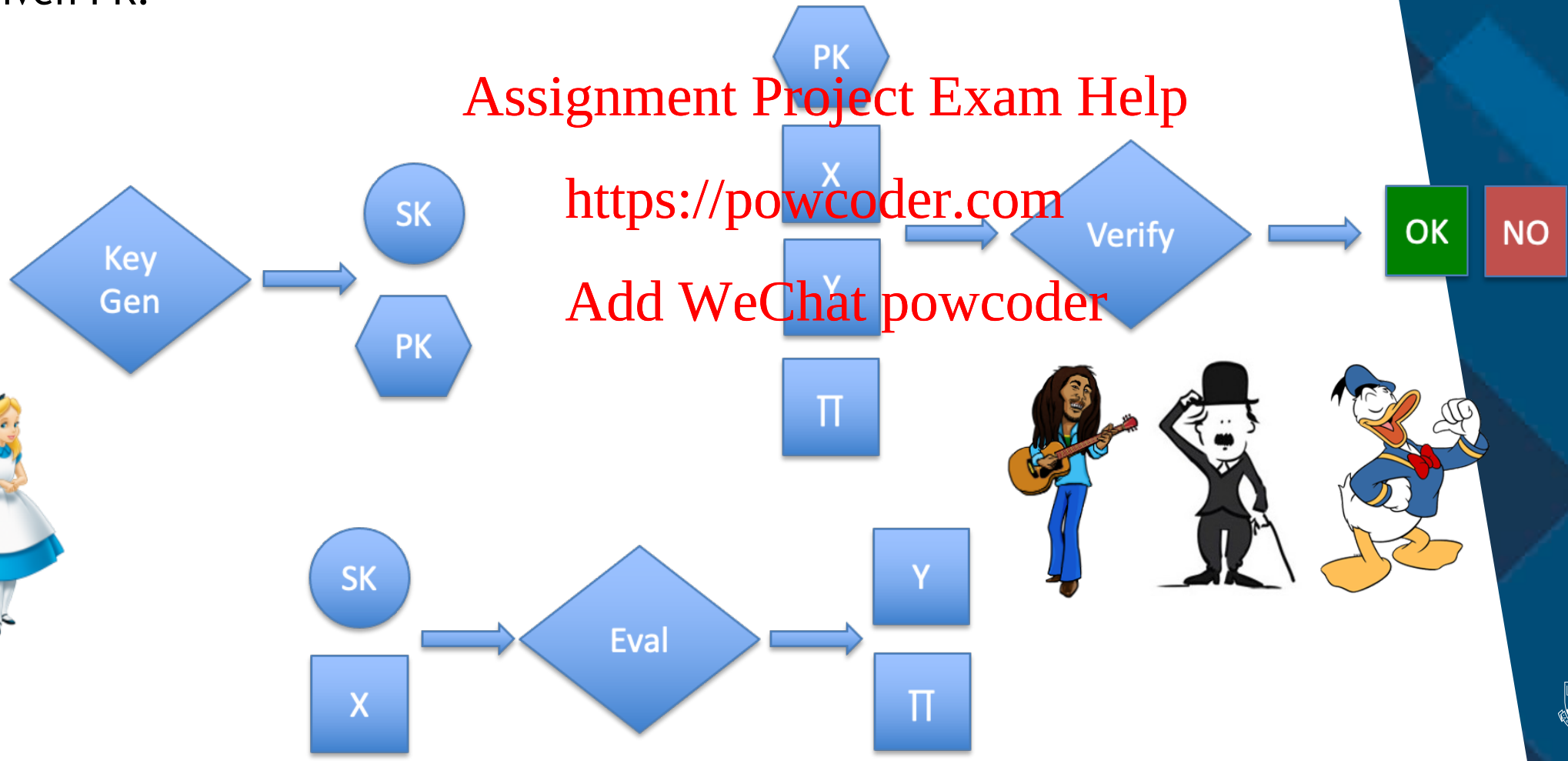
- Pseudorandomness: the output Y is pseudorandom, even when the adversary is given PK.



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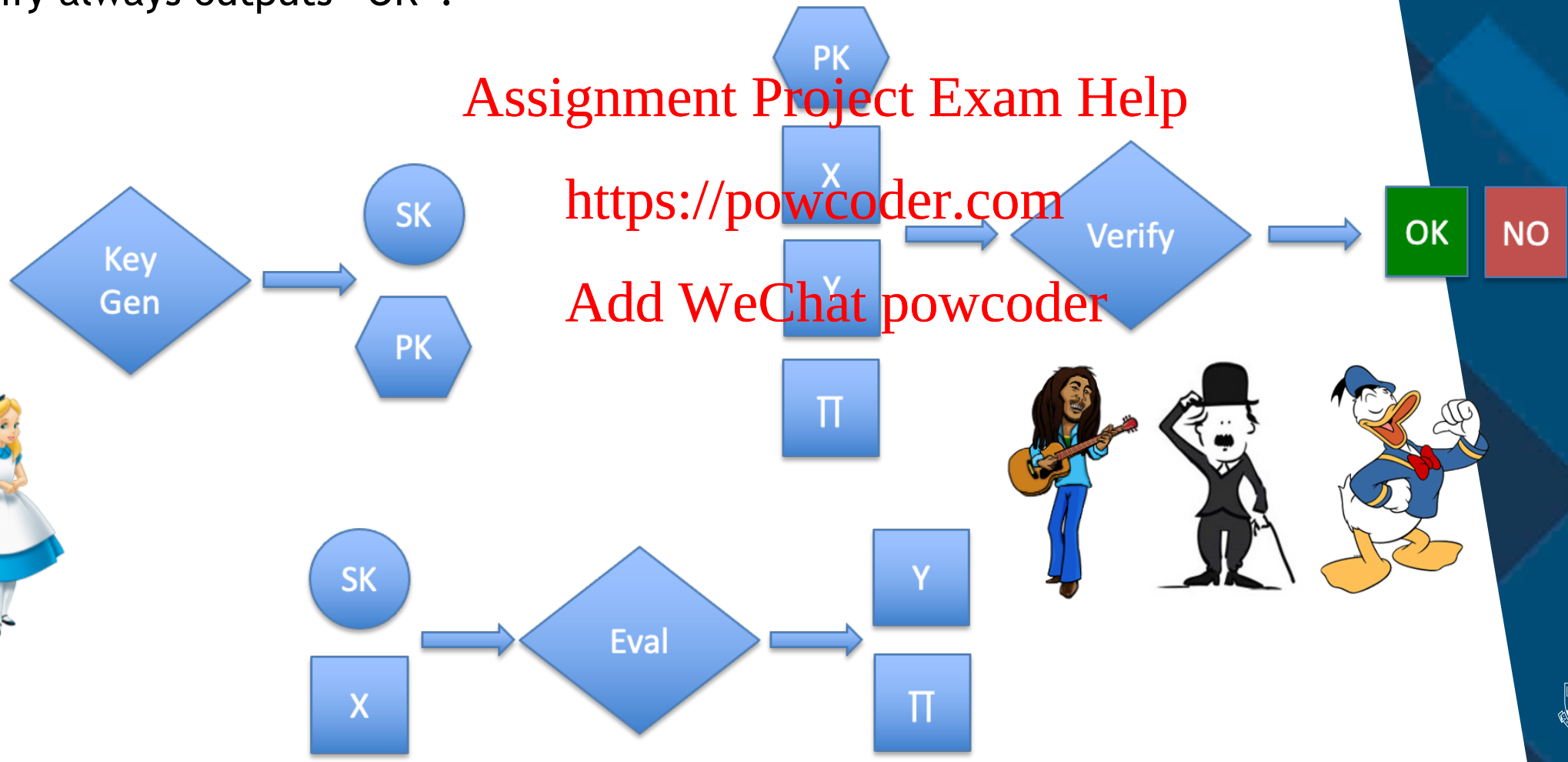
- Provability: For honestly generated keys, input X, output Y and proof ∏, Verify always outputs “OK”.



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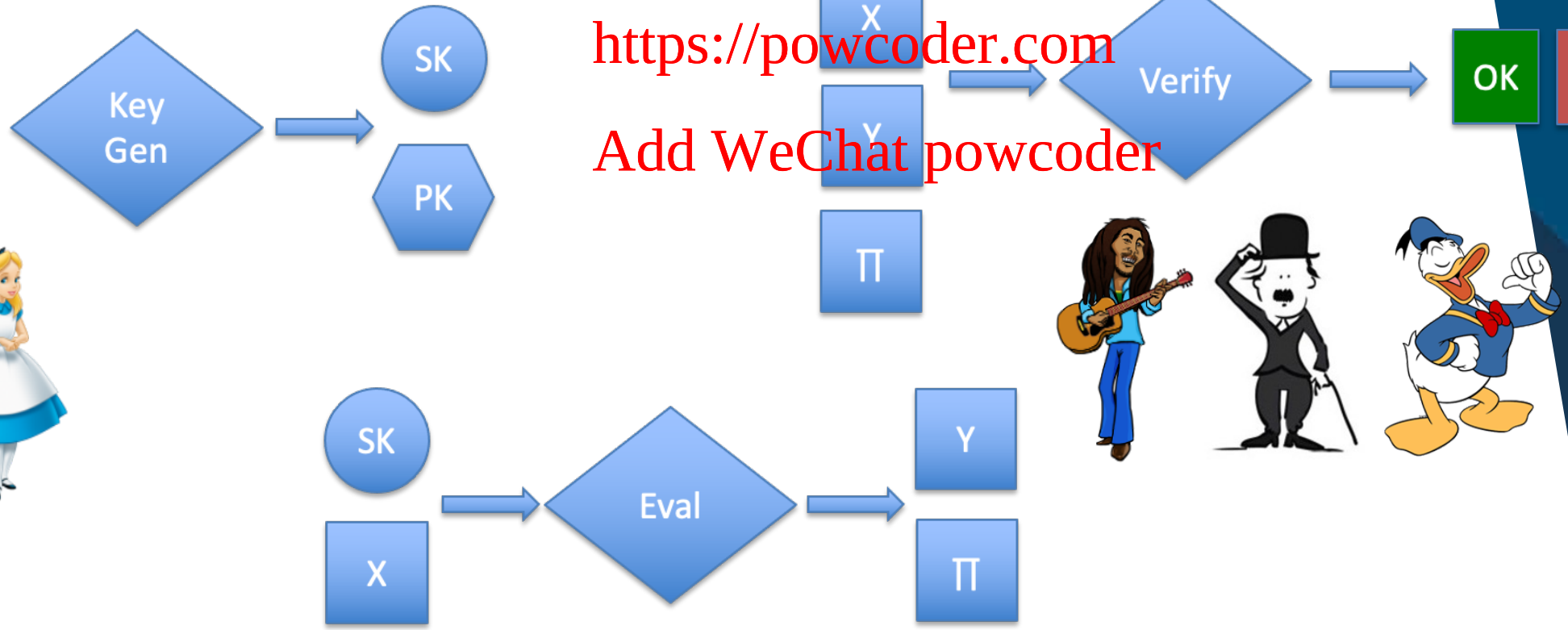
Recap: Verifiable Random Function (VRF)

- Uniqueness: No tuple (PK, X, Y_0, Π_0, Y_1, Π_1) such that Verify(PK, X, Y_0,Π_0)=OK, Verify(PK, X, Y_1, Π_1)=OK and $Y_0 \neq Y_1$.



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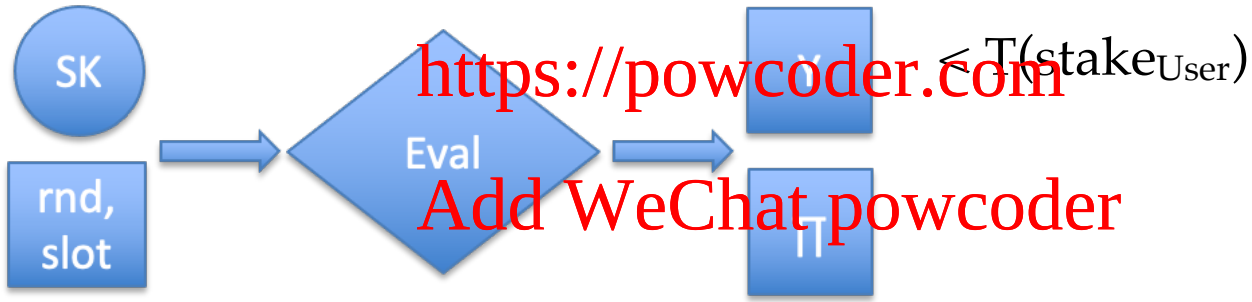

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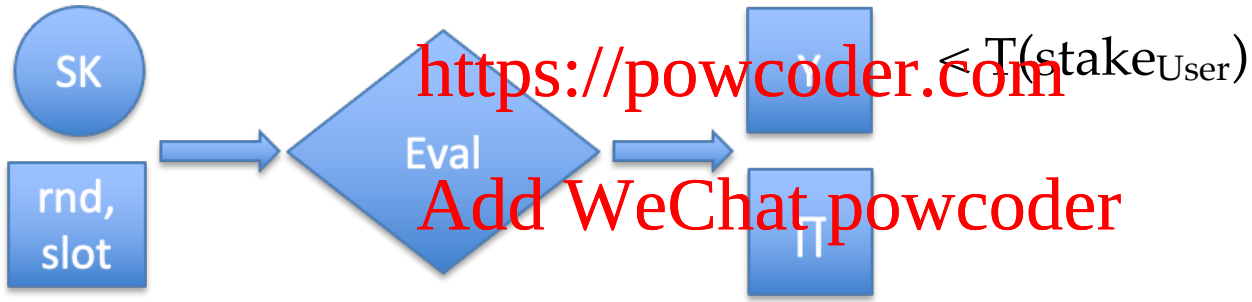

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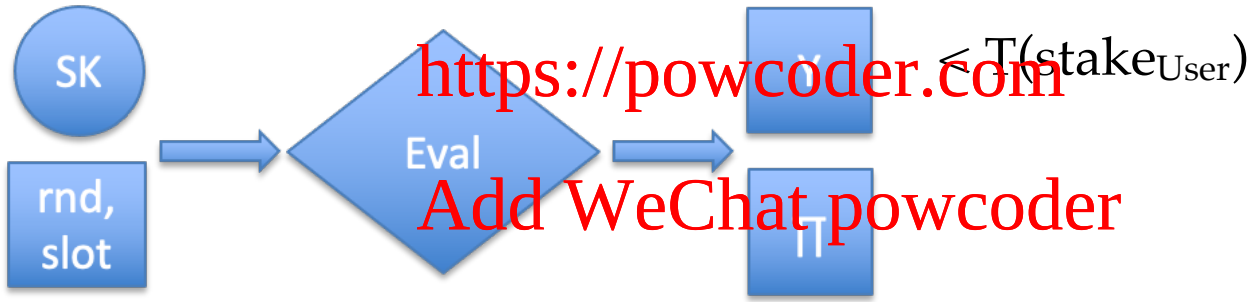

- **Using a private lottery helps mitigating adaptive attacks.**
- When a user claims to be a block proposer/committee member, anyone can publicly verify if that claim is legitimate or not.

BA⋆ Consensus

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- A transaction is confirmed when the transaction's block (or any of its successor blocks) reaches final consensus.

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- Each selected user has a priority, which can be compared between users, and a proof of the chosen user's priority.
- Since sortition is random, there may be multiple users selected to propose a block, and the priority determines which block everyone should adopt.
- Each user initialises BA* with the highest-priority block that they received.

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- Committee members broadcast a message for that step (which includes their proof of selection).
- Steps repeat until, in some step of BA⋆, enough users in the committee reach consensus.
- Steps are not synchronised across users; each user checks for selection as soon as he observes the previous step had ended.

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- In the second phase, BA⋆ reaches agreement on one of these options.
- The first phase always takes two steps. The number of steps on the second phase varies.

Votes

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- In the common case when the network is strongly synchronous and the highest-priority block proposer was honest, most votes will be for the same proposed block hash.
- If the users do not receive enough votes for any value, they time out, and their choice of vote for the next step is determined by the step number.

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- **Final consensus: a consensus on a value V is final only if it reached the very first step of the second phase, and if enough users observed this consensus being reached.**

Getting Unstuck

- If the honest users are split into two groups neither of which is large enough to gather enough votes on their own (but large enough together with the adversary's votes), they can get stuck with one group voting for the hash of a proposed block, and another for the empty hash (by being manipulated by the adversary).

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- Avoid this attack by pushing, in certain steps of BA, towards accepting one of the options based on a random "common coin" (i.e., a binary value that is predominantly the same for all users). Although this may sound circular, the users need not reach formal consensus on this common coin.

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- As long as enough users observe the same coin (and it is unknown to the attacker in advance of the step), consensus is reached in next iteration with probability 1/2.

BA⋆ Efficiency

- When the network is strongly synchronous, BA⋆ guarantees that if all honest users start with the same initial block (i.e., the highest priority block proposer was honest), then BA⋆ establishes final consensus over that block and terminates precisely in 4 interactive steps between users.

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- Under the same network conditions, and in the worst case of a particularly lucky adversary, all honest users reach consensus on the next block within expected 13 steps.

Reading

Reading material:
Algorand: Scaling Byzantine Agreements for Cryptocurrencies

Further information about Algorand:
https://www.algorand.com/technology/white-papers

Next Week

- Blockchain Network