Staking in depth: Anatomy and Extensions

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Brief Introduction

1. Anatomy of Staking Module
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how to eat elephant one bite at at time

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Module

- extrinsics

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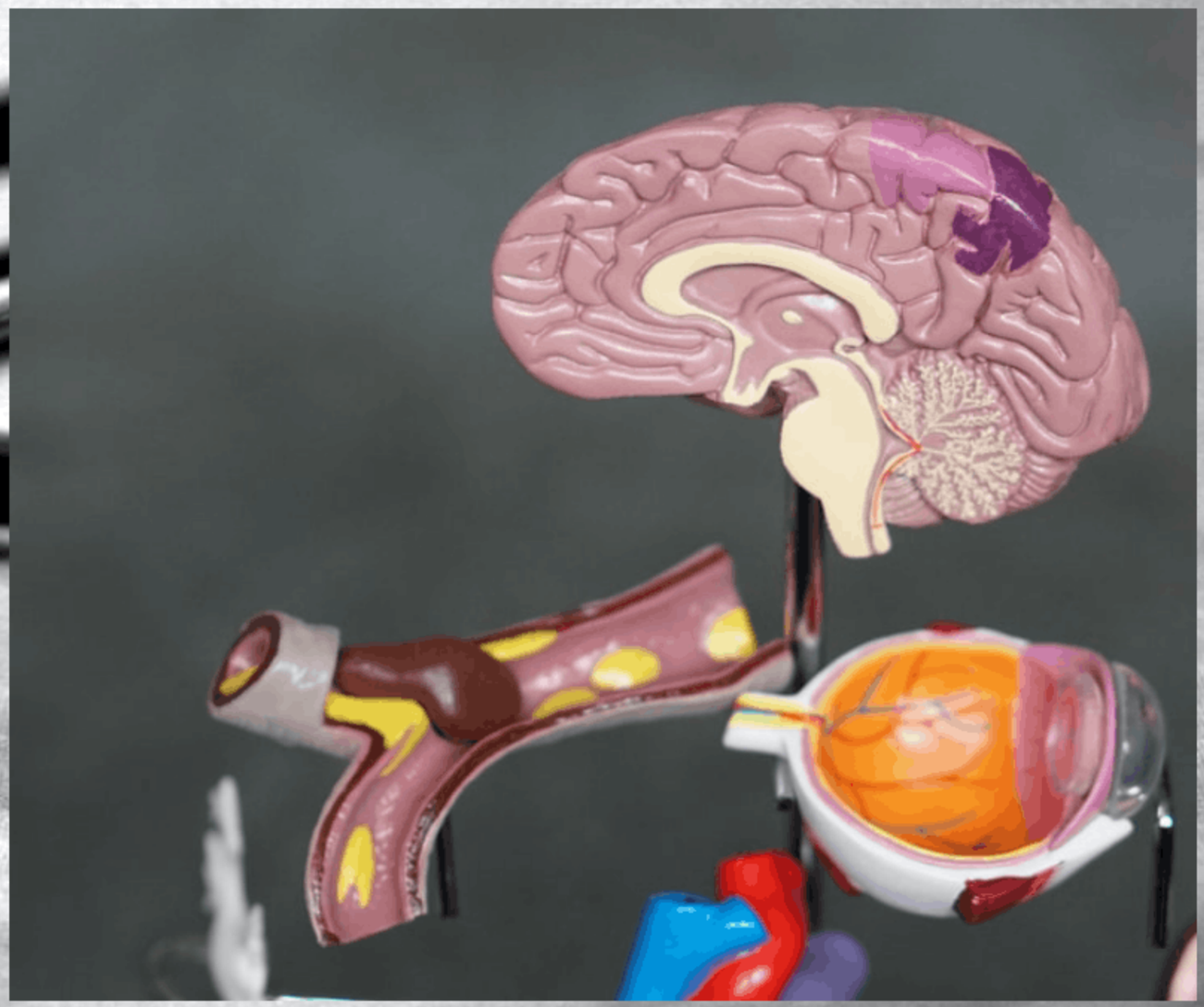

Configuration Trait

- A Trait where primitives from the runtime is imported to each runtime module
- Includes module functions

```rust
pub trait Trait: frame_system::Trait + SendTransactionTypes<Call<Self>> {
    /// The staking balance.
    type Currency: LockableCurrency<Self::AccountId, Moment=Self::BlockNumber>;

    /// Time used for computing era duration.
    ///
    /// It is guaranteed to start being called from the first `on_finalize`. Thus value at genesis
    /// is not used.
    type UnixTime: UnixTime;

    /// Convert a balance into a number used for election calculation. This must fit into a `u64`
    /// but is allowed to be sensibly lossy. The `u64` is used to communicate with the
    /// [`sp_npos_elections`] crate which accepts u64 numbers and does operations in 128.
    /// Consequently, the backward convert is used convert the u128s from sp-elections back to a
    /// [`BalanceOf`].
    type CurrencyToVote: Convert<BalanceOf<Self>, VoteWeight> + Convert<u128, BalanceOf<Self>>;

    /// Tokens have been minted and are unused for validator-reward.
    /// See [Era payout](./index.html#era-payout).
    type RewardRemainder: OnUnbalanced<NegativeImbalanceOf<Self>>;

    /// The overarching event type.
    type Event: From<Event<Self>> + Into<<Self as frame_system::Trait>::Event>;

    /// Handler for the unbalanced reduction when slashing a staker.
    type Slash: OnUnbalanced<NegativeImbalanceOf<Self>>;

    /// Handler for the unbalanced increment when rewarding a staker.
    type Reward: OnUnbalanced<PositiveImbalanceOf<Self>>;

    /// Number of sessions per era.
    type SessionsPerEra: Get<SessionIndex>;

    /// Number of eras that staked funds must remain bonded for.
    type BondingDuration: Get<EraIndex>;

    /// Number of eras that slashes are deferred by, after computation.
    ///
    /// This should be less than the bonding duration. Set to 0 if slashes
    /// should be applied immediately, without opportunity for intervention.
    type SlashDeferDuration: Get<EraIndex>;

    /// The origin which can cancel a deferred slash. Root can always do this.
    type SlashCancelOrigin: EnsureOrigin<Self::Origin>;

    /// Interface for interacting with a session module.
    type SessionInterface: self::SessionInterface<Self::AccountId>;

    /// The NPoS reward curve used to define yearly inflation.
    /// See [Era payout](./index.html#era-payout).
    type RewardCurve: Get<&'static PiecewiseLinear<'static>>;

    /// Something that can estimate the next session change, accurately or as a best effort guess.
    type NextNewSession: EstimateNextNewSession<Self::BlockNumber>;

    /// The number of blocks before the end of the era from which election submissions are allowed.
    ///
    /// Setting this to zero will disable the offchain compute and only on-chain seq-phragmen will
    /// be used.
```

Storage

- A key-value interface storage for blockchain state
- Trie is managed automatically
- getter is provided

```
decl_storage! {
    trait Store for Module<T: Trait> as Staking {
        /// Number of eras to keep in history.
        ///
        /// Information is kept for eras in `[current_era - history_depth; current_era]`.
        ///
        /// Must be more than the number of eras delayed by session otherwise. I.e. active era must
        /// always be in history. I.e. `active_era > current_era - history_depth` must be
        /// guaranteed.
        HistoryDepth get(fn history_depth) config(): u32 = 84;

        /// The ideal number of staking participants.
        pub ValidatorCount get(fn validator_count) config(): u32;

        /// Minimum number of staking participants before emergency conditions are imposed.
        pub MinimumValidatorCount get(fn minimum_validator_count) config(): u32;

        /// Any validators that may never be slashed or forcibly kicked. It's a Vec since they're
        /// easy to initialize and the performance hit is minimal (we expect no more than four
        /// invulnerables) and restricted to testnets.
        pub Invulnerables get(fn invulnerables) config(): Vec<T::AccountId>;

        /// Map from all locked "stash" accounts to the controller account.
        pub Bonded get(fn bonded): map hasher(twox_64_concat) T::AccountId => Option<T::AccountId>;

        /// Map from all (unlocked) "controller" accounts to the info regarding the staking.
        pub Ledger get(fn ledger):
            map hasher(blake2_128_concat) T::AccountId
            => Option<StakingLedger<T::AccountId, BalanceOf<T>>>;

        /// Where the reward payment should be made. Keyed by stash.
        pub Payee get(fn payee): map hasher(twox_64_concat) T::AccountId => RewardDestination<T::AccountId>;

        /// The map from (wannabe) validator stash key to the preferences of that validator.
        pub Validators get(fn validators):
            map hasher(twox_64_concat) T::AccountId => ValidatorPrefs;

        /// The map from nominator stash key to the set of stash keys of all validators to nominate.
        pub Nominators get(fn nominators):
            map hasher(twox_64_concat) T::AccountId => Option<Nominations<T::AccountId>>;

        /// The current era index.
        ///
        /// This is the latest planned era, depending on how the Session pallet queues the validator
        /// set, it might be active or not.
        pub CurrentEra get(fn current_era): Option<EraIndex>;

        /// The active era information, it holds index and start.
        ///
        /// The active era is the era currently rewarded.
        /// Validator set of this era must be equal to `SessionInterface::validators`.
        pub ActiveEra get(fn active_era): Option<ActiveEraInfo>;

        /// The session index at which the era start for the last `HISTORY_DEPTH` eras.
```

Module

- The main body of algorithms in each module
- Functions are divided into 3 kinds
  - Extrinsics in `decl_module`
  - Root extrinsics in `decl_module`
  - hooks(on_initialize, on_finalize)
  - Module methods

```
decl_module! {
    pub struct Module<T: Trait> for enum Call where origin: T::Origin {
        /// Number of sessions per era.
        const SessionsPerEra: SessionIndex = T::SessionsPerEra::get();
```

```
impl<T: Trait> Module<T> {
    /// The total balance that can be slashed from a stash account as of right now.
    pub fn slashable_balance_of(stash: &T::AccountId) -> BalanceOf<T> {
        // Weight note: consider making the stake accessible through stash.
        Self::bonded(stash).and_then(Self::ledger).map(|l| l.active).unwrap_or_default()
    }

    /// internal impl of [`slashable_balance_of`] that returns [`VoteWeight`].
    fn slashable_balance_of_vote_weight(stash: &T::AccountId) -> VoteWeight {
        <T::CurrencyToVote as Convert<BalanceOf<T>, VoteWeight>>::convert(
            Self::slashable_balance_of(stash)
        )
    }
```

Extrinsics(Module)

- General functions that can be executed from polkadot.js
- Executed via api.tx.{module}.method(arguments, {callback}) after websocket connection

```rust
/// (Re-)set the controller of a stash.
///
/// Effects will be felt at the beginning of the next era.
///
/// The dispatch origin for this call must be _Signed_ by the stash, not the controller.
///
/// # <weight>
/// - Independent of the arguments. Insignificant complexity.
/// - Contains a limited number of reads.
/// - Writes are limited to the `origin` account key.
/// ----------
/// Weight: O(1)
/// DB Weight:
/// - Read: Bonded, Ledger New Controller, Ledger Old Controller
/// - Write: Bonded, Ledger New Controller, Ledger Old Controller
/// # </weight>
#[weight = T::WeightInfo::set_controller()]
fn set_controller(origin, controller: <T::Lookup as StaticLookup>::Source) {
    let stash = ensure_signed(origin)?;
    let old_controller = Self::bonded(&stash).ok_or(Error::<T>::NotStash)?;
    let controller = T::Lookup::lookup(controller)?;
    if <Ledger<T>>::contains_key(&controller) {
        Err(Error::<T>::AlreadyPaired)?
    }
    if controller != old_controller {
        <Bonded<T>>::insert(&stash, &controller);
        if let Some(l) = <Ledger<T>>::take(&old_controller) {
            <Ledger<T>>::insert(&controller, l);
        }
    }
}
```

Root Extrinsics(Module)

- Requires `ensure_root` macro to check whether this come from root or guard to be executed through democracy module

```rust
/// (Re-)set the controller of a stash.
///
/// Effects will be felt at the beginning of the next era.
///
/// The dispatch origin for this call must be _Signed_ by the stash, not the controller.
///
/// # <weight>
/// - Independent of the arguments. Insignificant complexity.
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/// - Writes are limited to the `origin` account key.
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/// Weight: O(1)
/// DB Weight:
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/// # </weight>
#[weight = T::WeightInfo::set_controller()]
fn set_controller(origin, controller: <T::Lookup as StaticLookup>::Source) {
    let stash = ensure_signed(origin)?;
    let old_controller = Self::bonded(&stash).ok_or(Error::<T>::NotStash)?;
    let controller = T::Lookup::lookup(controller)?;
    if <Ledger<T>>::contains_key(&controller) {
        Err(Error::<T>::AlreadyPaired)?
    }
    if controller != old_controller {
        <Bonded<T>>::insert(&stash, &controller);
        if let Some(l) = <Ledger<T>>::take(&old_controller) {
            <Ledger<T>>::insert(&controller, l);
        }
    }
}
```

Hooks

- Repetitive task that can be executed in each module in every block
- on_finalize: executes right after the last extrinsic is executed from a block
- on_initialize: executes right before the first extrinsic is executed from a block

Module Methods

- Methods for repeating operations within the module
- Used for simulating test cases regarding sessions

```rust
impl<T: Trait> Module<T> {
    /// The total balance that can be slashed from a stash account as of right now.
    pub fn slashable_balance_of(stash: &T::AccountId) -> BalanceOf<T> {
        // Weight note: consider making the stake accessible through stash.
        Self::bonded(stash).and_then(Self::ledger).map(|l| l.active).unwrap_or_default()
    }

    /// internal impl of [`slashable_balance_of`] that returns [`VoteWeight`].
    fn slashable_balance_of_vote_weight(stash: &T::AccountId) -> VoteWeight {
        <T::CurrencyToVote as Convert<BalanceOf<T>, VoteWeight>>::convert(
            Self::slashable_balance_of(stash)
        )
    }
```

Event & Error

- Events are Events that are returned in executing extrinsics

```
decl_event!(
    pub enum Event<T> where Balance = BalanceOf<T>, <T as frame_system::Trait>::AccountId {
        /// The era payout has been set; the first balance is the validator-payout; the second is
        /// the remainder from the maximum amount of reward.
        /// \[era_index, validator_payout, remainder\]
        EraPayout(EraIndex, Balance, Balance),
        /// The staker has been rewarded by this amount. \[stash, amount\]
        Reward(AccountId, Balance),
        /// One validator (and its nominators) has been slashed by the given amount.
        /// \[validator, amount\]
        Slash(AccountId, Balance),
        /// An old slashing report from a prior era was discarded because it could
        /// not be processed. \[session_index\]
        OldSlashingReportDiscarded(SessionIndex),
        /// A new set of stakers was elected with the given \[compute\].
        StakingElection(ElectionCompute),
        /// A new solution for the upcoming election has been stored. \[compute\]
        SolutionStored(ElectionCompute),
        /// An account has bonded this amount. \[stash, amount\]
        ///
        /// NOTE: This event is only emitted when funds are bonded via a dispatchable. Notably,
        /// it will not be emitted for staking rewards when they are added to stake.
        Bonded(AccountId, Balance),
        /// An account has unbonded this amount. \[stash, amount\]
        Unbonded(AccountId, Balance),
        /// An account has called `withdraw_unbonded` and removed unbonding chunks worth `Balance`
        /// from the unlocking queue. \[stash, amount\]
        Withdrawn(AccountId, Balance),
    }
);
```

- Errors are the Error type to describe errors without generic string

```
decl_error! {
    /// Error for the staking module.
    pub enum Error for Module<T: Trait> {
        /// Not a controller account.
        NotController,
        /// Not a stash account.
        NotStash,
        /// Stash is already bonded.
        AlreadyBonded,
        /// Controller is already paired.
        AlreadyPaired,
        /// Targets cannot be empty.
        EmptyTargets,
        /// Duplicate index.
        DuplicateIndex,
```

Dependency Injection Trait

- Used to reduce ambiguation on module's trait due to Rust's trait inheritance
- Declare public trait from inside the module or aggregated support package
- implement the trait in a module and set dependency as the implemented module in others

```rust
/// A currency whose accounts can have liquidity restrictions.
pub trait LockableCurrency<AccountId>: Currency<AccountId> {
    /// The quantity used to denote time; usually just a `BlockNumber`.
    type Moment;

    /// The maximum number of locks a user should have on their account.
    type MaxLocks: Get<u32>;

    /// Create a new balance lock on account `who`.
    ///
    /// If the new lock is valid (i.e. not already expired), it will push the struct to
    /// the `Locks` vec in storage. Note that you can lock more funds than a user has.
    ///
    /// If the lock `id` already exists, this will update it.
    fn set_lock(
        id: LockIdentifier,
        who: &AccountId,
        amount: Self::Balance,
        reasons: WithdrawReasons,
    );

    /// Changes a balance lock (selected by `id`) so that it becomes less liquid in all
    /// parameters or creates a new one if it does not exist.
    ///
    /// Calling `extend_lock` on an existing lock `id` differs from `set_lock` in that it
    /// applies the most severe constraints of the two, while `set_lock` replaces the lock
    /// with the new parameters. As in, `extend_lock` will set:
    /// - maximum `amount`
    /// - bitwise mask of all `reasons`
```

```rust
impl<T: Config<I>, I: 'static> LockableCurrency<T::AccountId> for Pallet<T, I>
where
    T::Balance: MaybeSerializeDeserialize + Debug
{
    type Moment = T::BlockNumber;

    type MaxLocks = T::MaxLocks;

    // Set a lock on the balance of `who`.
    // Is a no-op if lock amount is zero or `reasons` `is_none()`.
    fn set_lock(
        id: LockIdentifier,
        who: &T::AccountId,
        amount: T::Balance,
        reasons: WithdrawReasons,
    ) {
```

```rust
impl pallet_staking::Config for Runtime {
    type Currency = Balances;
    type UnixTime = Timestamp;
    type CurrencyToVote = U128CurrencyToVote;
    type RewardRemainder = Treasury;
    type Event = Event;
    type Slash = Treasury; // send the slashed funds to the treasury.
    type Reward = (); // rewards are minted from the void
    type SessionsPerEra = SessionsPerEra;
    type BondingDuration = BondingDuration;
    type SlashDeferDuration = SlashDeferDuration;
    /// A super-majority of the council can cancel the slash.
    type SlashCancelOrigin = EnsureOneOf<
        AccountId,
        EnsureRoot<AccountId>,
        pallet_collective::EnsureProportionAtLeast< 3,  4,  AccountId,  CouncilCollective>
```

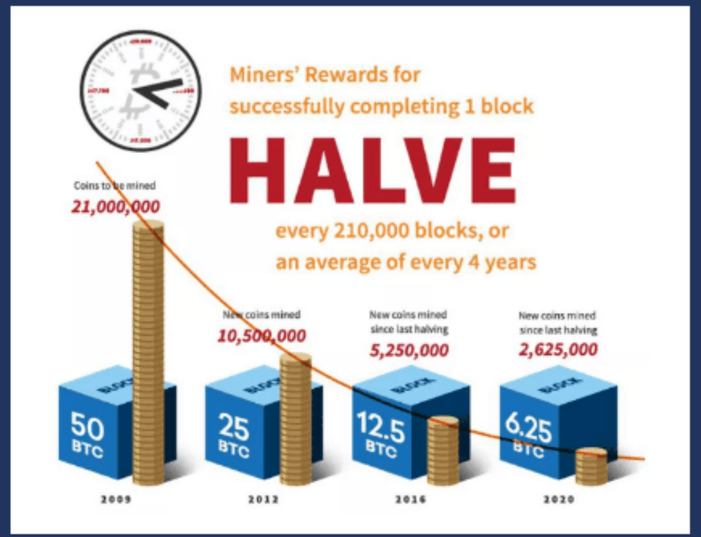
```rust
pub trait Config: frame_system::Config + SendTransactionTypes<Call<Self>> {
    /// The staking balance.
    type Currency: LockableCurrency<Self::AccountId, Moment = Self::BlockNumber>;
```

Possible Mutations

What new chains can come out with this?

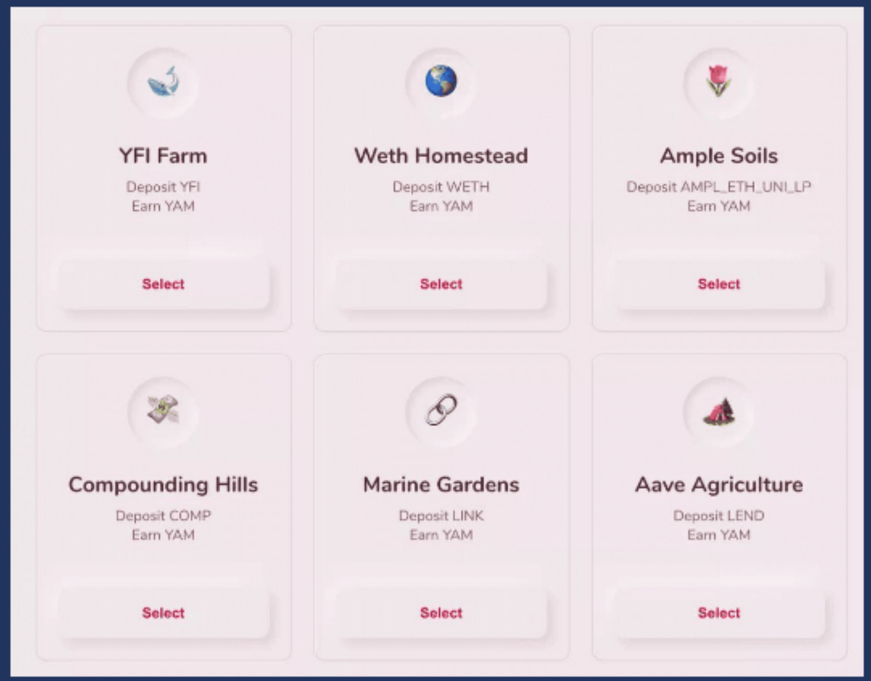
New inflation logic

- Inside inflation.rs file, there is a logic which manages the total reward minted in and each era.
- Make it like Bitcoin where blockchain does not make total reward when the total supply exceeds a certain number and record only imbalances for the total reward
- Let inflation governed by democracy(Something that FED cannnot do)



Add new way to use block rewards

- Turns out the block reward can be split
- Reward is given to dapps in plasm's case
- Try to come up with your own slashing/reward logic in each era



Staking module sets

What other modules are needed to report?

Reporting modules

- Babe: Equivocation report for BABE
- Grandpa: Equivocation report for Grandpa
- ImOnline: Validator reporting that it is online in each era

Tracking modules

- Authorship: Records author in each block
- Offences: Module for recording generic offence cases in a blockchain for evidence
- AuthorityDiscovery: Retrieve current authority set for generating a block
- Session: manages session key for validator node and checks if a session has passed

Treasury Module

- Treasury: Collects slashed balances here and use it for good
- Collective: Council management module
- Elections: Gateway for becoming a council to manage treasury and cancel slashing

Node Configuration

Here comes the hardest part

You need to change

- Your runtime dependancies
- Your node api dependancies and logics in service.rs and api.rs
- Probably your workspaces


Codes to look at:
paritytech/substrate's api and runtime lib.rs file
or here with substrate node template

Let's draw!

- Get 30 mins to imagine your token economics
- Share each other on how you are going to implement it
- Show your code in discord when you make it, no pressure

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