Streamlet: Textbook Streamlined Blockchains

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Joint work with Elaine Shi

cbr.stanford.edu/sbc20/
“Simplifying Consensus”

Benjamin Chan
Cornell University

Joint work with Elaine Shi
1. Modeling consensus  (5min)
2. Motivating simplicity as a goal  (a few seconds)
3. Our protocol  (20min)
1. Modeling consensus (5min)
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Goal: walk away
1. Modeling consensus (5min)
2. Motivating simplicity as a goal (a few seconds)
3. Our protocol (20min)

Goal: walk away and understand a consensus protocol
What is consensus?
What is consensus? Modeling Blockchain
Modeling Blockchain
Modeling Blockchain

- Some known set of users
  - “permissioned”
Modeling Blockchain

Why the permissioned setting?
Modeling Blockchain

Why the permissioned setting?

Answer: Proof-of-Stake
Modeling Blockchain

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Different setting than PoW!!
Modeling Blockchain

Why the permissioned setting?

Answer: Proof-of-Stake

Different setting than PoW!! (true finality, speed, partition-resistant)
Modeling Blockchain

- Some *known* set of users
  - “permissioned”
Modeling Blockchain

- Some *known* set of users
  - “permissioned”
- Each user maintains ordered chain of blocks
Modeling Blockchain

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Modeling Blockchain

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- **Consistency**: Everyone sees a prefix of the same chain!
Modeling Blockchain

- Some known set of users
  - “permissioned”
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- Consistency
- Liveness
Modeling Blockchain

- Some *known* set of users
  - “permissioned”
- Each user maintains ordered chain of blocks

- **Consistency**
- **Liveness:** must be able to confirm new blocks
Introducing adversaries
Introducing adversaries

- Malicious users
Introducing adversaries

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- Messages may be lost, delayed, reordered
Introducing adversaries

- Malicious users
- Messages may be lost, delayed, reordered
This problem is notoriously hard!
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- Paxos (‘70s)
- PBFT (‘99)
- Raft (2014)
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- Blockchains (2016+)
  - Dfinity
  - Casper
  - Algorand
  - Hotstuff
  - Pala
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- Blockchains (2016+) - New “streamlined” paradigms...
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  New “streamlined” paradigms...

  ...but can we eliminate the subtleties?
Motivating Simpler Consensus Protocols
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- Simpler Implementation
Motivating Simpler Consensus Protocols

- Simpler Implementation
- Fewer Bugs
Motivating Simpler Consensus Protocols

- Simpler Implementation
- Fewer Bugs
- Lower onboarding cost
- Better Open Source
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Motivating Simple Consensus Protocols

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Our Work: Streamlet
Our Work: Streamlet

Goal:
A “Simplest Possible”,
Easy-to-Understand,
Textbook Consensus Protocol
Our Work: Streamlet

**Goal:**
A “Simplest Possible”, Easy-to-Understand, Textbook Consensus Protocol (Blockchain)
Our Work: Streamlet

Two Assumptions:

1. **Epochs**
   Processes have local clocks, and run in synchronized* epochs of 1 sec each.
Our Work: Streamlet

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2. **Elect a leader in each epoch, known by all**
Two Assumptions:

1. **Epochs**
   Processes have local clocks, and run in synchronized* epochs of 1 sec each.

2. **Elect a leader in each epoch, known by all**
   i.e. randomly chosen, given epoch $e$
   $L_e = H(e) \mod n$
Assumptions:
- (Synchronized*)
  epochs of length 1 sec
- Each epoch
  has random leader
Definitions

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Definitions

- Block $b = (H(b'), e, txs)$

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pointer to parent block
Definitions

- Block $b = (H(b'), e, txs)$

Assumptions:
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Epoch number in which block was ‘proposed’
Definitions

- Block $b = (H(b'), e, txs)$

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Definitions

- Block \( b = (H(b'), e, \text{txs}) \)
- Notarized block

Assumptions:
- (Synchronized*) epochs of length 1 sec
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Definitions

- Block $b = (H(b'), e, txs)$
- Notarized block
  - A block ‘signed’ by $\frac{2}{3}$ distinct processes

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Definitions

- Block \( b = (H(b'), e, txs) \)
- Notarized block
  - A block ‘signed’ by \( \frac{2}{3} \) distinct processes
    (implies a majority of honest processes have signed it)

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Definitions

- Block  $b = (H(b'), e, \text{txs})$
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  - A block ‘signed’ by $\frac{2}{3}$ distinct processes
- Notarized blockchain

Assumptions:
- (Synchronized*) epochs of length 1 sec
- Each epoch has random leader

epoch 7 -> epoch 8 -> epoch 10 -> epoch 12 -> ...
Definitions

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- Notarized block
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- Block “height” ≠ epoch #

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Assumptions:
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Definitions:
- Block $b = (H(b'), e, txs)$
- Notarized block: signed by 2/3 processes

Assumptions:
- (Synchronized*)
  epochs of length 1 sec
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The Streamlet Protocol

**Definitions:**
- Block $b = (H(b'), e, txs)$
- Notarized block: signed by $2/3$ processes

**Assumptions:**
- (Synchronized*) epochs of length 1 sec
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The Streamlet Protocol

In every epoch $e = 1, 2, \ldots$

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In every epoch \( e = 1, 2, \ldots \)

- **leader**, creates a new block \( b = (H(b'), e, \text{txs}) \)
  extending longest notarized chain they’ve seen so far

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- Block \( b = (H(b'), e, \text{txs}) \)
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The Streamlet Protocol

In every epoch  $e = 1, 2, \ldots$

- **leader**,  
  creates a new block $b = (H(b'), e, \text{txs})$  
  extending longest notarized chain they’ve seen so far

- **voters**,  
  signs first proposal $b$ (from leader, for $e$)  
  i.f.f. $b$ extends a longest notarized chain seen so far (by voter)

**Assumptions:**
- (Synchronized*)  
  epochs of length 1 sec  
  Each epoch  
  has random leader

**Definitions:**
- Block $b = (H(b'), e, \text{txs})$  
- Notarized block: signed by 2/3 processes
The Streamlet Protocol

**finalization rule:**

- **Definitions:**
  - Block \( b = (H(b'), e, txs) \)
  - Notarized block: signed by 2/3 processes

- **Assumptions:**
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The Streamlet Protocol

**finalization rule:**
take any notarized chain that ends in 3 consecutive epochs;

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**Definitions:**
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The Streamlet Protocol

**finalization rule:**
take any notarized chain that ends in 3 consecutive epochs; chop off the last block, and finalize

---

**Assumptions:**
- (Synchronized*) epochs of length 1 sec
- Each epoch has random leader

**Definitions:**
- Block $b = (H(b'), e, txs)$
- Notarized block: signed by 2/3 processes
Example

In every epoch $e = 1, 2, \ldots$
- **leader** proposes $b = (H(b'), e, \text{txs})$ extending longest notarized chain they've seen
- **voters** sign the first valid proposal $b$, but i.f.f. $b$ also extends a longest notarized chain the **voter** has seen (notarized=2/3 votes)

**finalize** any notarized chain ending with 3 consecutive epochs, chopping off last block
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- **leader** proposes \( b = (H(b'), e, \text{txs}) \) extending longest notarized chain they've seen.
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Example (3 honest, 1 malicious)

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**Example**

```
epoch 2
epoch 8
```
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Analysis

**Consistency:** no synchrony assumptions, $f < n/3$

In every epoch $e = 1, 2, \ldots$
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**Liveness**: synchrony assumptions, expected $O(1)$ rounds!

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**Liveness:** synchrony assumptions, expected \( O(1) \) rounds!

(optimizable)

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**finalize** any notarized chain ending with 3 consecutive epochs, chopping off last block

Allows two notarized blocks at the same height!
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Consistency Sketch

Cannot both be notarized!!
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- Each honest process votes only once for each epoch.
- Each notarized block requires $2n/3$ distinct votes.
- Multiple notarized blocks within epoch = $4n/3$ votes.
- Letting $f < n/3$, we have (at best) $2n/3 + 2f < 4n/3$ votes to go around.
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Now, the main lemma...
Consistency Sketch

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Case X < 5:

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4 processes, 3 honest, 1 malicious
Require 3 votes to notarize
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voters sign the first valid proposal b, but i.f.f. b also extends a longest notarized chain the voter has seen
**Consistency Sketch**

- **Lemma 2:** No other notarized block, in past or future, can share the same height as block 6

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Consistency Sketch

epoch 1 ➔ epoch 2
epoch 3 ➔ epoch 5 ➔ epoch 6 ➔ epoch 7 ➔ epoch X
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Intuition: Can’t rewrite history
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Intuition: Can’t rewrite history

(can add a new notarized block at the same height as an existing notarized block, but never in the past)
Consistency Sketch

Lemma 1: Each epoch is associated with at most one notarized block.

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No synchrony assumptions!
Can’t rewrite history
2. One block per epoch
3. Demonstrate sudden chain growth
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   = chain provably longer than competitors
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2. One block per epoch
3. Demonstrate sudden chain growth (why 3?)
   = chain provably longer than competitors
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**Finalize** any notarized chain ending with 3 consecutive epochs, chopping off last block.
We need many good leaders in a row
Liveness?

We need many good leaders in a row

- Random leaders: get lucky
- Stable leader mechanism
- Not bad!
Recap

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**Goal**: “Simplest-Possible”, Drop-in replacement for PBFT
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**Result**: Consensus with a single message type, minimal subtlety
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**Goal**: “Simplest-Possible”, Drop-in replacement for PBFT

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  - **Consistency**: \( f < n/3 \), no synchrony assumptions!
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**Result**: Consensus with a single message type, minimal subtlety

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- **Liveness**: when network is reliable (GST model)
Recap

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**Goal**: “Simplest-Possible”, Drop-in replacement for PBFT  
**Result**: Consensus with a single message type, minimal subtlety  
- **Consistency**: $f < n/3$, no synchrony assumptions!  
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**Eprint**: ia.cr/2020/088
Questions?

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