# Principals and Practice of Cryptocurrencies

Cornell CS 5437, Spring 2016

**Project**

# Project of Your Choice

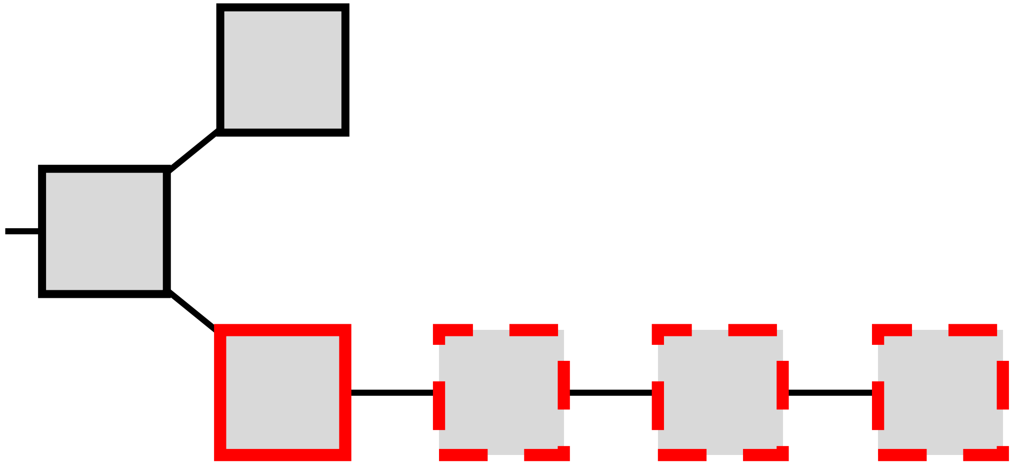
- Simulate
  - Study the behavior of protocols
- Experiment
  - Measure properties of implementations
- Build
  - Add features to existing clients

# Example:
# Advanced Selfish Mining Simulation

# Selfish Mining

Goal: Get more than fair share

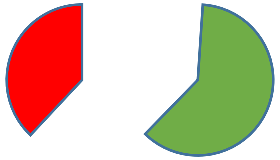
How: Maintain secret blocks, publish judiciously



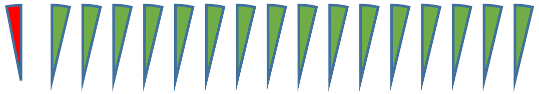
Intuition: Risk some work, others waste a lot

# Known Results

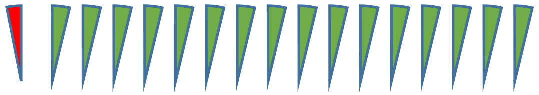
- Selfish miner vs. single miner: threshold at 1/3



- Selfish miner vs. many small not well connected miners: threshold at 0



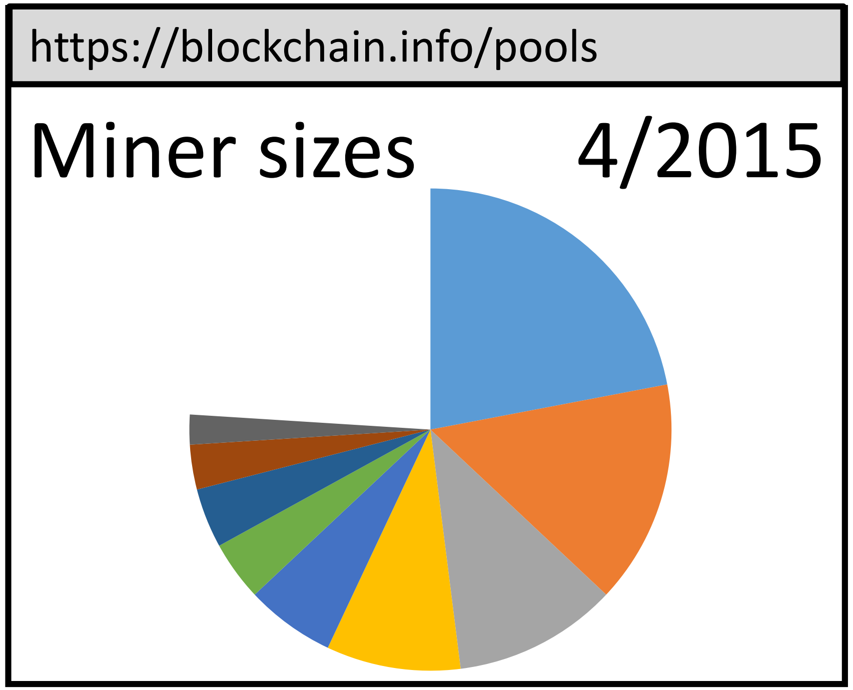
- Selfish miner vs. many small miners with fix: threshold at 1/4



**What about other distributions of honest miner sizes?**

# Project Goal

Study selfish mining with various miner size distributions



https://blockchain.info/pools

Miner sizes 4/2015

# Project Parts

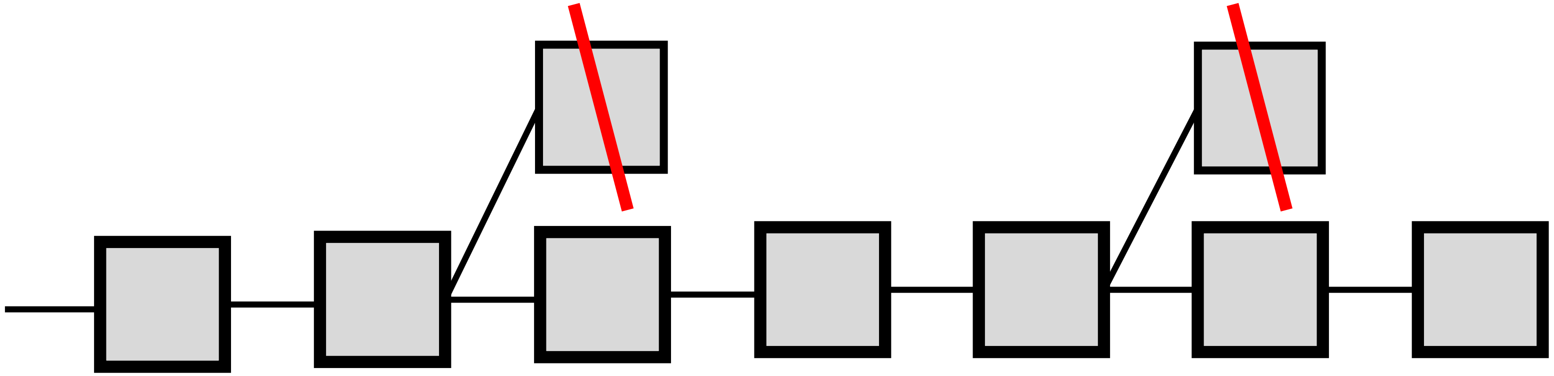
- Understand the attack and known bounds
    - Read paper, reproduce math
- Formal analysis
    - Make approximations for new model
    - Analyze attack under new model
    - Instantiate results for different cases
    - Confirm edge cases with known results
- Simulation
    - Obtain pool sizes from measurements
    - Choose approximations
    - Design simulation
    - Confirm edge cases with known results
    - Confirm formal analysis

# Example:
# Propagate Pruned Blocks

# Background

- Main chain is longest one
- Off-chain blocks are pruned
- They are not propagated
    - Both in theory and in the standard Bitcoin implementation, Bitcoin Core.

- Important data is lost –
  for system security and fairness analysis



# Project Goal

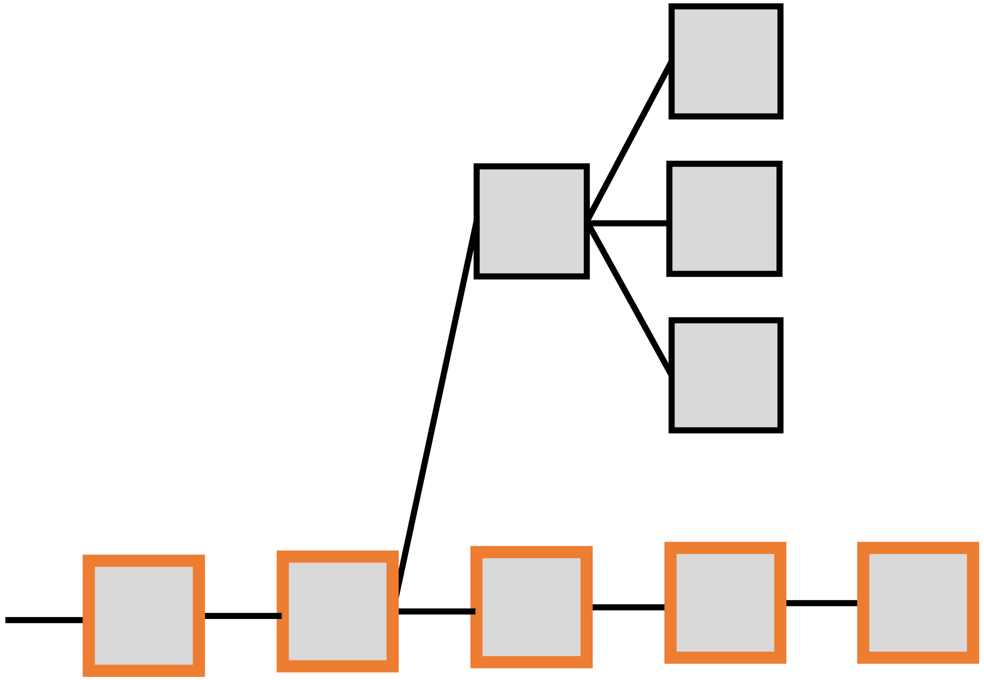
Implement pruned blocks propagation as a patch to the standard Bitcoin client

# Project Parts

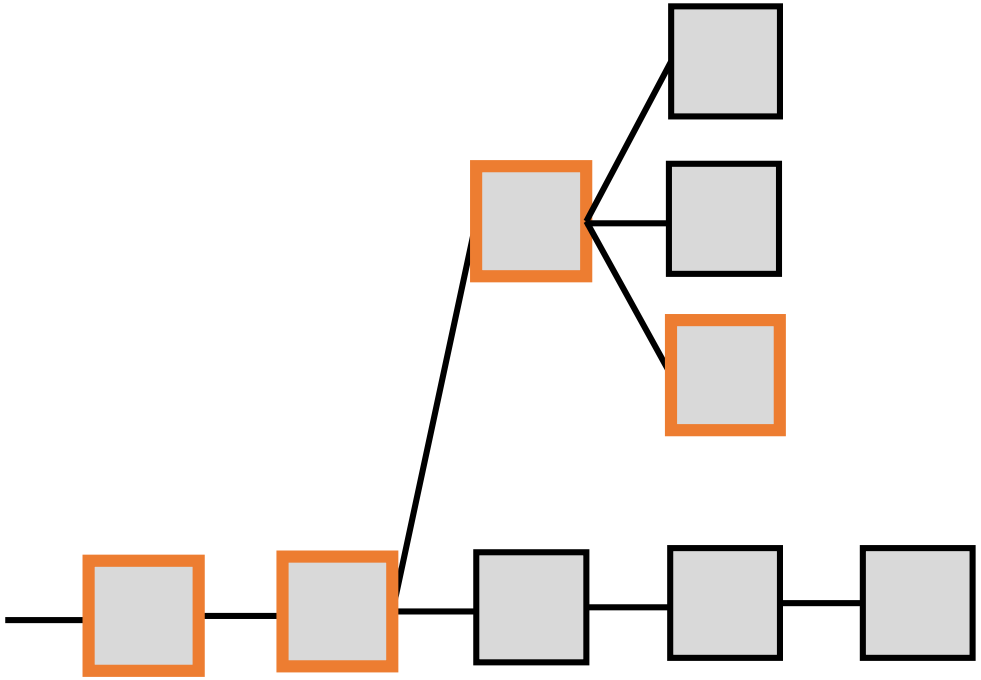
- Understand current system behavior
  - Relevant data structures and their update
  - Communication protocol
- Implement changes
  - Change data structures
  - Change communication protocol
    - In a backward-compatible way
- QA
  - Extensive regression testing
  - Implications on security (mostly DoS)
  - Implications on performance

# Example:
# Simulate Protocols

# Blockchain Protocols

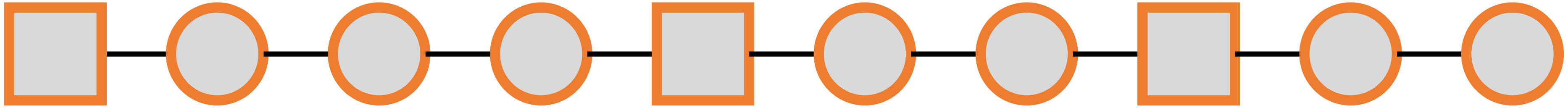


Bitcoin – longest chain



GHOST – heaviest tree

Bitcoin-NG – longest chain, different block types



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# Project Goal

Simulate various protocols and compare their properties

# Project Parts

- Study protocols and understand design choices
  - Bitcoin
  - GHOST
  - Bitcoin-NG
- Simulate
  - Make approximations
  - Construct **modular** simulation environment
  - Implement the protocols and measure
  - Confirm edge cases with known results

# Example: Client Profiling

# Background

- A cryptocurrency client has many tasks
    - Send and receive state
    - Verify state
        - Transaction signatures are correct
        - Data structure correctness (e.g. block PoW)
    - Store state for crash tolerance

- Client speed is critical to system behavior
    - Limits bandwidth (transactions per second)
    - Limits propagation speed
        - Implications to security
        - Implications to performance

# Project Goal

Evaluate client bottlenecks

# Project Parts

- Locate potential bottlenecks
    - Storage
    - Communication
    - Processing
- Create experiment environment
    - Instrument code to measure
    - Create workloads (synthetic / real)
- Measure
    - Run experiments
    - Analyze results
    - Estimate speedup by replacing bottlenecks with artificial delays

# Example:
# Network Structure Simulation

# Background

- Bitcoin uses a unique network topology construction
  - Gossip-based
  - Unstructured
  - Robust
- Best specification (I'm aware of) in Heilman et al.'s *Eclipse Attacks on Bitcoin's Peer-to-Peer Network*.

# Project Goal

Study Bitcoin’s network topology

# Project Parts

- Understand the protocol
    - Standard operation
    - Edge cases (e.g., DNS bootstrapping)
    - Dynamics
- Simulate
    - Decide on approximations
    - Implement simulator and protocol
    - Study behavior in various scenarios
        - Network sizes
        - Latencies
        - Under attack

# Other Examples

- Add a transaction script operation
  - Analyze security implications
  - Implement
  - Implement use cases
  - Add regression tests
- Change a cryptocurrency’s chain selection rule
- Tune cryptocurrency’s parameters (e.g., block size, frequency)

# Logistics

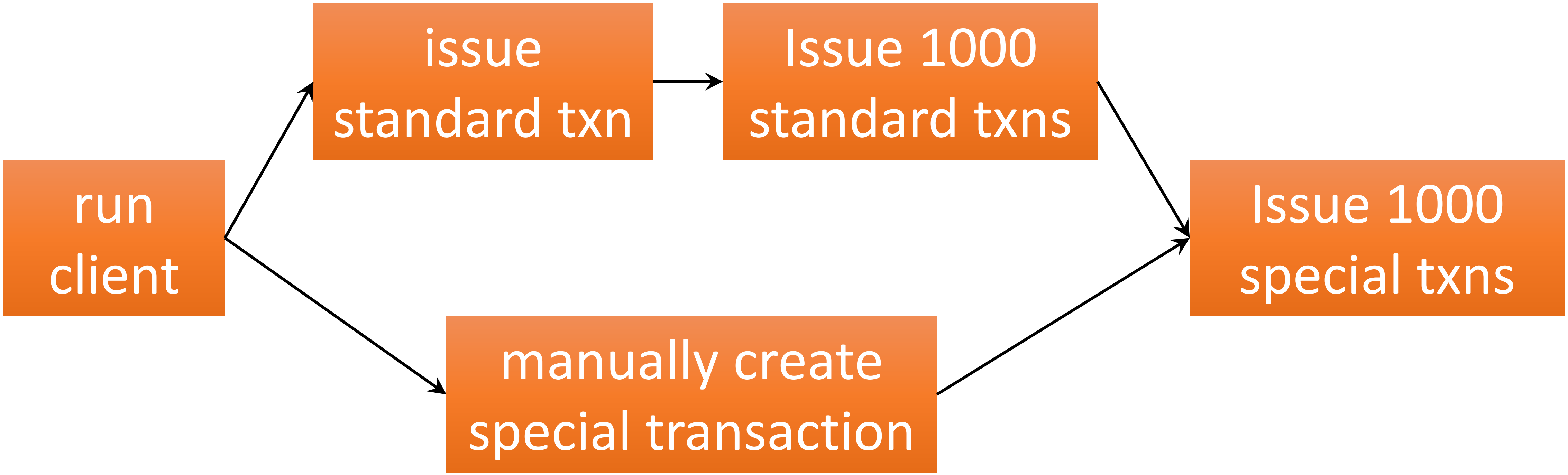
# Plan

- Teams of 4 (four, explicit permission in advance otherwise)
- Different leader per phase: coordinates and reports
- Delivery: 15min meeting, lead by leader, choose time in advance, all should be ready to answer questions

| Phase end | Task | Deliverable |
|---|---|---|
| Feb 8-12 | Make plan | Topic, architecture, mission assignment, timed plan |
| Phase 2 | Check point | Results, plan updates |
| Phase 3 | Check point | Results, plan updates |
| May 9-11 | Report | Report + meeting + class presentation |

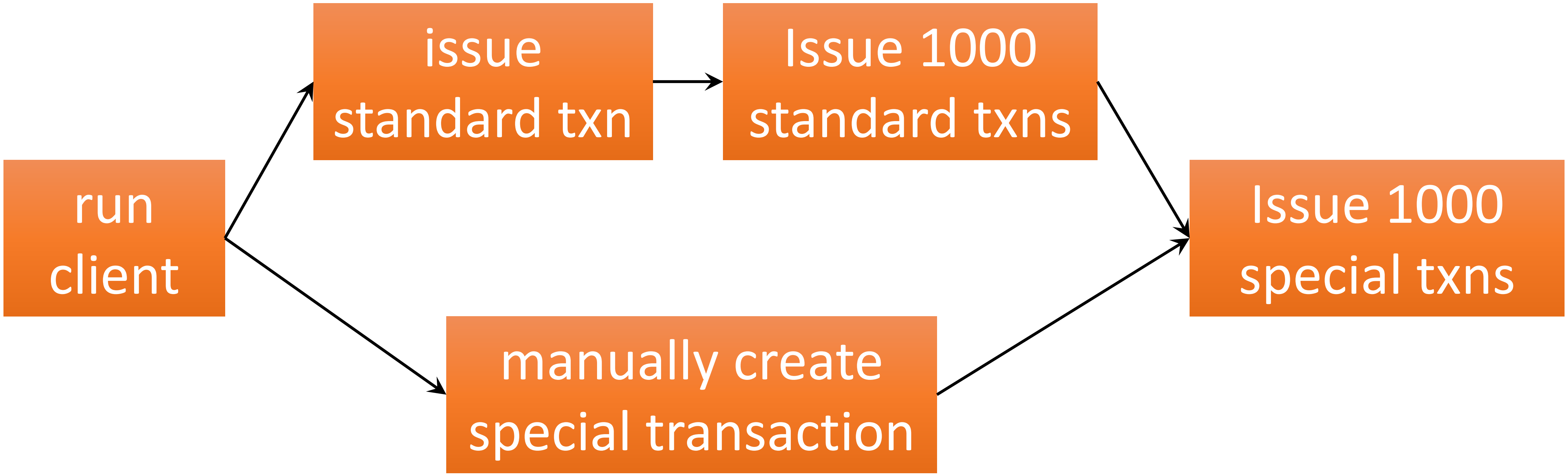
# Make Plan

- Topic choice: confirm with me in advance by email
- Architecture: high-level but concrete design
- Timed plan:
    - **Flow diagram** of tasks **with nice little deliverables**



# Mission Assignment

- Parallelize
- Assign tasks by preference/specialty



# Checkpoints

- Report on finished tasks
- Report on changes to plan (same level of detail)
  - Tasks that took longer than expected
  - New tasks you didn't foresee

# Final Report

- Paper report (1-2 pages, appendix if necessary)
  - Write it as you go
- Class presentation
  - 5-15 minutes, by phase leader
- Meeting
  - As in previous phases

# Logistics

- Be thorough with planning
  **A few days of programming can save you hours of planning**
  **Also – 50% of the project grade**
- Coordinate frequently and efficiently
- Help the phase leader
  - Respect intermediate deadlines
- **Use a distributed version control system** (e.g. Git, Mercurial)
- Choose the right tools.
  (matlab/excel, matlab/python, python/java…)
- Ask for help when unsure: email, office hours.

# Grade

- Total of 60%:
  - 50% planning
    - Decomposition to tasks
    - Work division and time planning
    - Group effort (talk to me)
    - Peer review
  - 50% result
    - Code quality (structure, documentation)
    - Result (efficiency, analysis)
    - Report
  - Factored per individual if necessary