Detecting failures in distributed systems with the FALCON spy network

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Presenter: Neal Mangaokar

Failure Detectors

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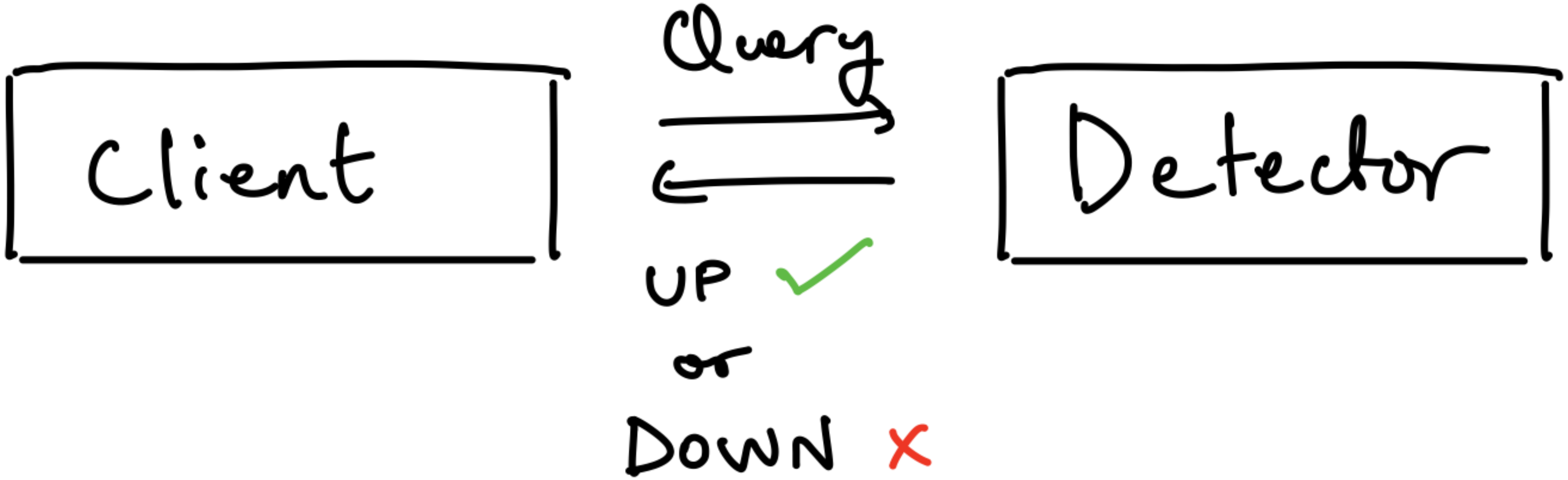

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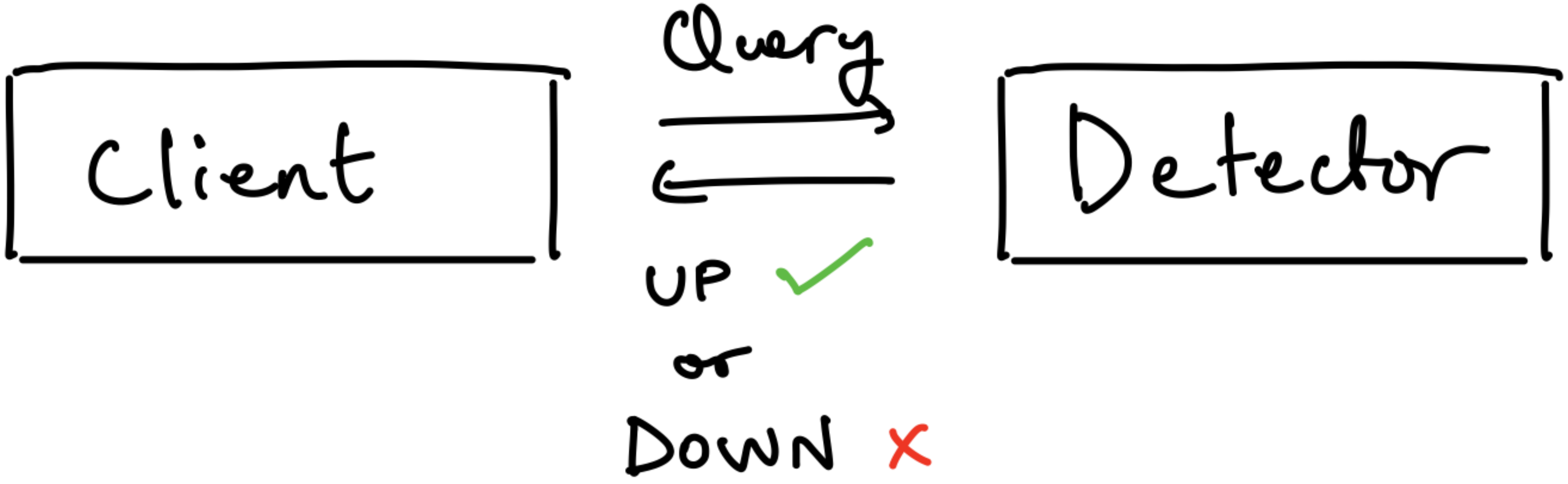

- Fundamental primitive in distributed applications

Reliable Failure Detectors (RFDs)

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RFD reports process is **DOWN** $\implies$ process crashed

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- **SAFETY (STRONG ACCURACY):**

RFD reports process is **DOWN** $\Longrightarrow$ process crashed

- **LIVENESS (STRONG COMPLETENESS):**

Process crashes $\Longrightarrow$ RFD eventually reports process is **DOWN**

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    - Can't differentiate between crashed process vs. slow network
- Consensus is reducible to RFD:
    - Consensus is impossible $\implies$ **RFD is impossible**

Solutions

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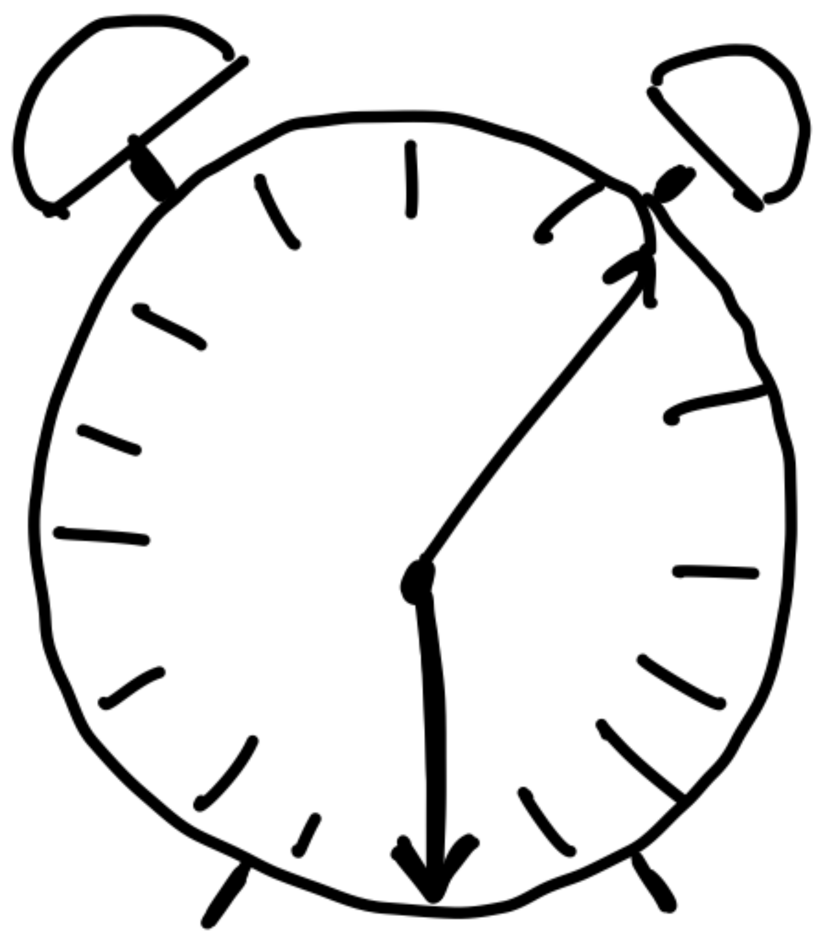
- Assume synchrony and use **end-to-end timeouts:**



Solutions

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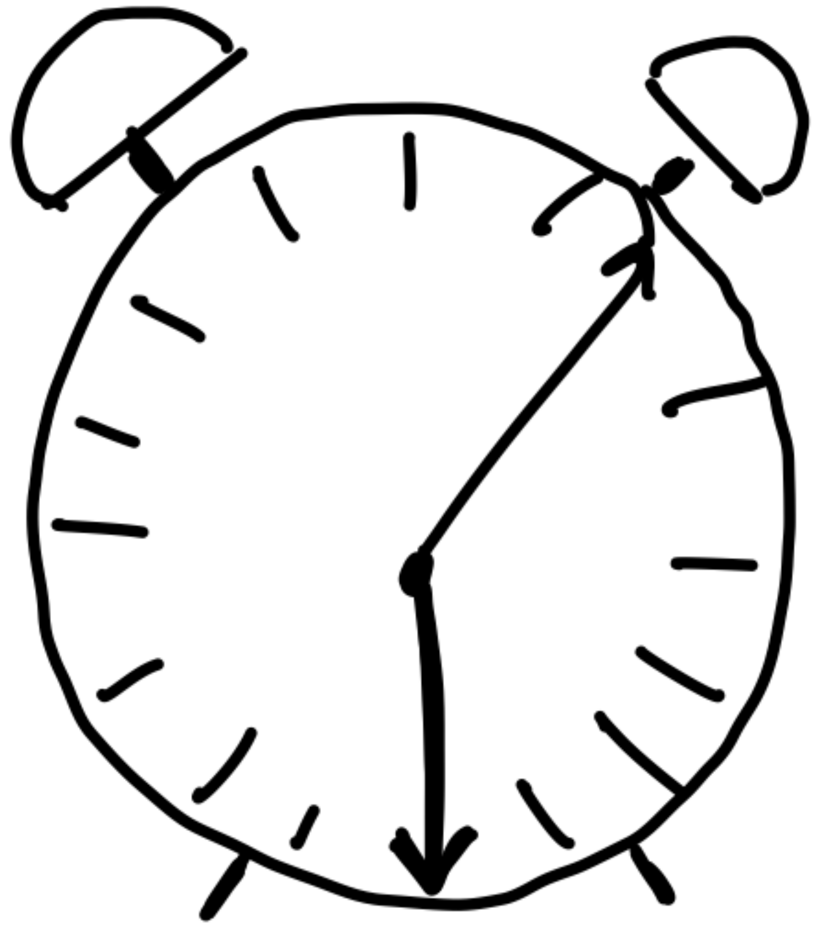

- **Problem:** doesn't extend very well to asynchrony:
    - Too short: might violate safety
    - Too long: might be overly slow zzz...

Solutions (cont.)

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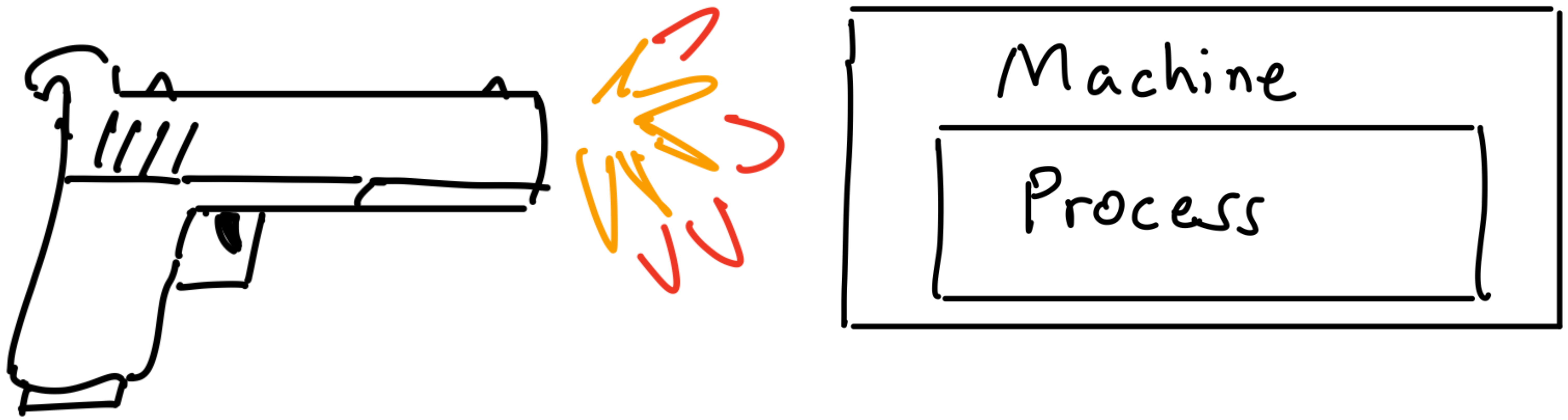

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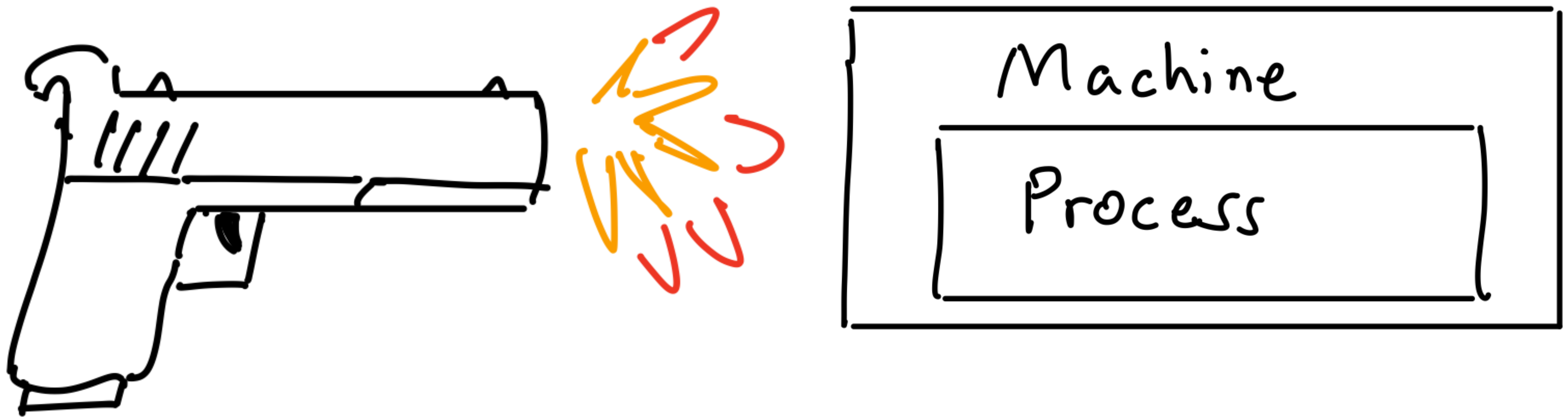

- **Problem:** disruptive (and sociopathic)

A Better Solution: FALCON

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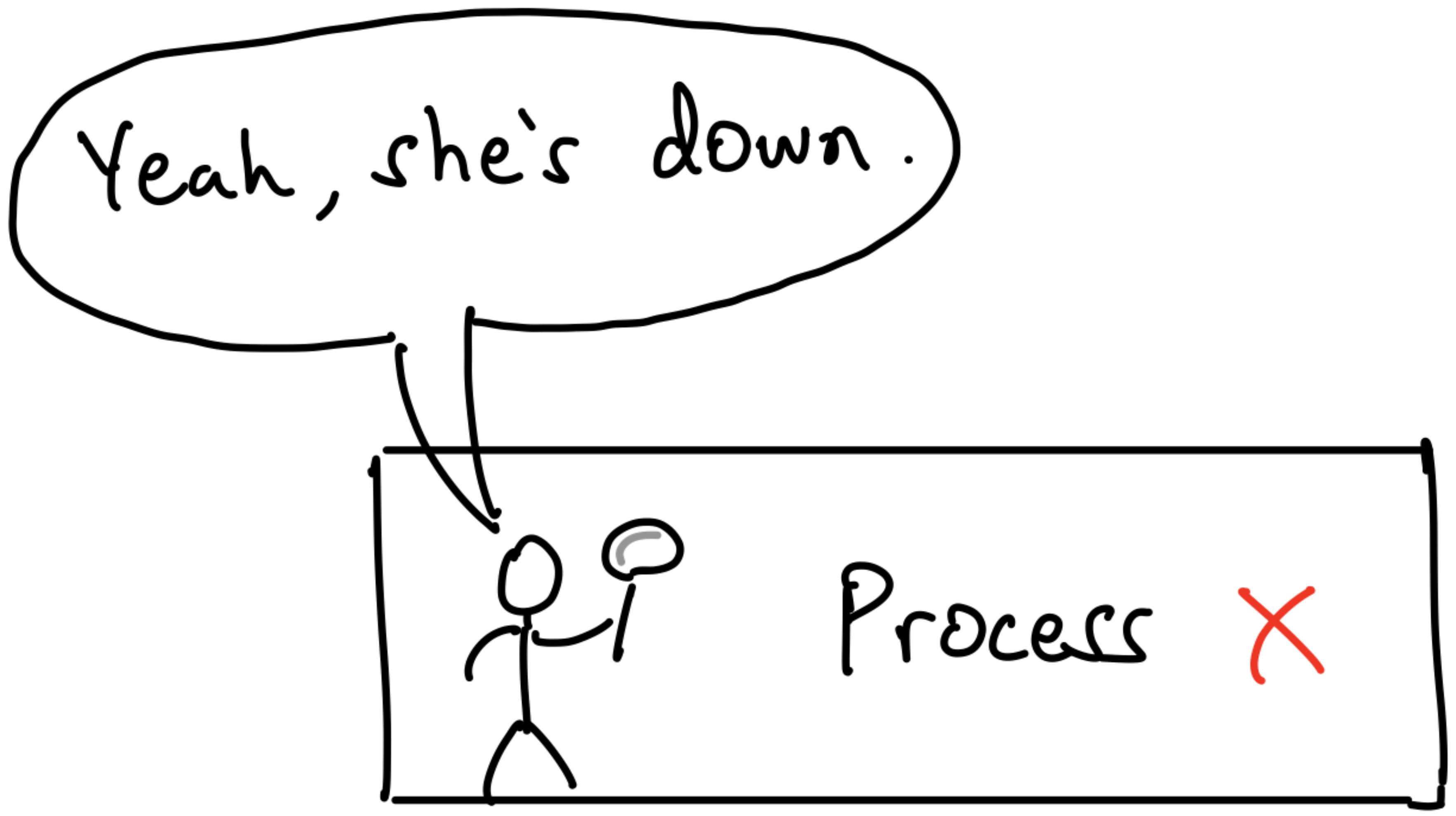
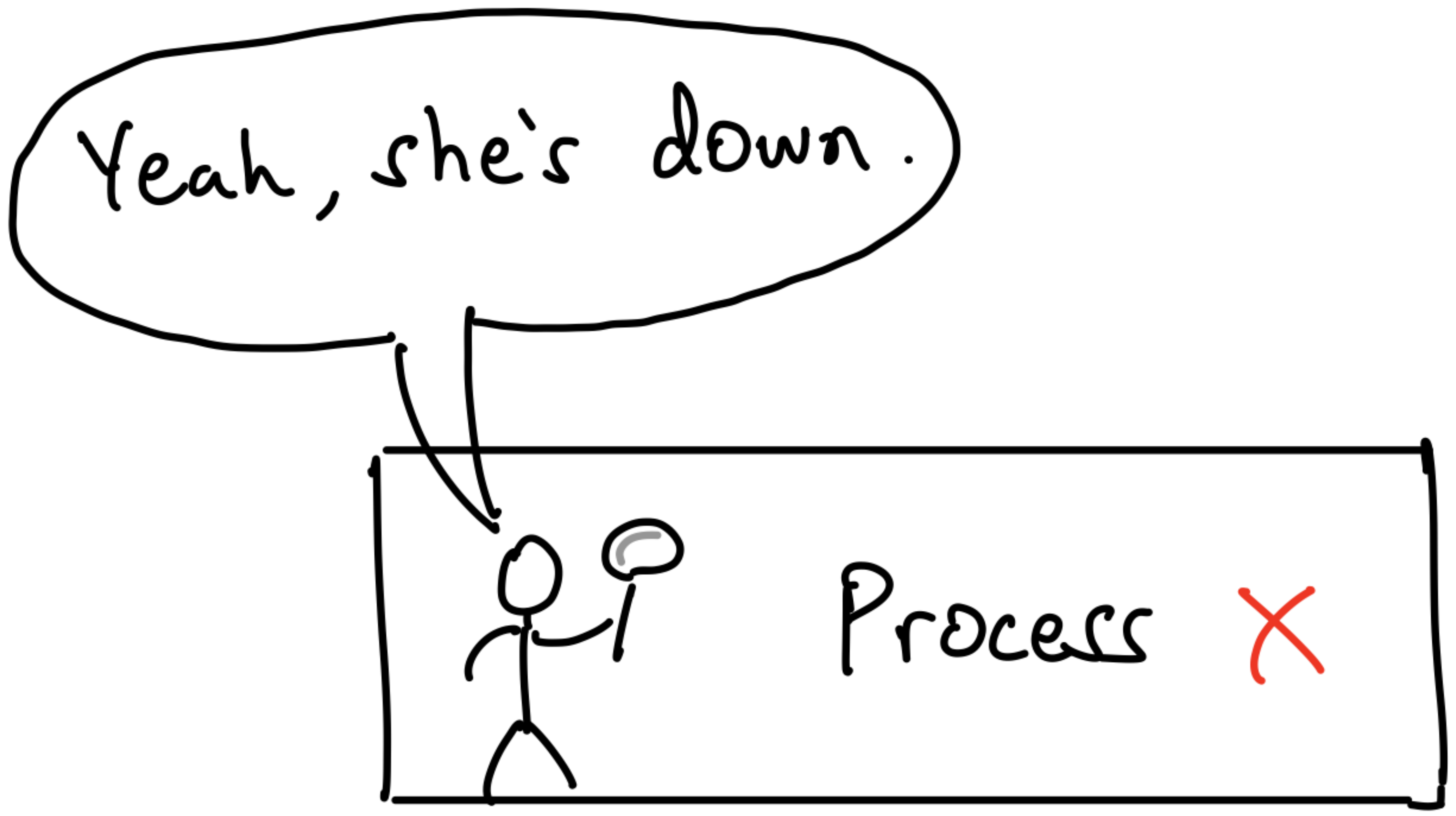
- **Detect** failures with insider information from process:
    - can make us almost always safe and fast



A Better Solution: FALCON

- **Detect** failures with insider information from process:
  - can make us almost always safe and fast
- **Fallback** onto suboptimal solutions as a failsafe:
  - Timeouts + killing ensures liveness and safety when “almost always” fails
- **Don’t worry** about extreme asynchrony:
  - Block!



Collecting Insider Information with Spies

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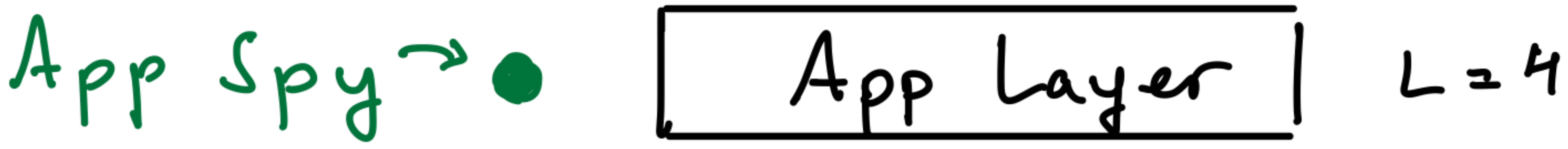
- Client can gather information using a spy:
    - Spy sits on remote machine and monitors "layer" L



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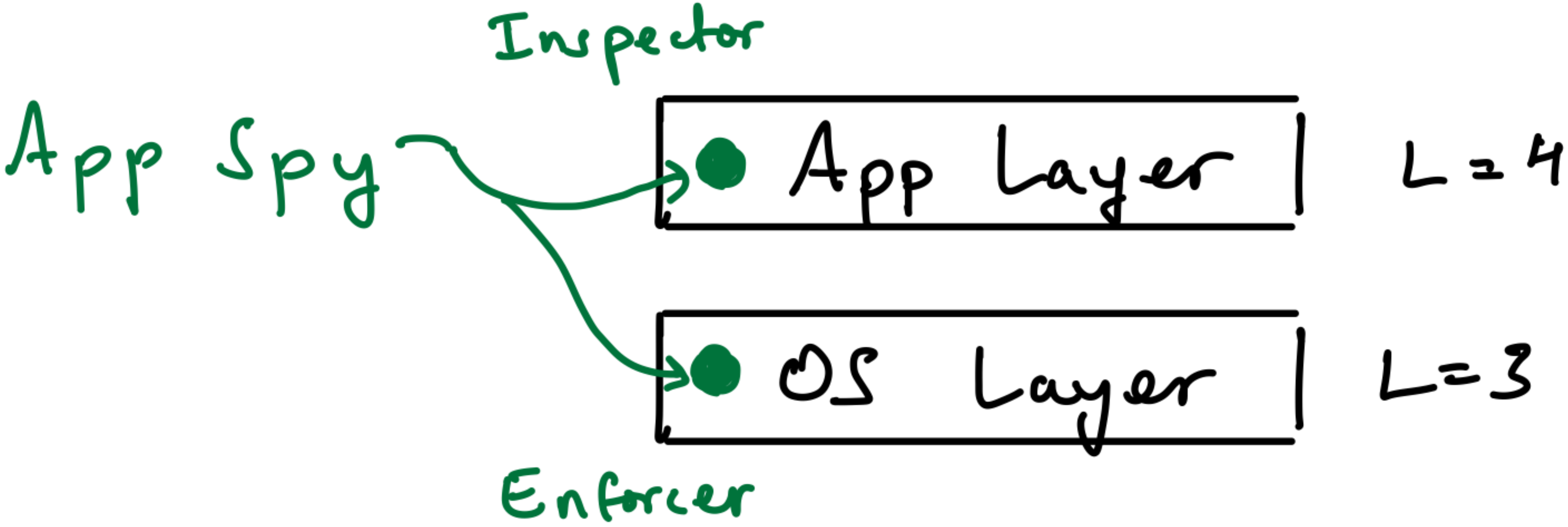

  - Spy monitors L, but occupies L and $L-1$ (inspector and enforcer)

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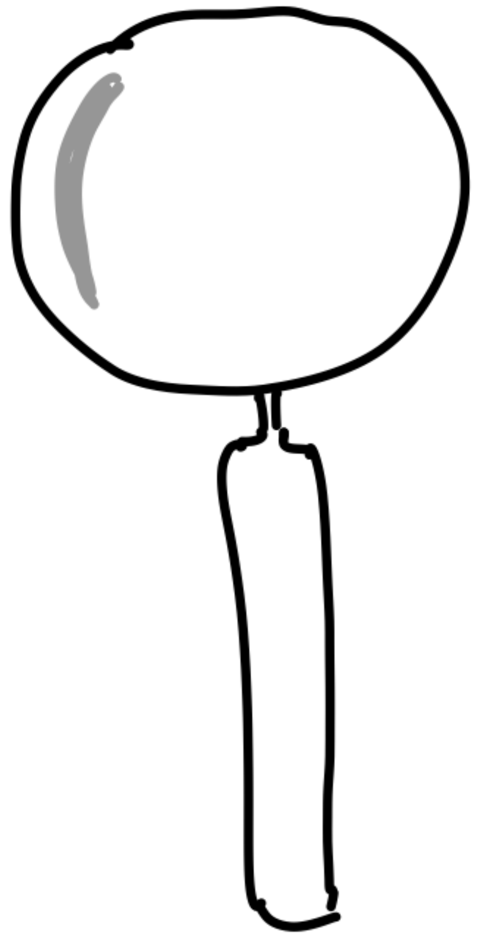
- Inspector:
    - Tries to infer operational status (alive, or not)



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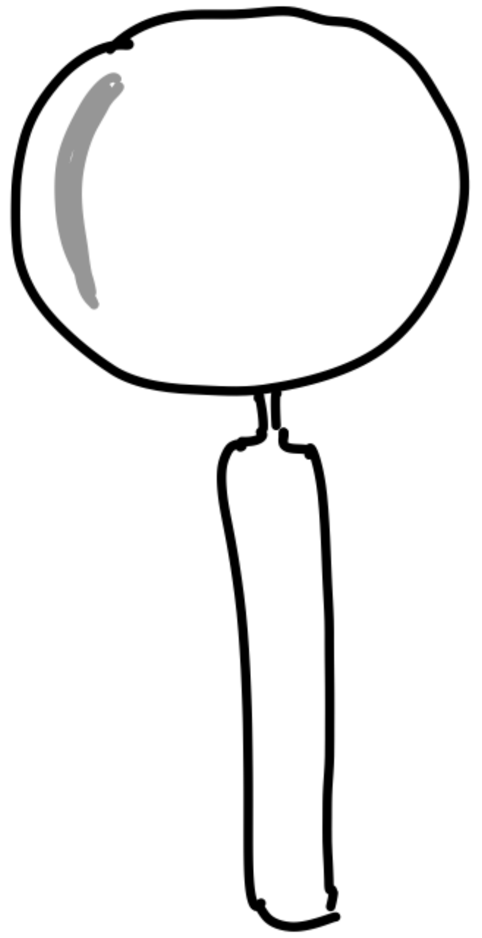

- Enforcer:
  - Tells client operational status
  - **LAYER_DOWN** or **LAYER_UP**

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- Inspector:
  - Is a thread inside the process
  - Looks for signs of life
- Enforcer:
  - Is its own process
  - Communicates with inspector via IPC to make quick decisions
  - Before reporting **LAYER_DOWN**, double-checks process table

Collecting More Information: A Spy Network

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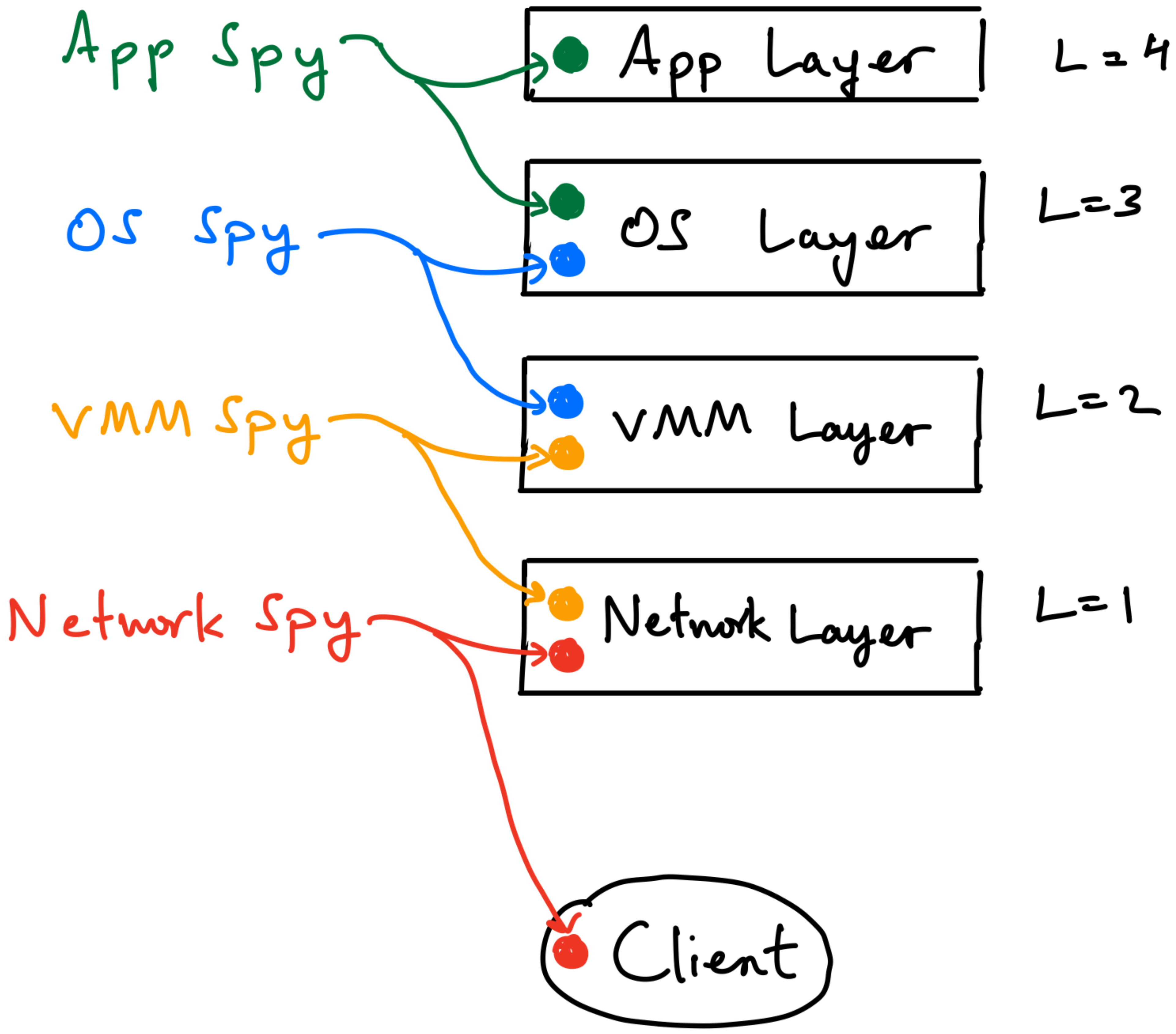
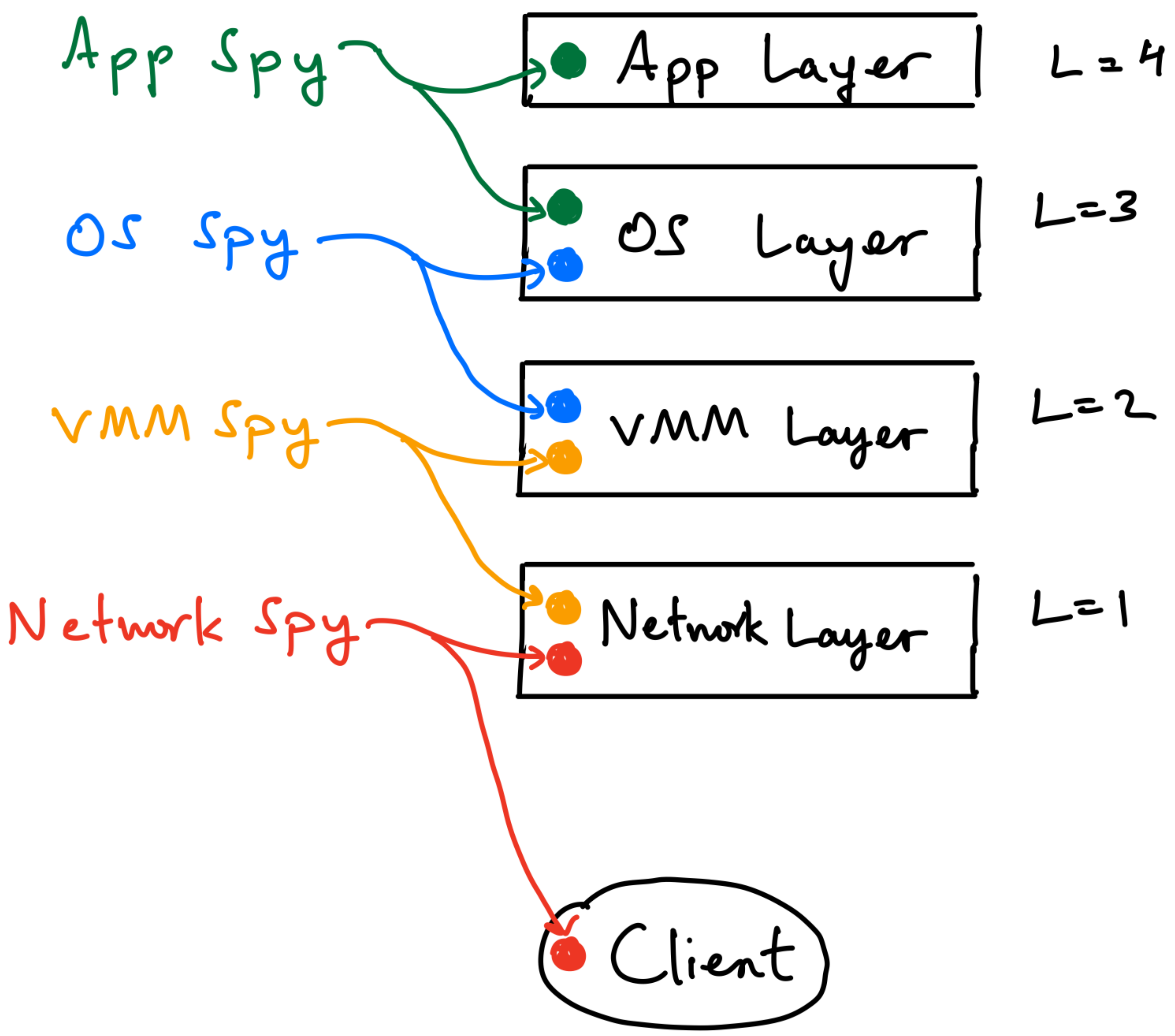
- One spy per layer



Collecting More Information: A Spy Network

- One spy per layer
- Each spy implicitly monitors spy above it
  - App spy enforcer dead ⟺ OS layer dead
  - OS layer dead ⟹ OS spy says **LAYER_DOWN**



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- **Problem:** app spy enforcer could die without OS layer dying
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- **Problem:** app spy could miss layer failure (bad "insider" information)
- **Solution:** again, long end-to-end timeout as fallback

The Failure Detection Algorithm

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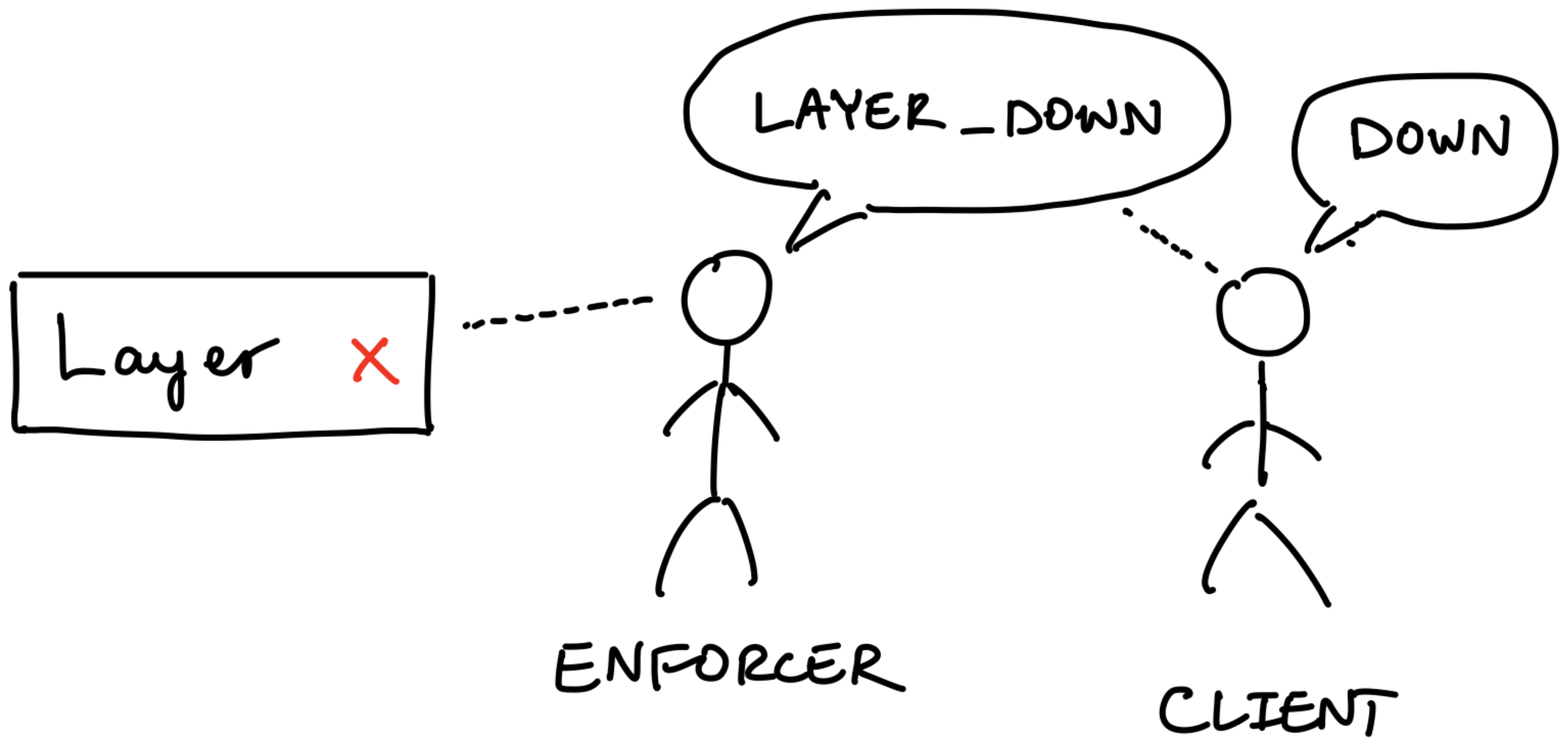
- If any enforcer confident of crash:
  - It reports **LAYER_DOWN** to FALCON
  - FALCON reports final decision **DOWN**
    (works because **any layer down** $\implies$ **process is down**)



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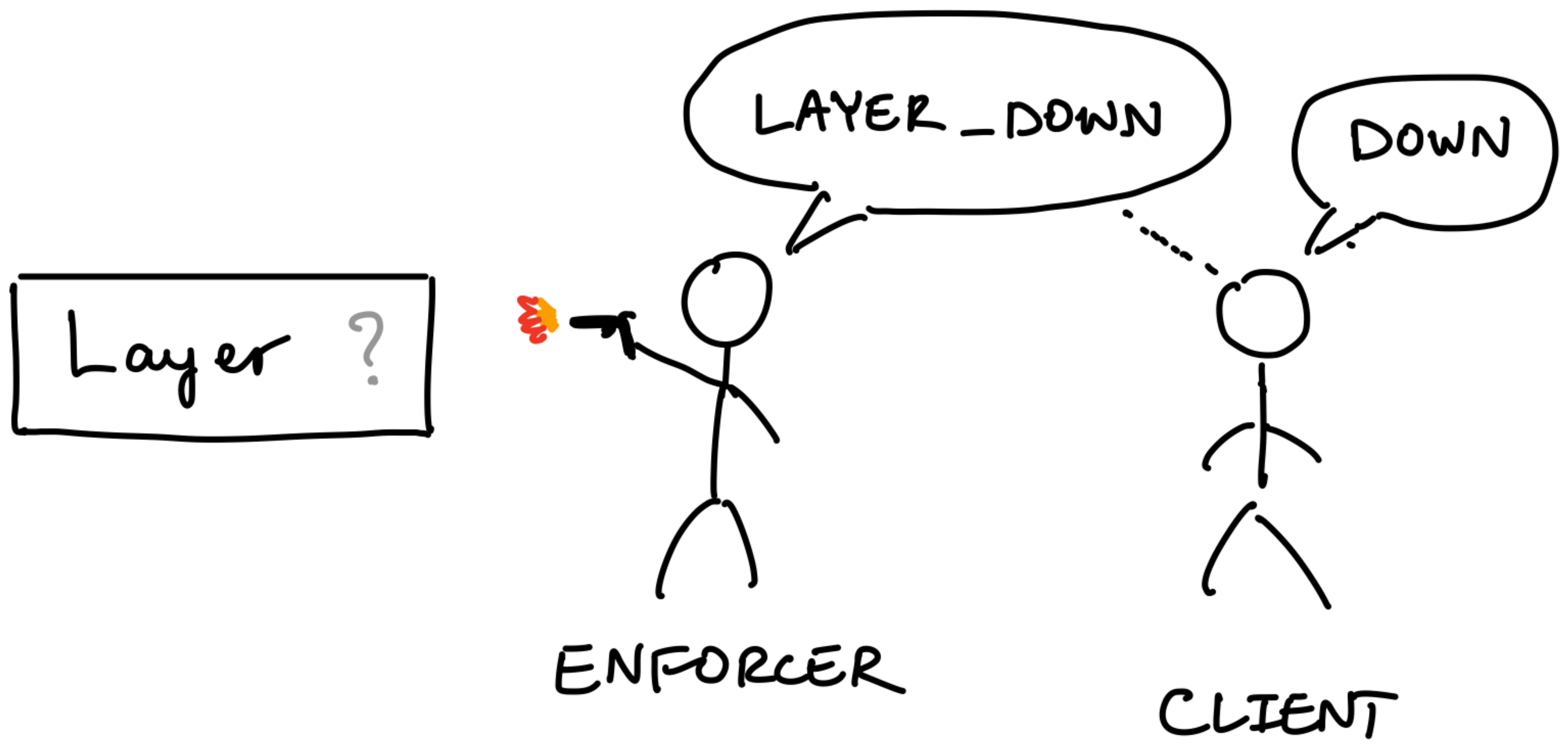

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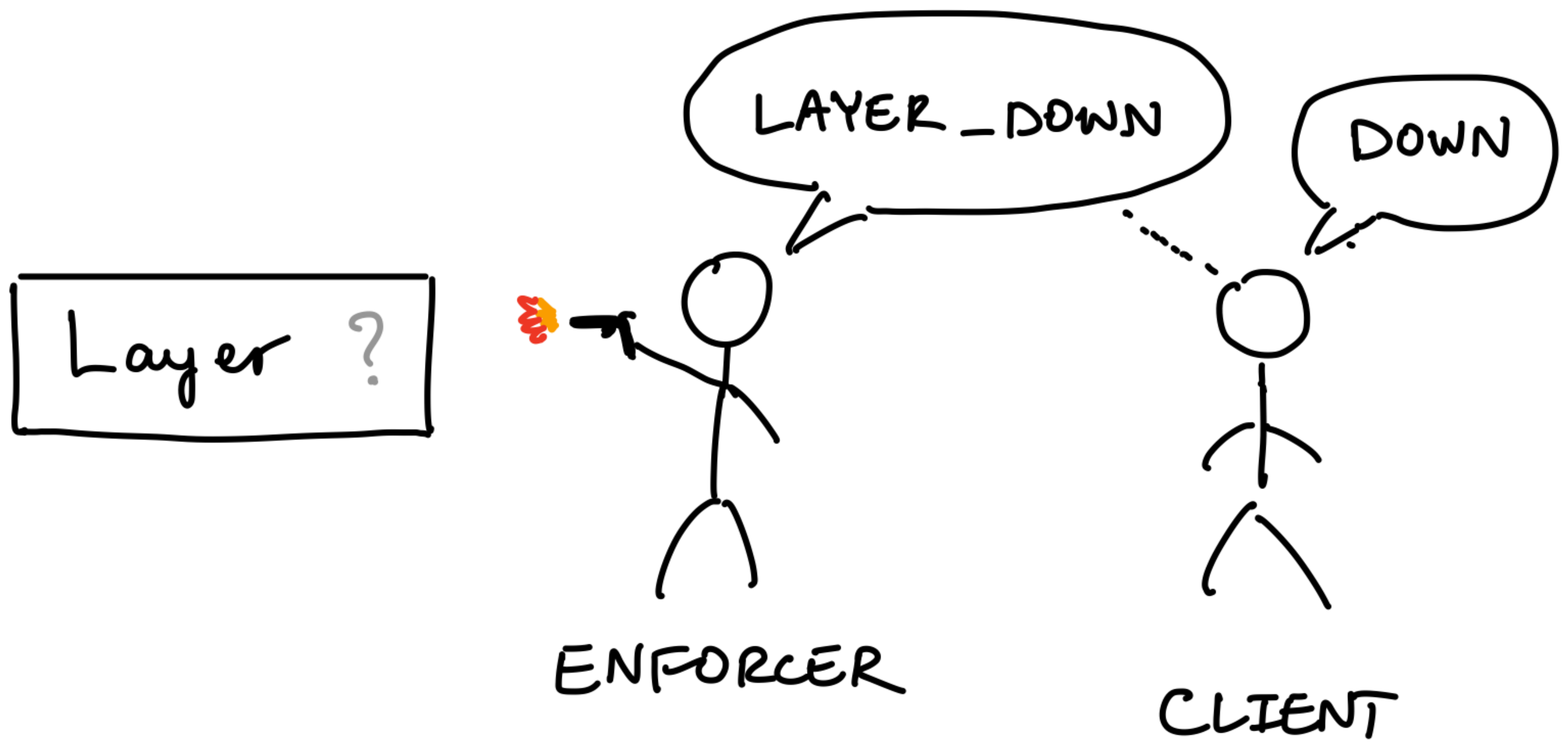

- If timeout expires:
    - FALCON issues surgical kill orders and says **DOWN**

Corner Case

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- **Solution:** block, because this means either:
    - extreme asynchrony
    - network layer crash (indistinguishable from asynchrony)

FLP

Evaluating FALCON

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- **Criteria**:
  1. Failure detection time (and thus system availability)
  2. Disruption (when and how much killing)
  3. Computational complexity
  4. Code complexity

Detection Time and Availability

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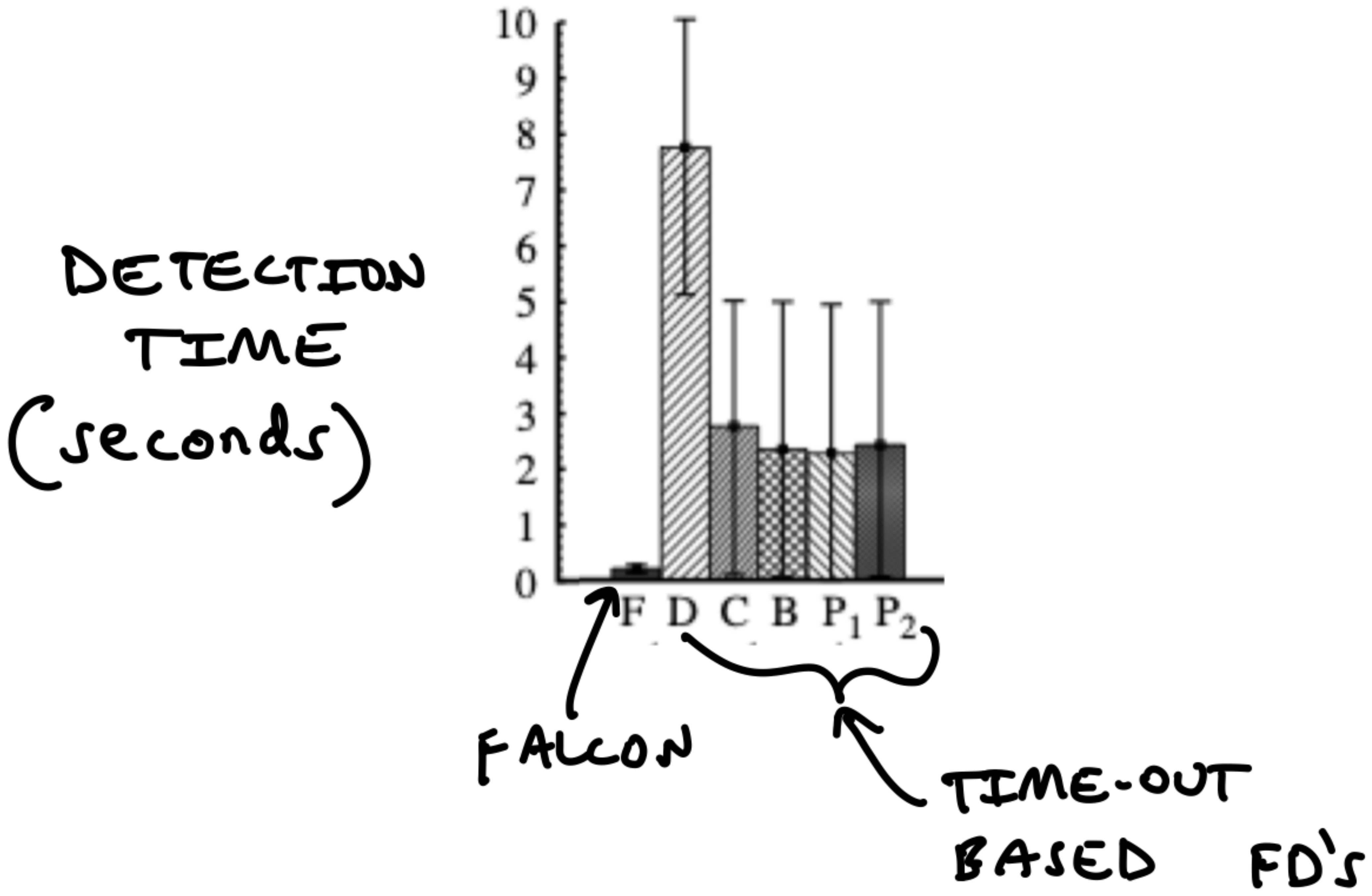
- Sub-second detection time:



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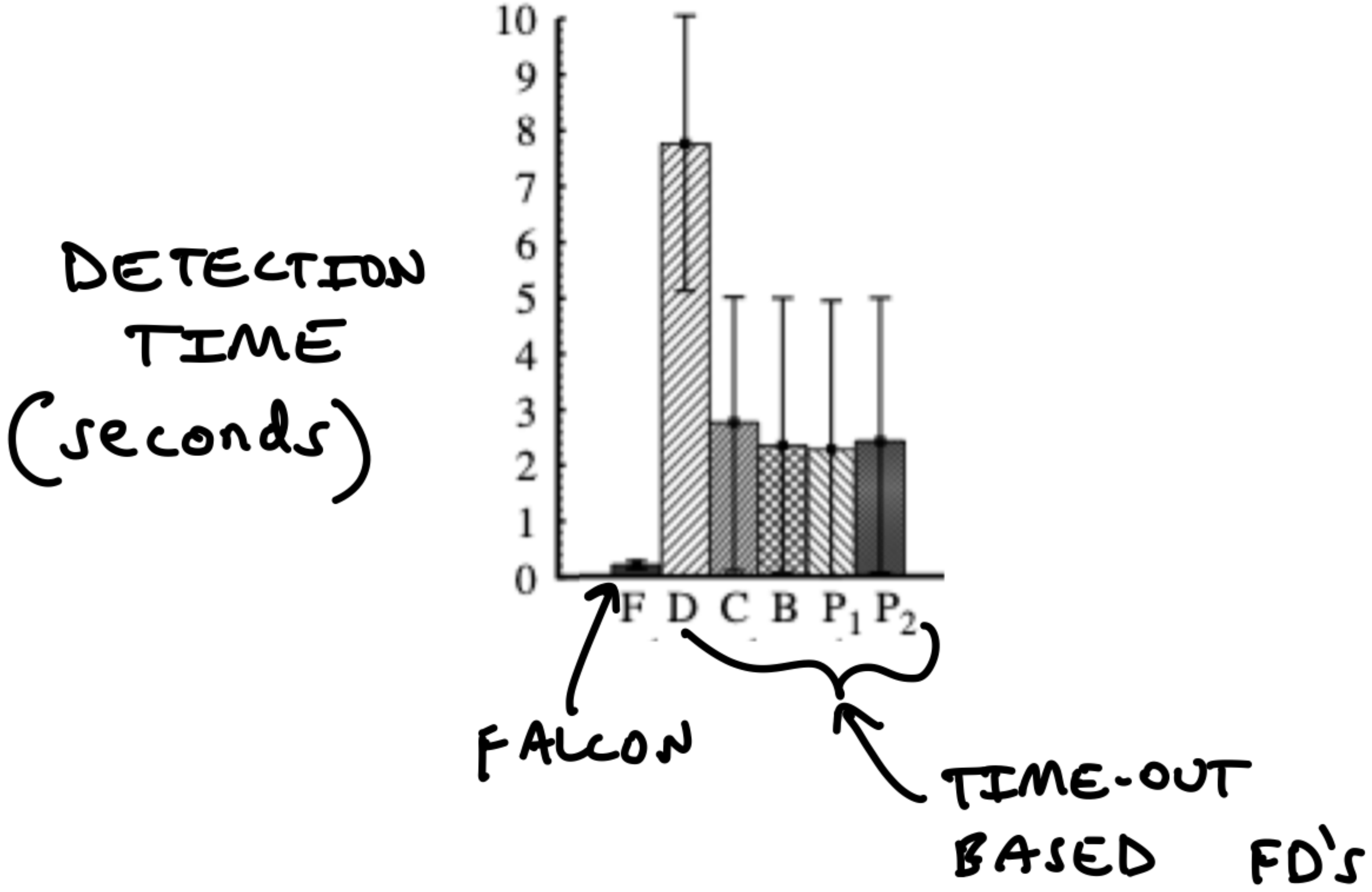

- Reduces median ZooKeeper unavailability time by ~6x (kernel/host crashes)

System Disruption

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- Usually **minimal killing**
- Few cases where it goes overboard:
  - E.g., Network load causes VMM spy enforcer to suspect death (and kill VMM)
  - **Can be fixed** by better enforcer logic!

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- Reduces code complexity:
  - FALCON is a **R**FD $\Longrightarrow$ don't need to handle failure mistakes
  - **Primary-backup + FALCON = 21% less code** than Paxos + timeout!

More Discussion In The Paper

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- FALCON after recovery
- FALCON for different platforms
- More evaluation against large failure and stress-test suite