Distributed Hash Tables, Video, and Fun!

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Section 1

About Us

Who are we?

- Thomas Gebert
  - Software Engineer in New York, NY.
  - Certified Eccentric.
  - Mostly focuses on backend services.
- Nicholas Misturak
  - Front-End Web Developer in Orlando, FL.
  - Work in JavaScript and React.
  - Know some functional programming.

Not Experts

- We are hobbyists who want to build cool things.
- Possible we are doing things sub-optimally
  - If you see something we're doing wrong, let us know!

Section 2

Background

We want to make a video sharing platform

- YouTube has a near-monopoly on video-sharing on the web
- As a central entity, they have the benefit of complete control of their platform
- However, they also assume all of the cost of maintaining this platform
  - Video transcoding and storage are incredibly expensive
  - Completely infeasable to scale with the resources of most startups

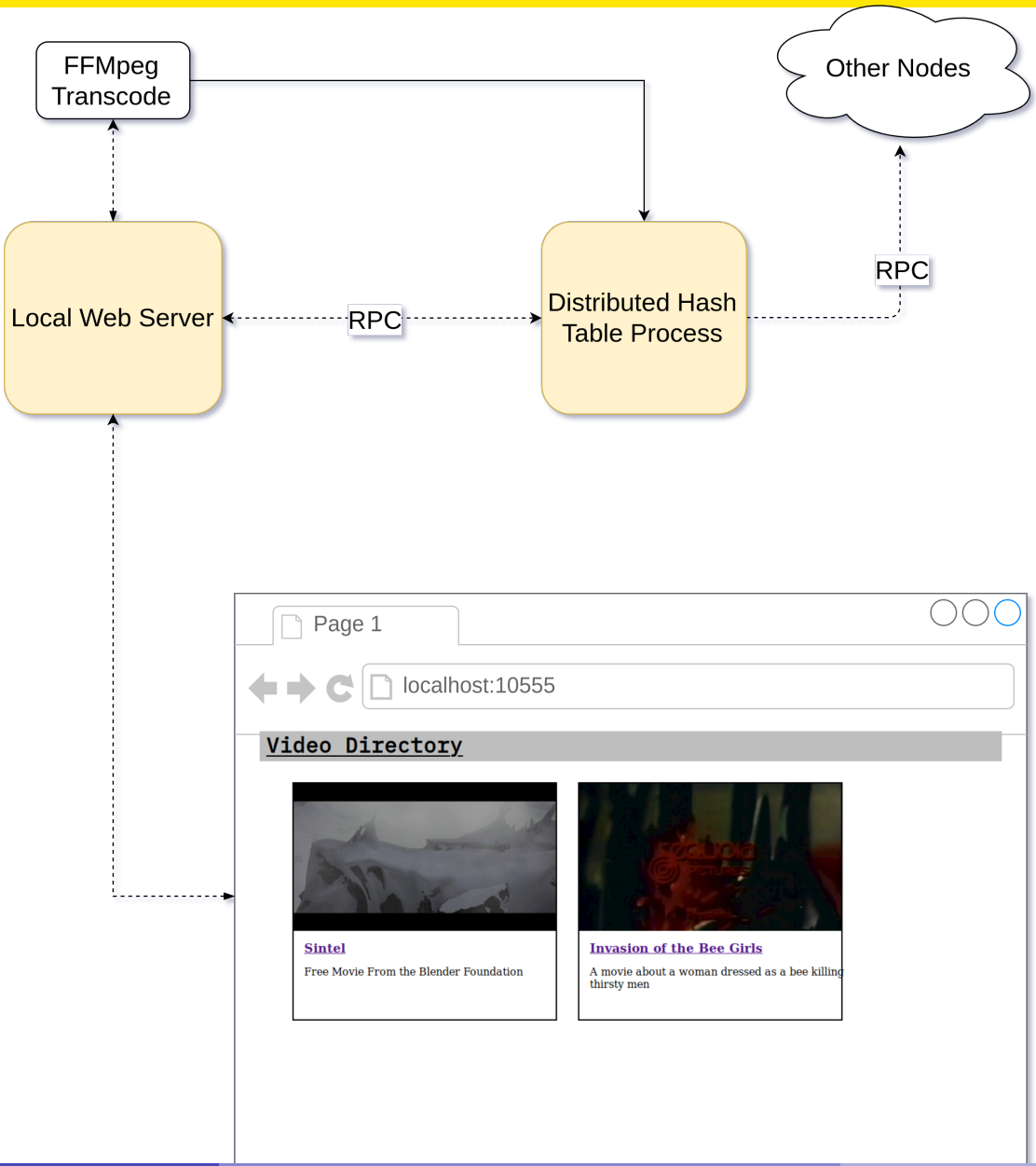
The Solution

- Don't write a centralized system, write a distributed one
- By distributing, we can ask participants in the platform to do the work of transcoding and storage
- In this way, we are sharing the cost of the platform

What we've built

- An efficient, peer-to-peer video sharing platform.
- Every node on the system is a client *and* a server.
- Communication happens over TCP. . . even for the local client.

What we've built



Prototype

- Original version built in early 2018 in Haskell.
- Code was a mess
  - Haskell's networking libraries can be very primitive.
  - There was difficulty in making Haskell's shared-memory-style system work with the model that I wanted for the project.
- Needed a rewrite in a language with better library support.

Rewrite

- Decided to rewrite prototype in Clojure.
- Wanted Go's CSP in a functional language.
- Needed mature and well-supported network libraries.
  - Could not be vanilla Java because life is too short as it is.
- Clojure also has Haskell-style transactional memory for non-reactive concurrency.
- Dynamic languages can be more-pleasant than typed languages for handling low-level networking stuff.

Software Used

Backend

- JeroMQ
  - Low-level socket library to handle TCP and UDP logic.
- MessagePack
- Incredibly fast binary-serialization library with bindings in virtually every language.
- core.async
  - Implementation of Go's CSP for Clojure.

Frontend

- Re-frame
  - React port to ClojureScript

HTTP Live Streaming

- The ability to partition videos and glue them together on the fly is an interesting Computer Science topic in itself.
- HTTP Live Streaming (HLS)
  - Part of the web standard.
  - Works by creating a Winamp Playlist file (.m3u8), and requesting chunks of the video on the fly.
  - This allows us to store any video across the whole network, increasing redundancy and parallelism.

Section 3

Distributed Hash Tables

What is a DHT?

- A data structure to store data and routing information across a cluster of nodes without a centralized server.
- Data is shared and replicated across nodes.
  - There are no central servers.
- Popular algorithms include Chord, Pastry, Tapestry, and Kademlia

Kademlia

- Most popular algorithm for distributed hash table programs
- Used by Facebook and other companies to distribute updates.
- Provides worst-case $\log_2(n)$ lookups

Section 4

Routing

What is a routing table?

A routing table provides a way for us to look up and store nodes that are of interest to us.

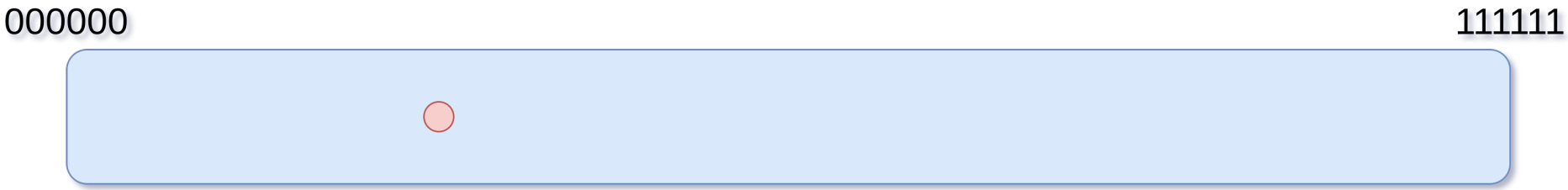
What's the point of a routing table?

- It would be infeasible to store reference to all the nodes in the cluster.
- Ideally, we want to store a small subset of all the nodes that will allow us to find any given value or node in the table eventually.
- It would be best if these lookups were faster than linear time and were likely to resolve.

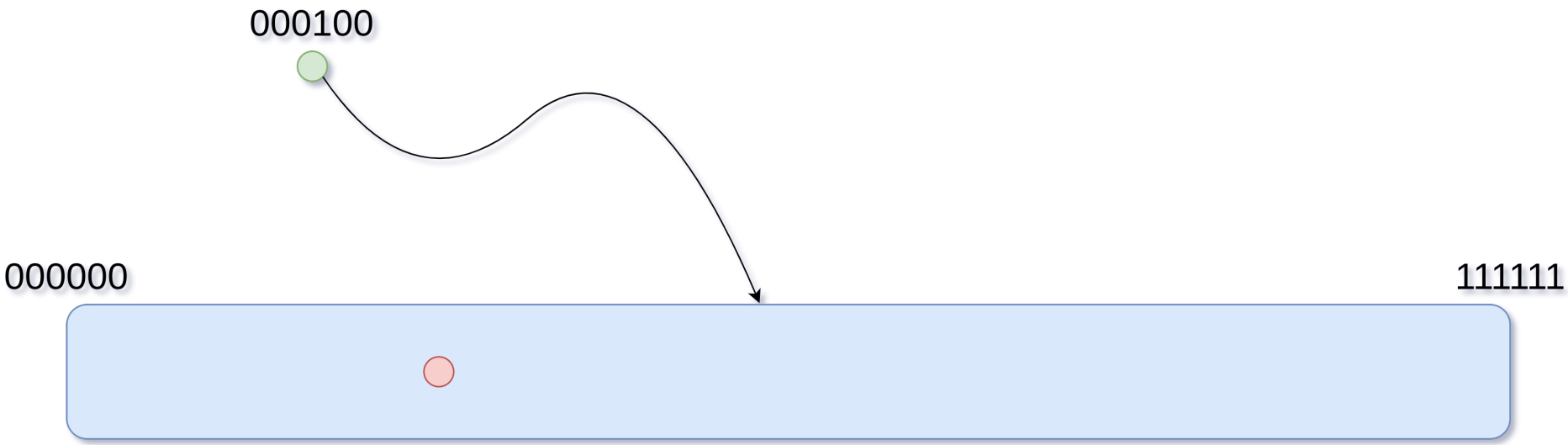
Routing Table

- Each machine participating in the DHT is a Node.
- Nodes are given random 160 bit IDs.
- "Distance" is defined by XORing two IDs.
  - Might seem weird to use as a distance metric but consider this.
    - $a \oplus b = 0 \iff a = b$
    - $a \oplus b = b \oplus a$
  - Gives us a deterministic way to figure out path to where data is stored without central synchronization.
- Each node has its own routing table.
- The table is divided into buckets of a set size.
  - For the sake of this demo, let's assume that the size is 5.

Routing Table



Routing Table



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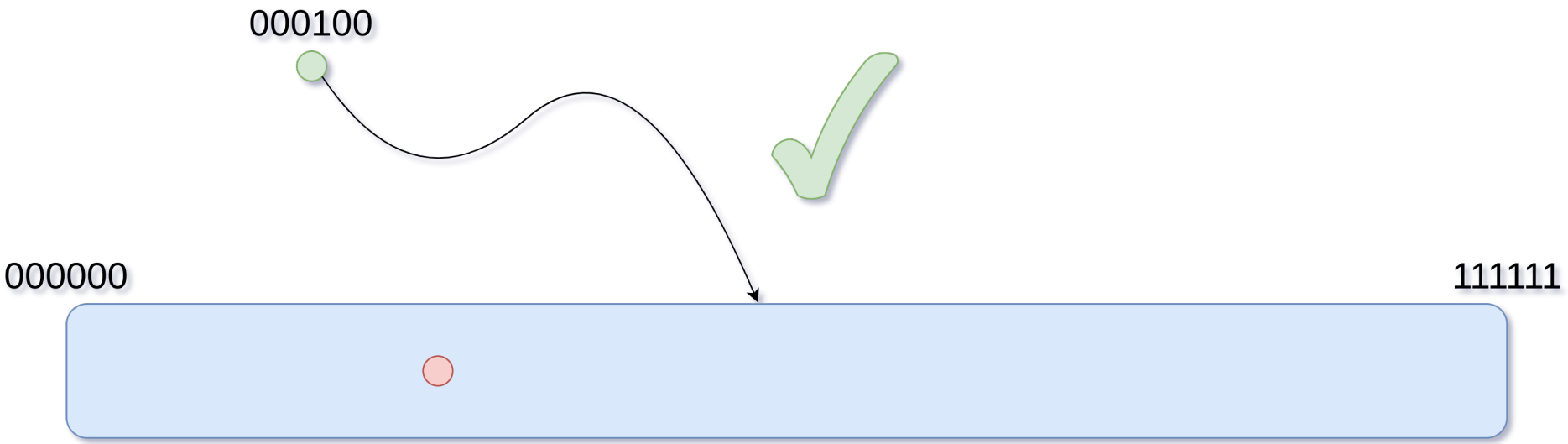

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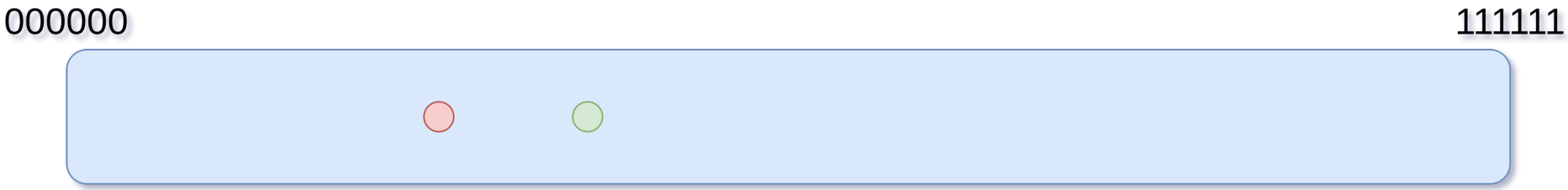

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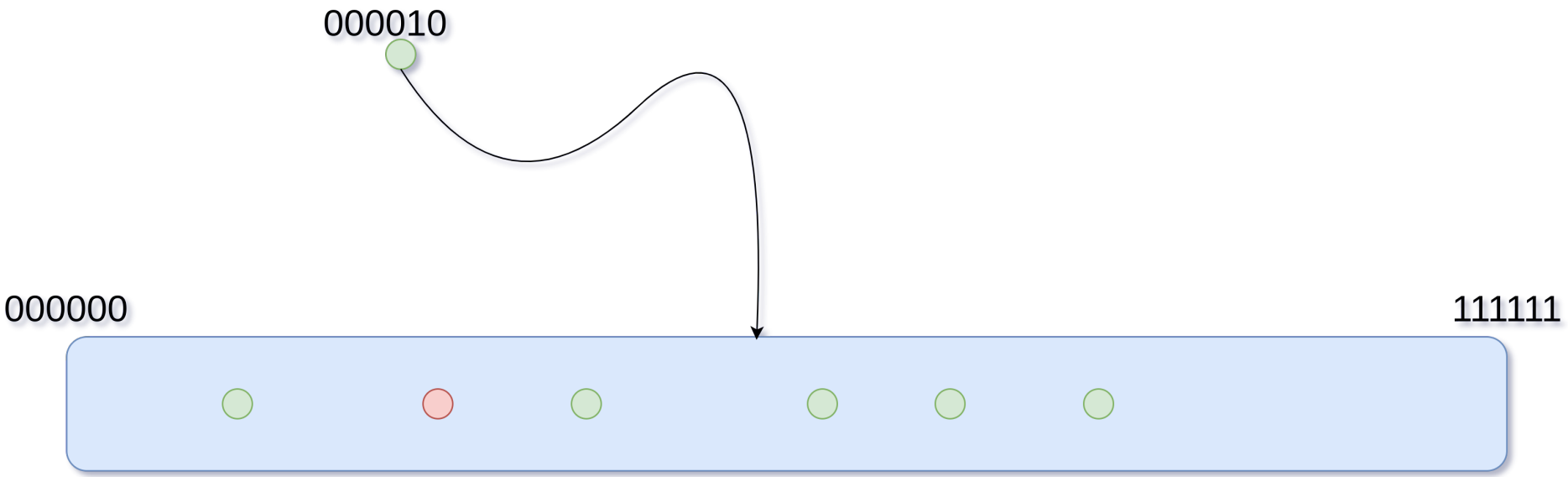

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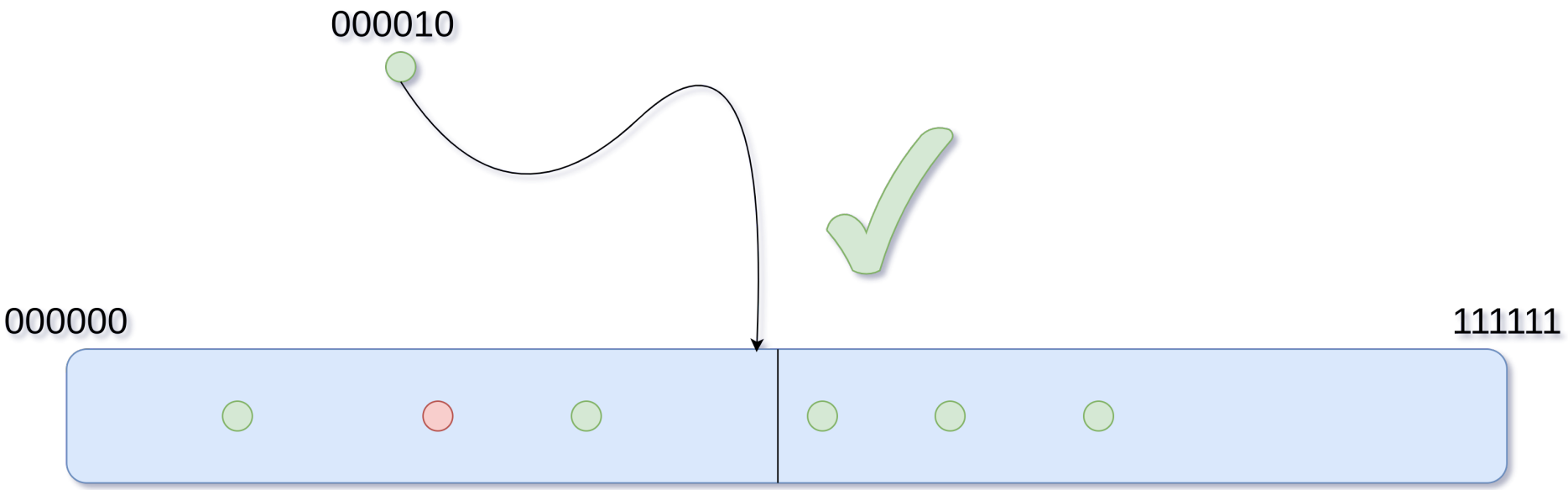

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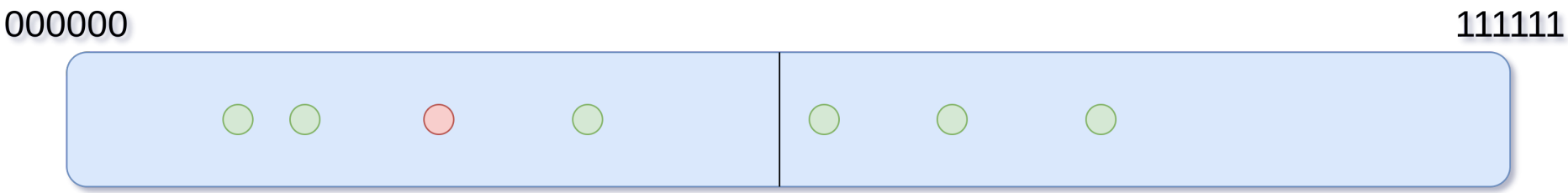

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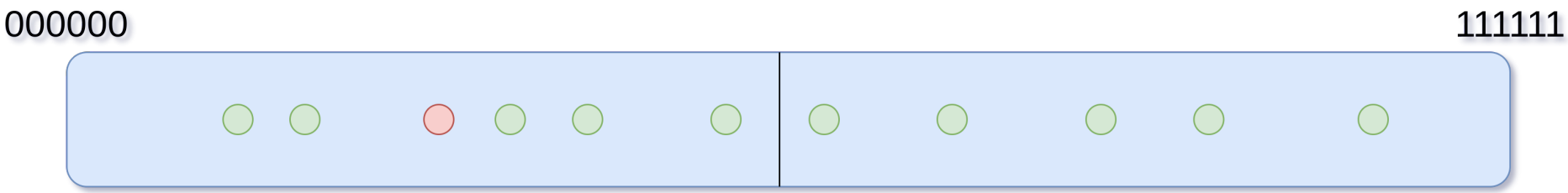

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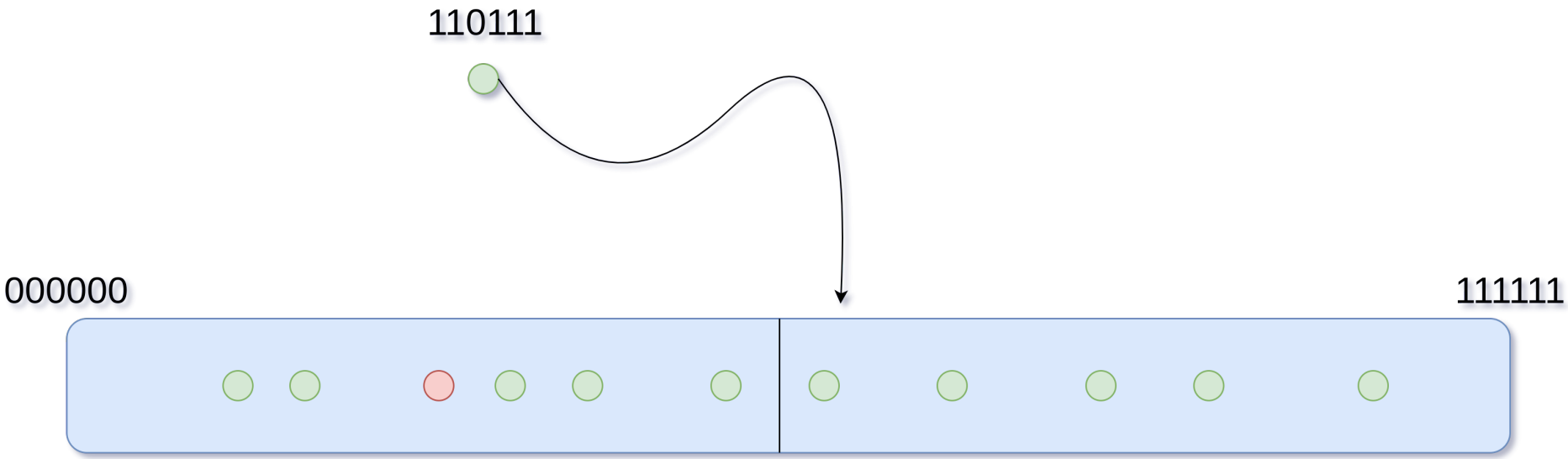

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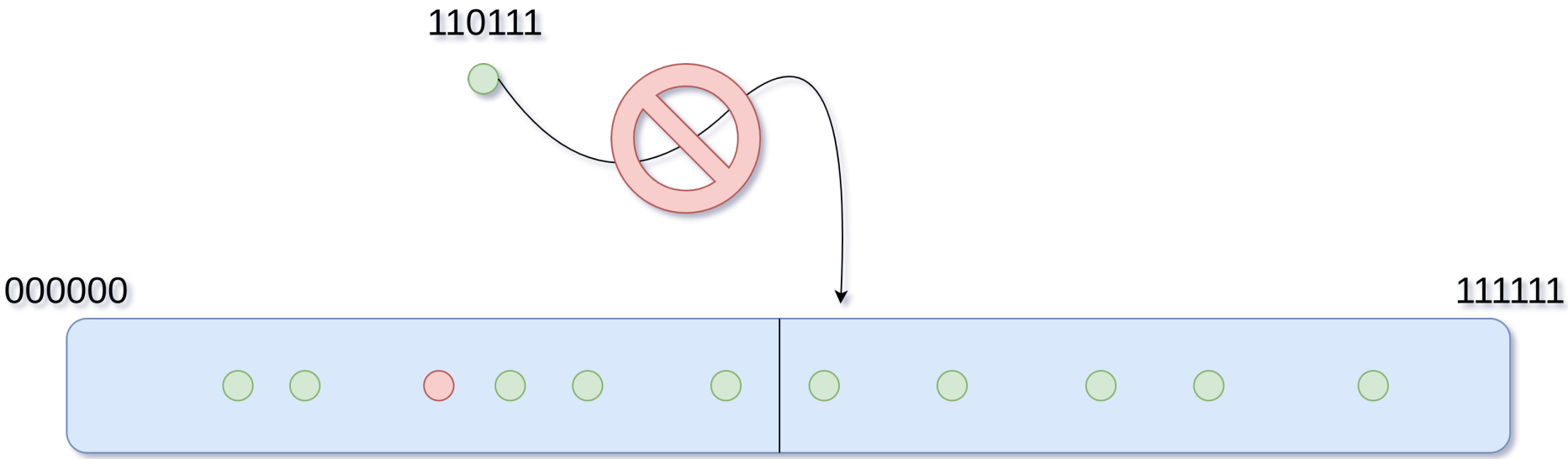

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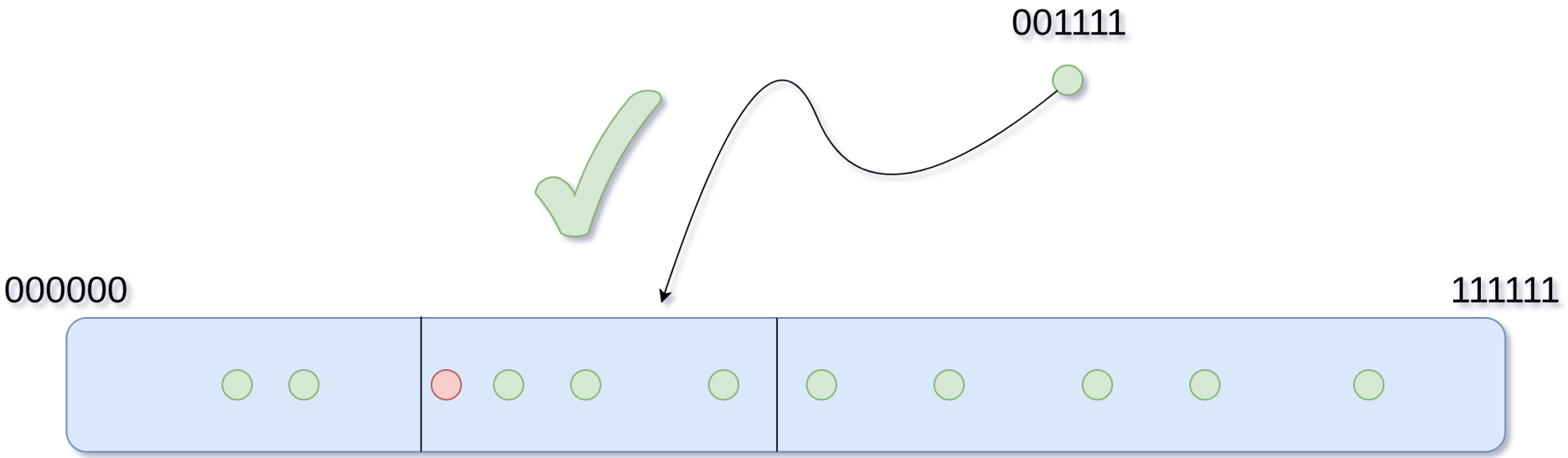

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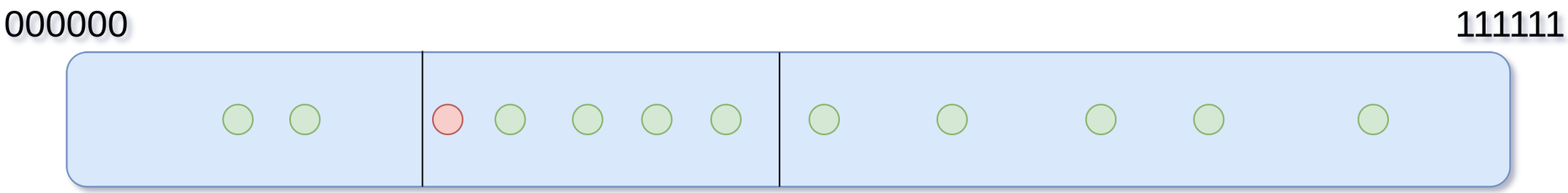
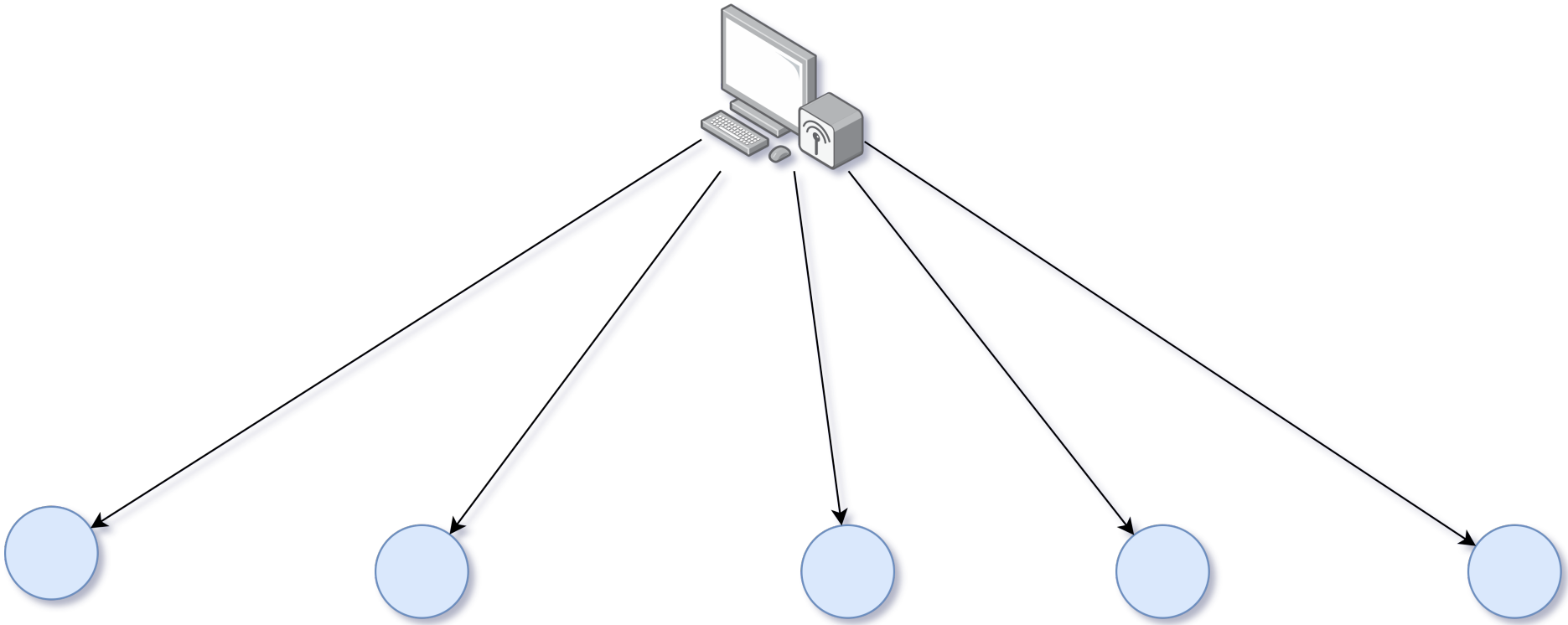


Eviction



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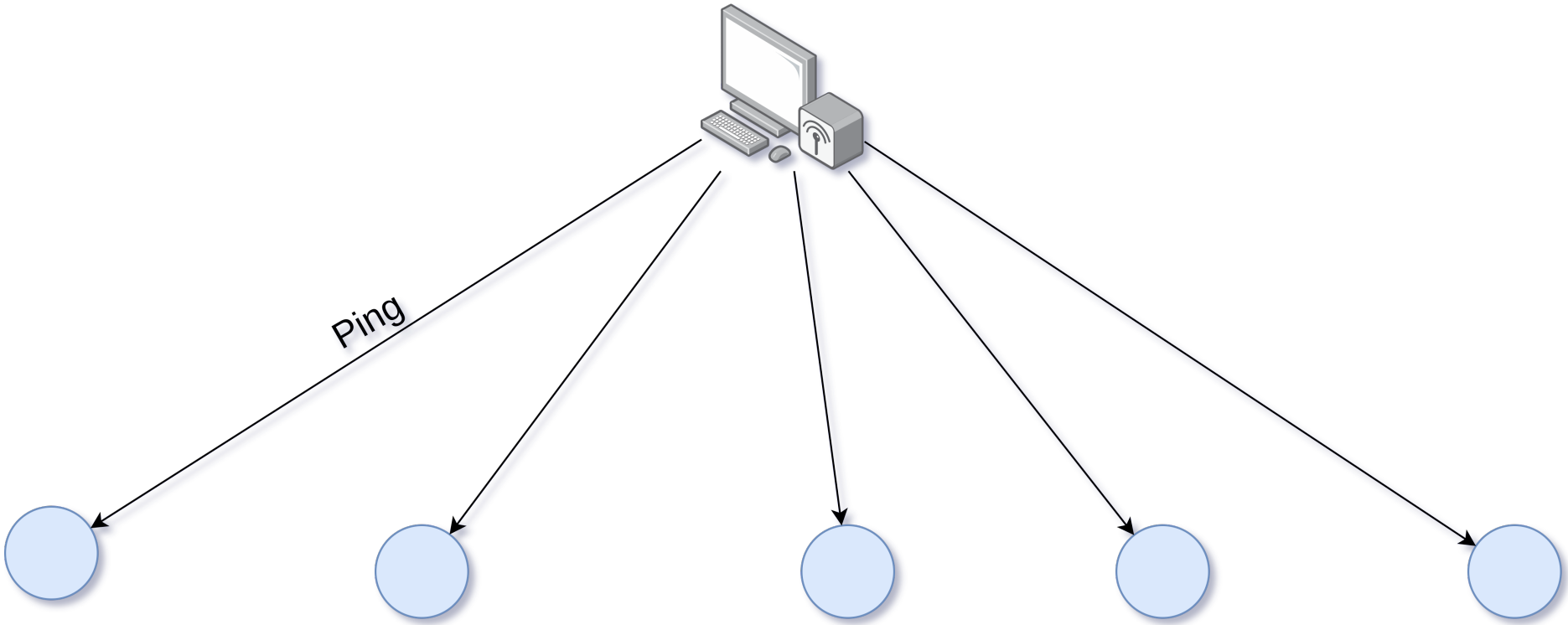

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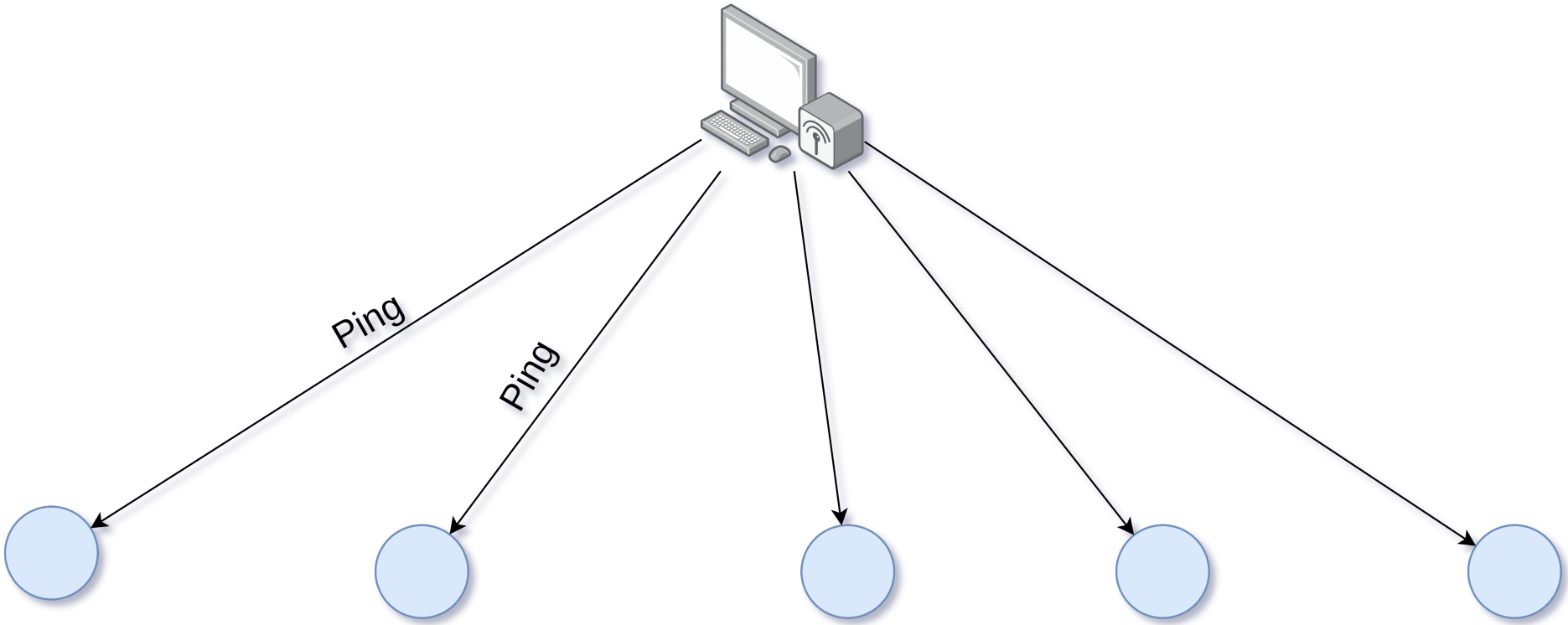

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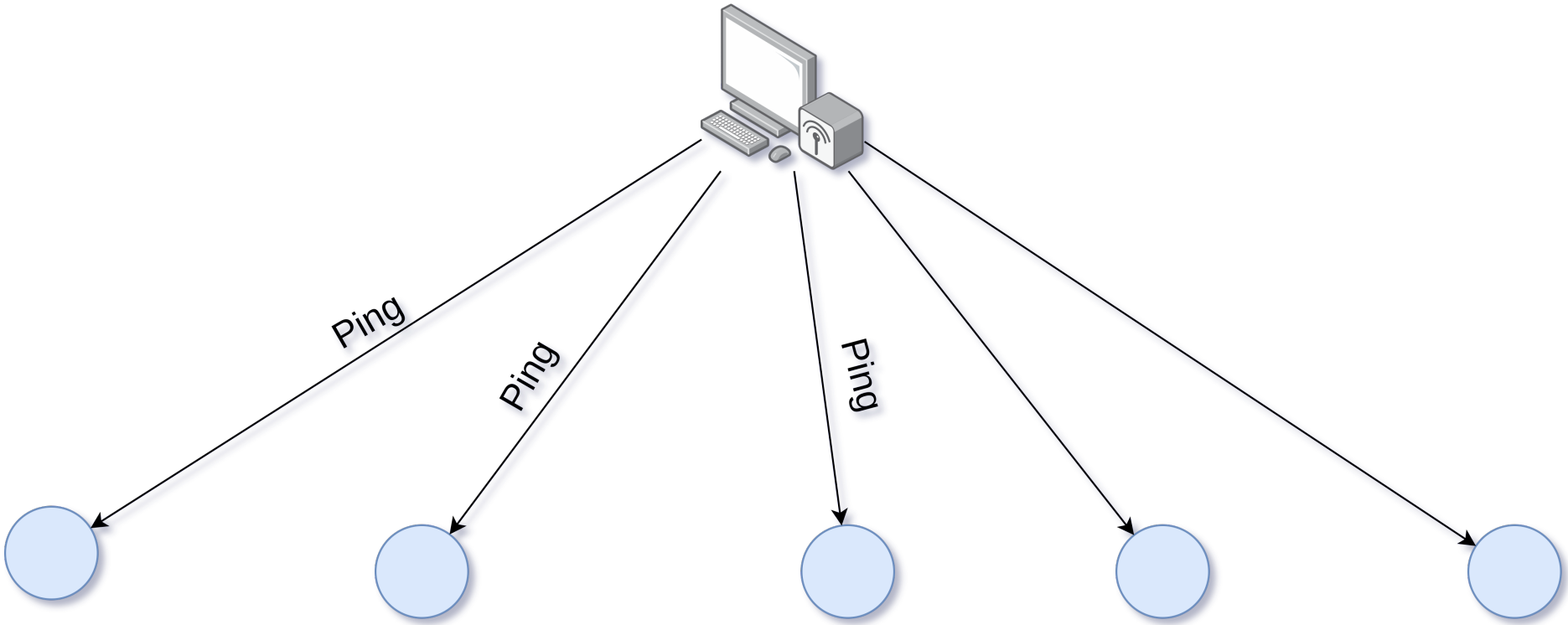

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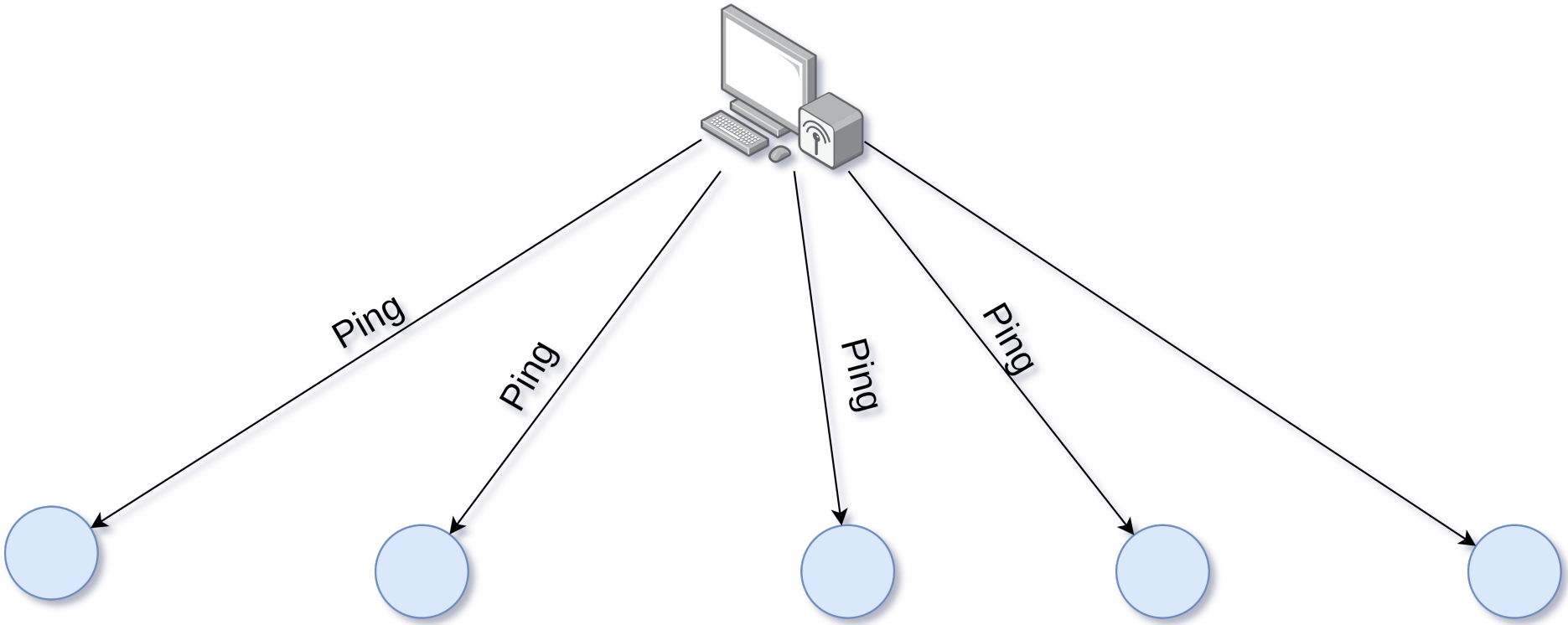

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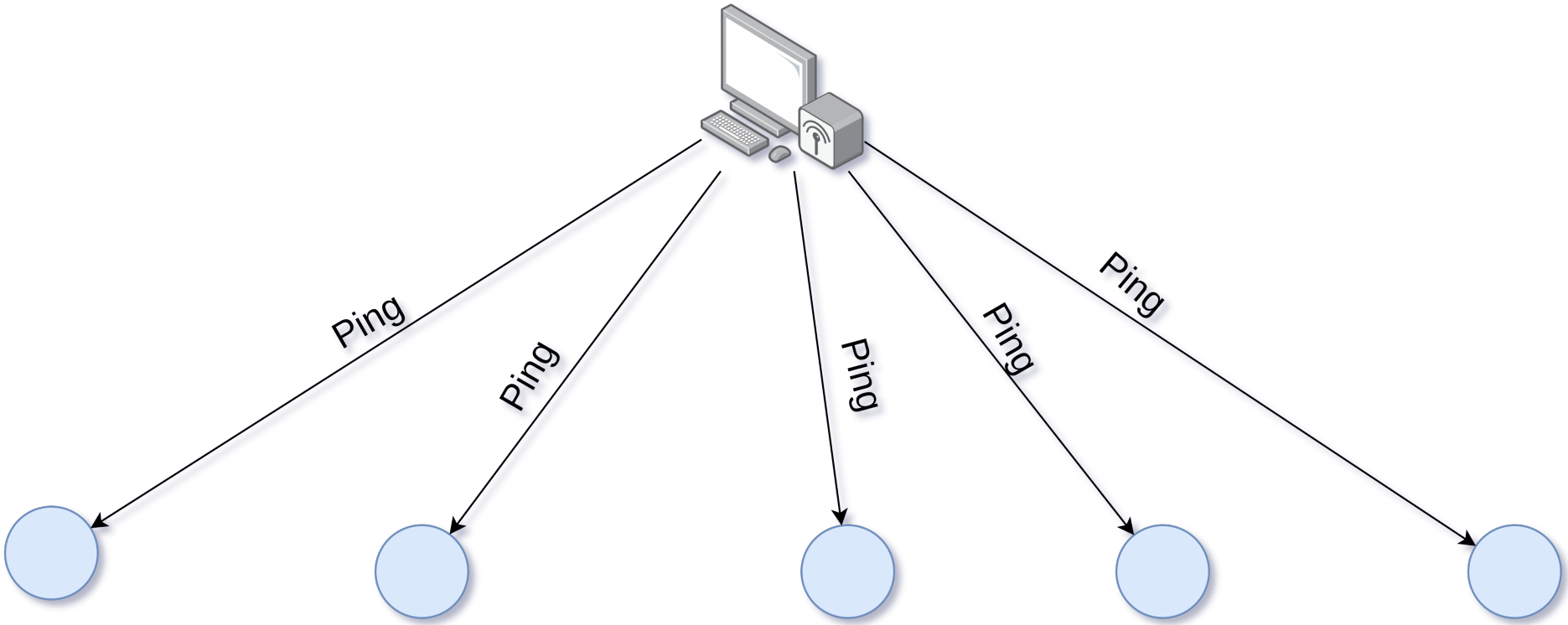

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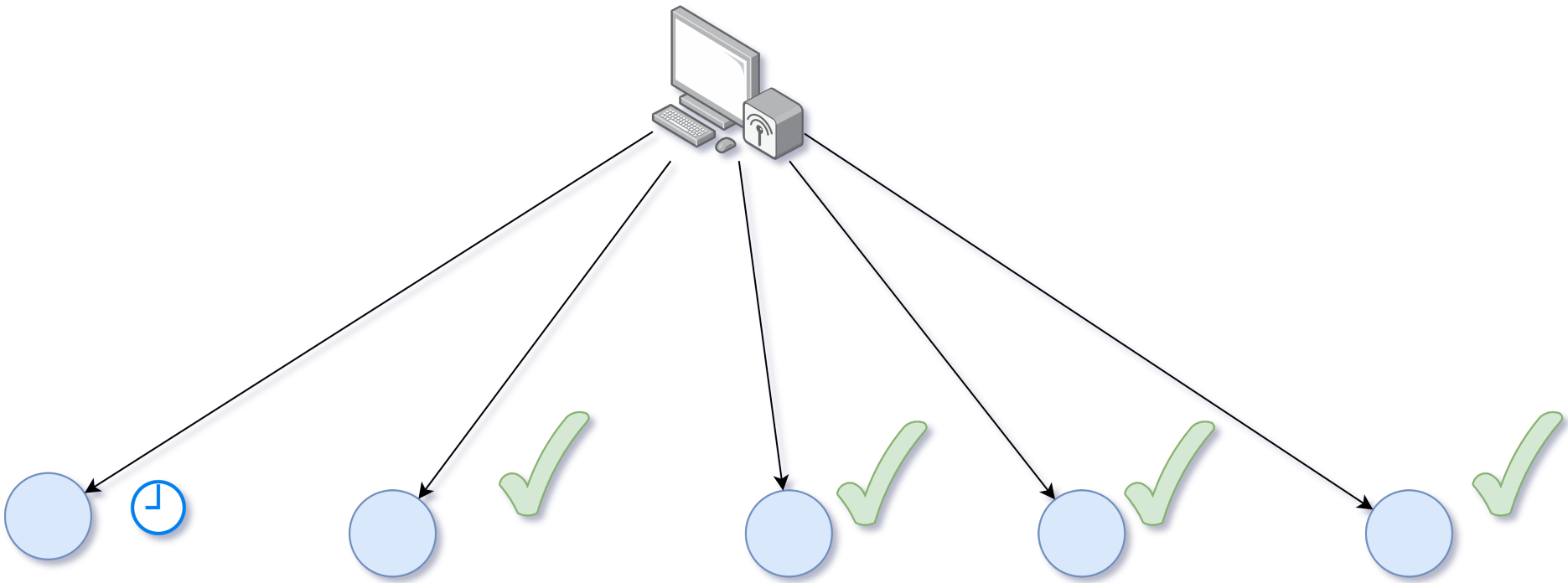

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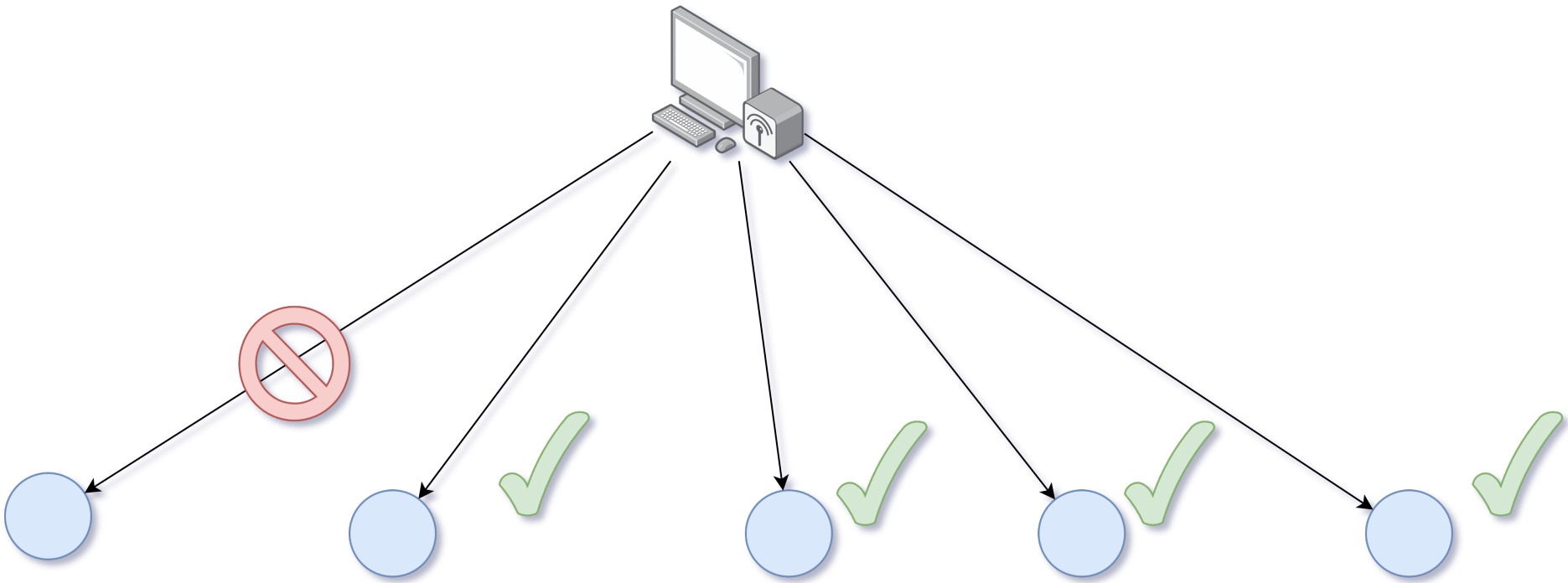

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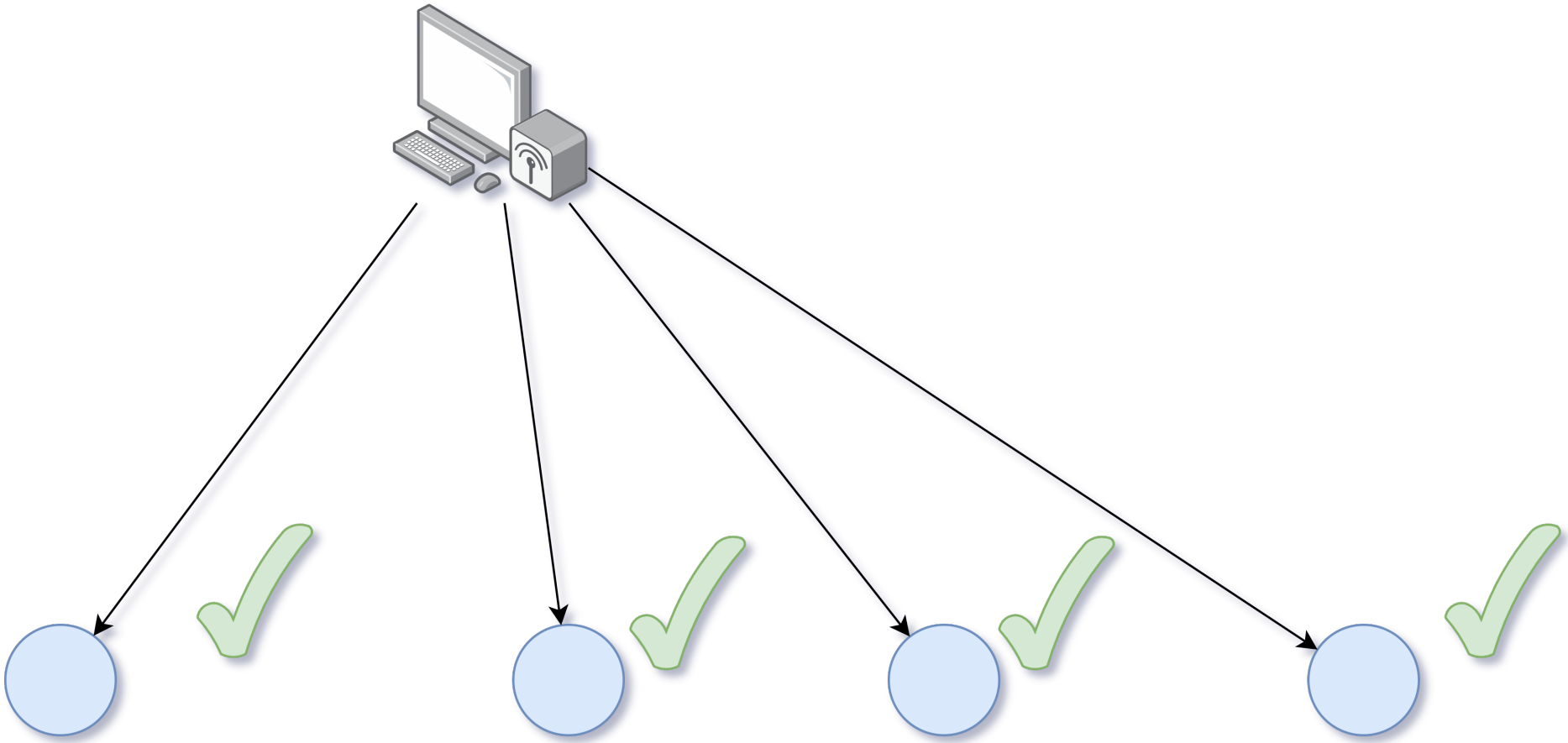


Routing Table

- Storing nodes this way allows us to convert the address space into a directed graph.
- Lookups tend to be logarithmic.
- Allows a traversal accross the entire address space by storing a lot of information about our neighbors, but allowing a wide distribution to "far-away" nodes.

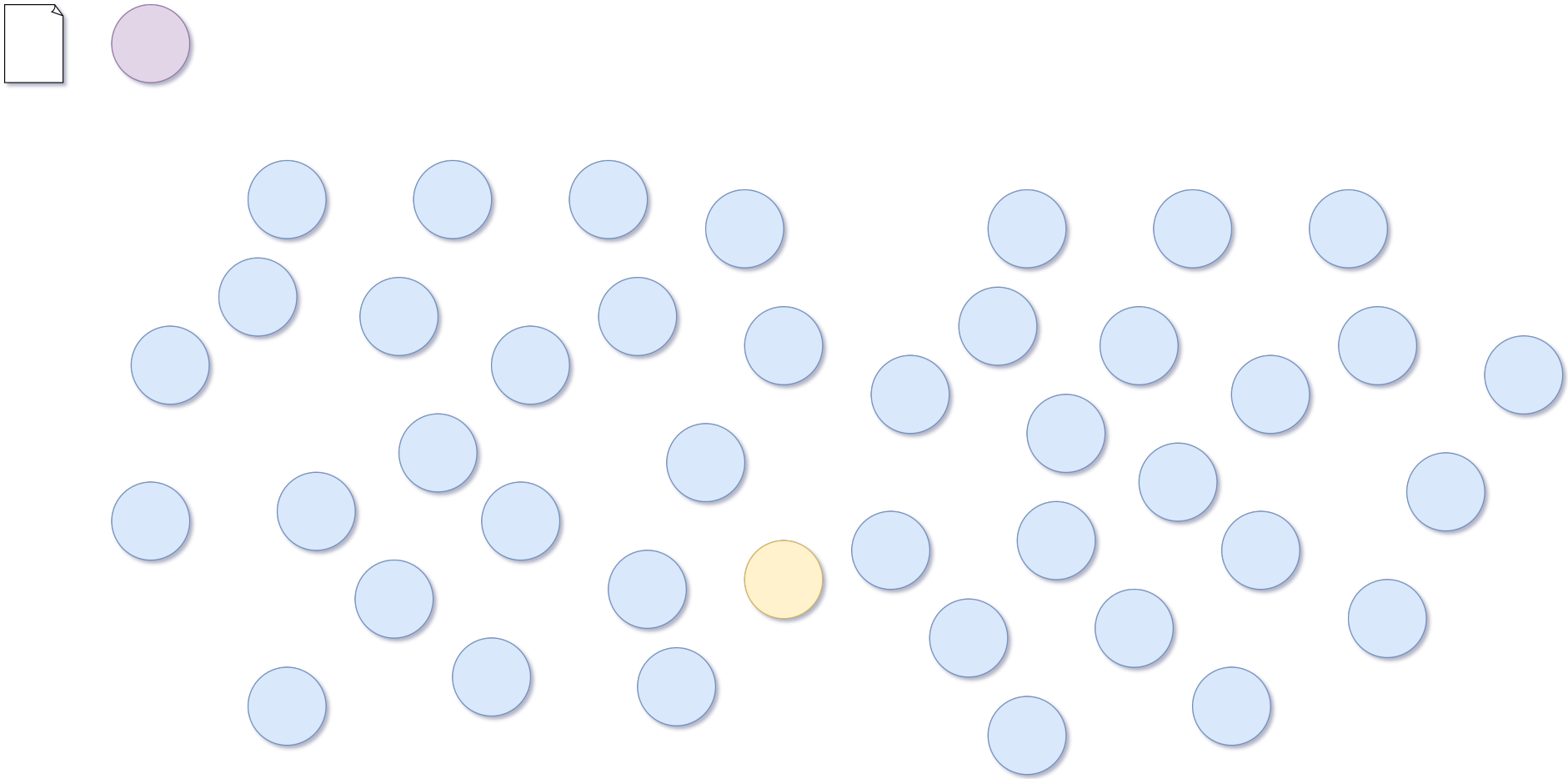
Section 5

Put and Get

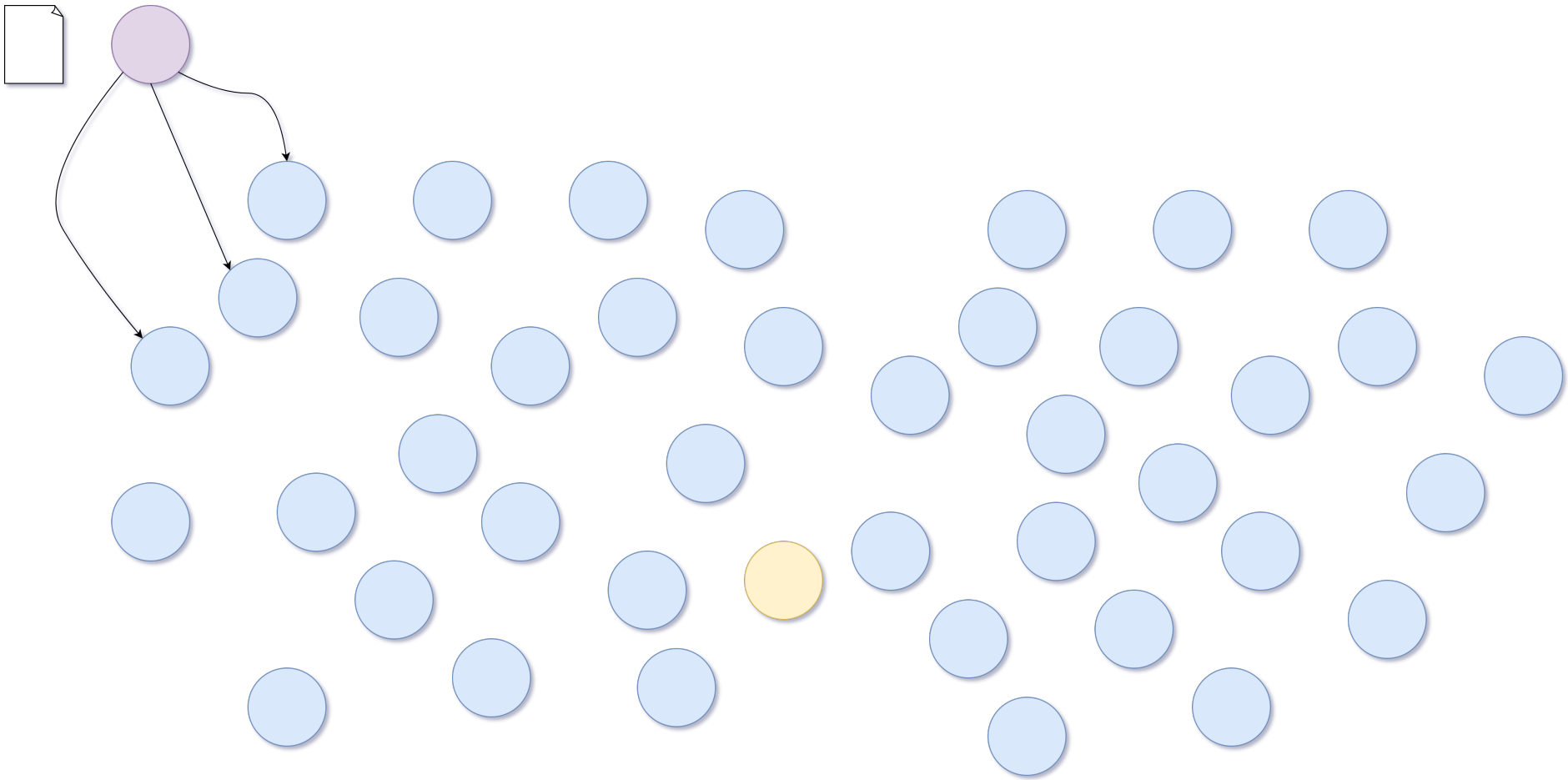
Hashing

- Like a normal hash table, keys are hashed before insertion.
- The hash length *must* be the same length as the node ID length.
  - By doing this, we keep our graph directed and allow for deterministic traversal.

Put Logic



Put Logic



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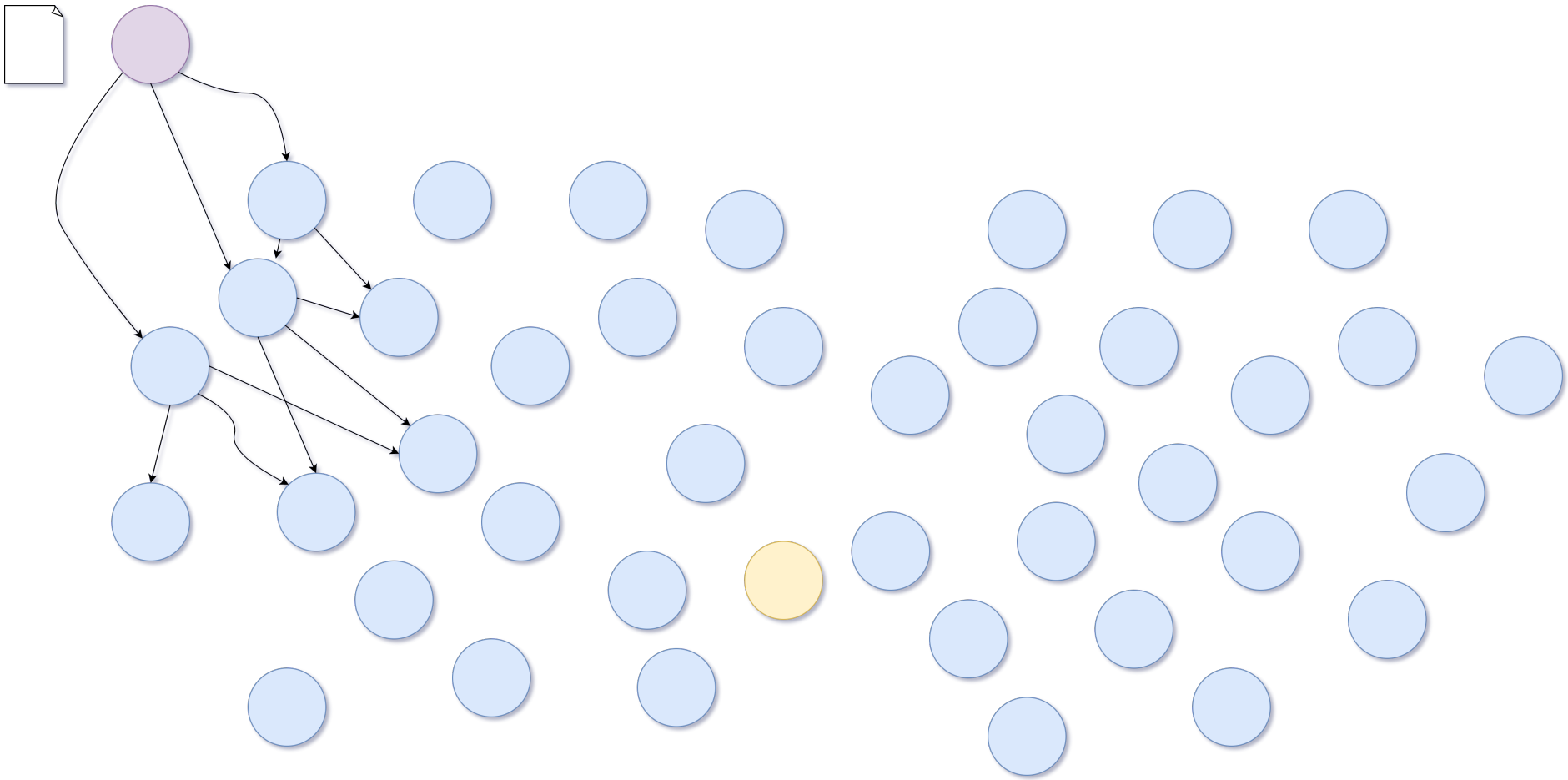
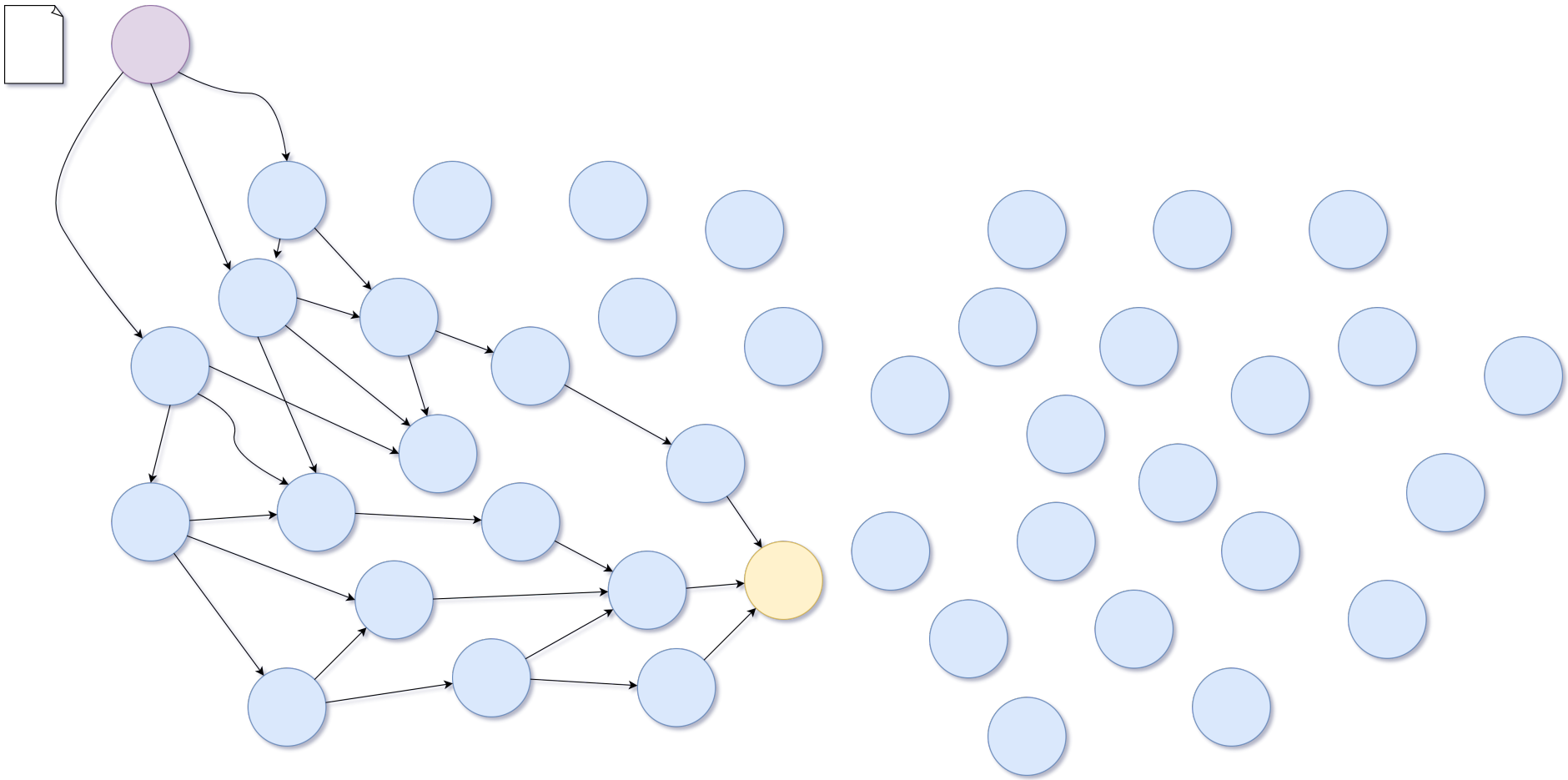
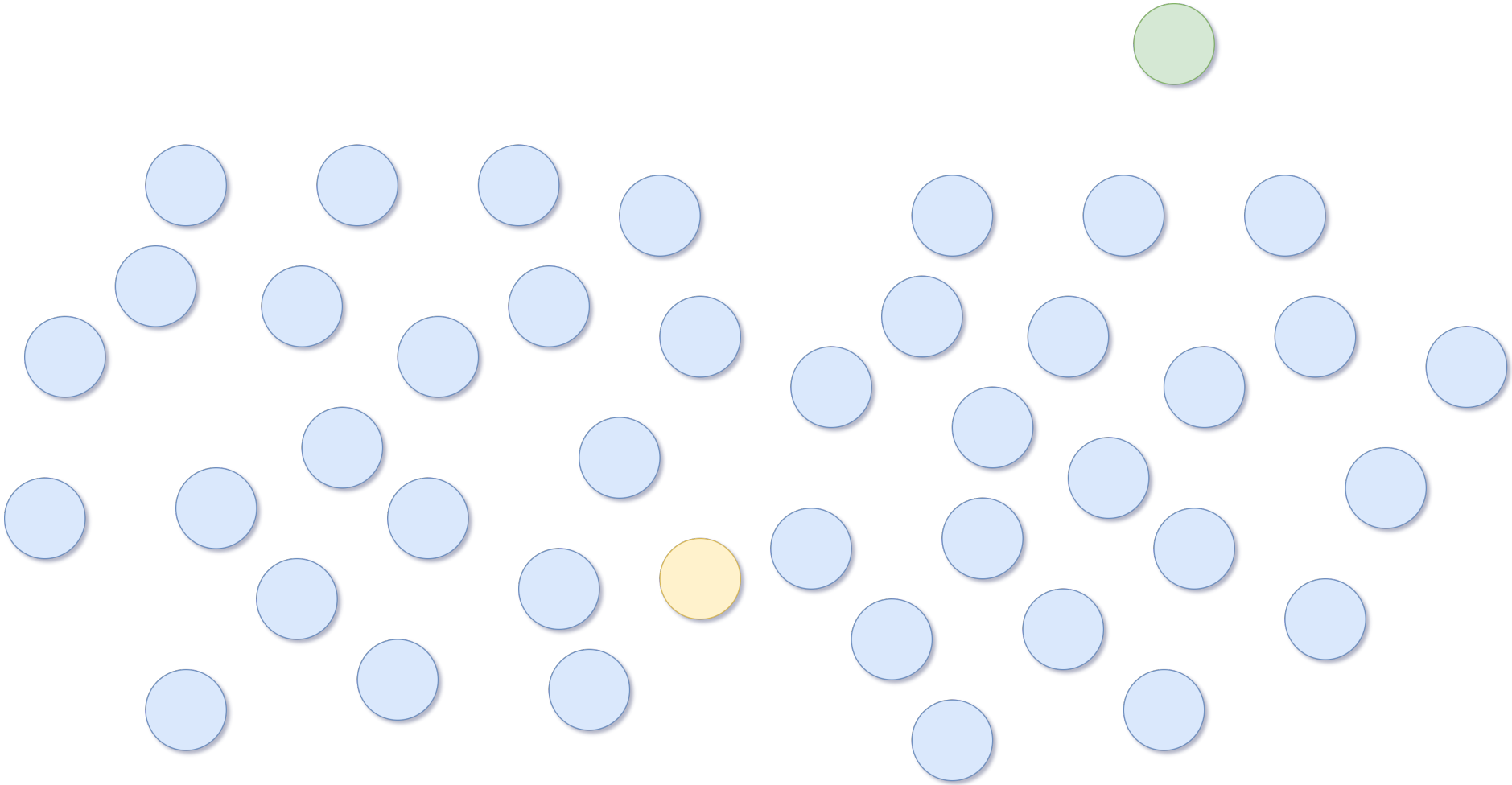


Put Logic



Get Logic



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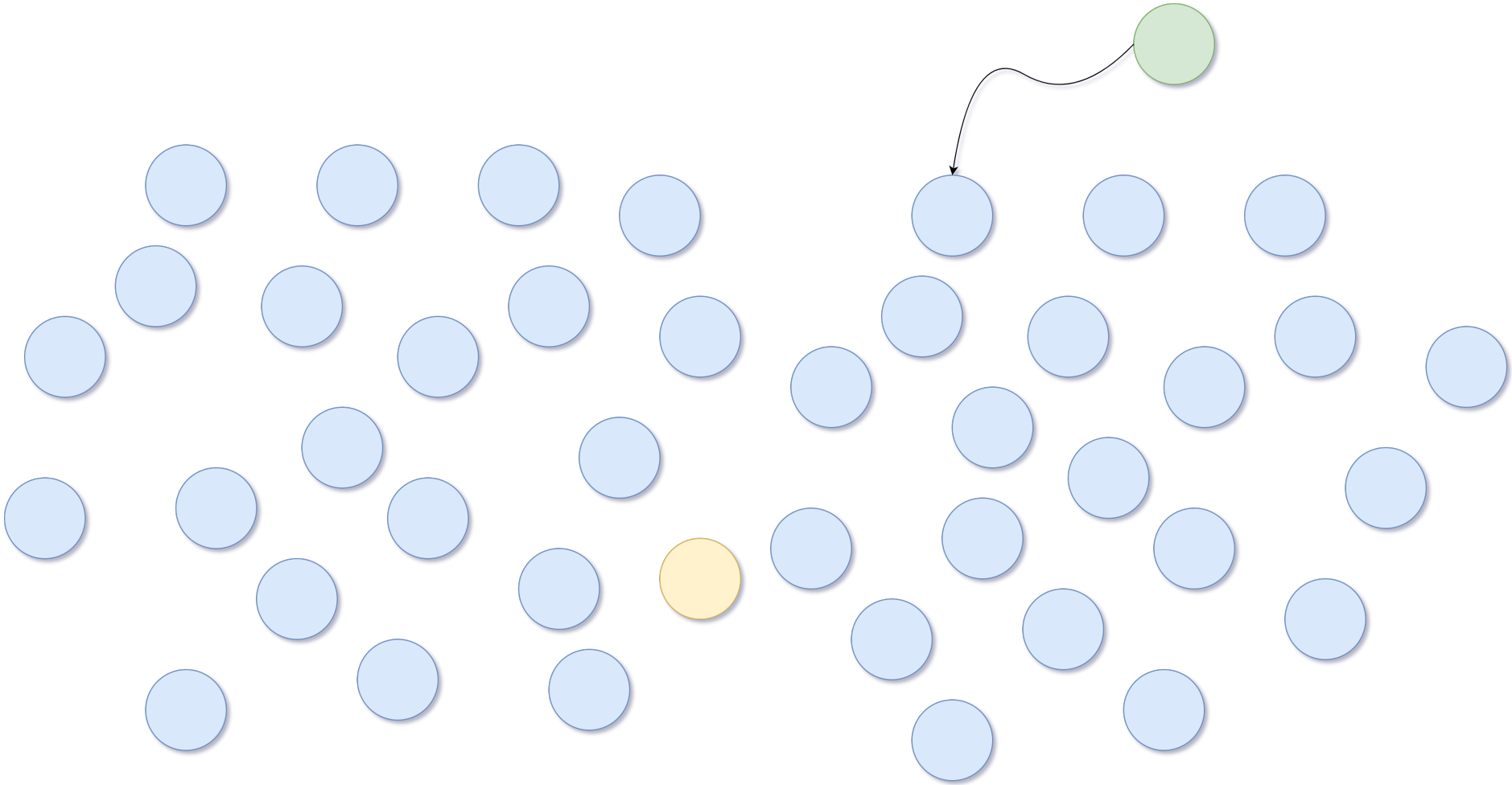

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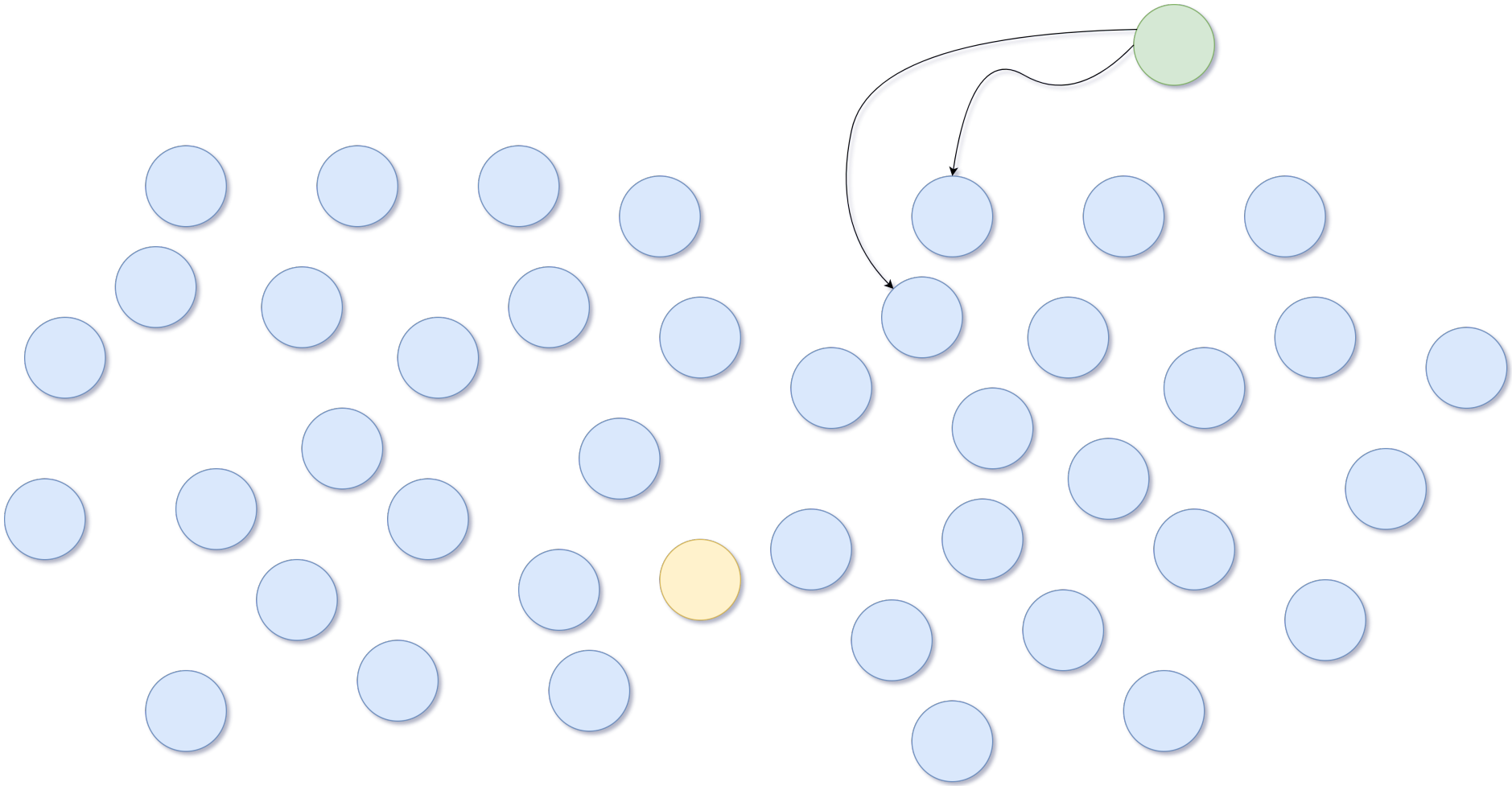

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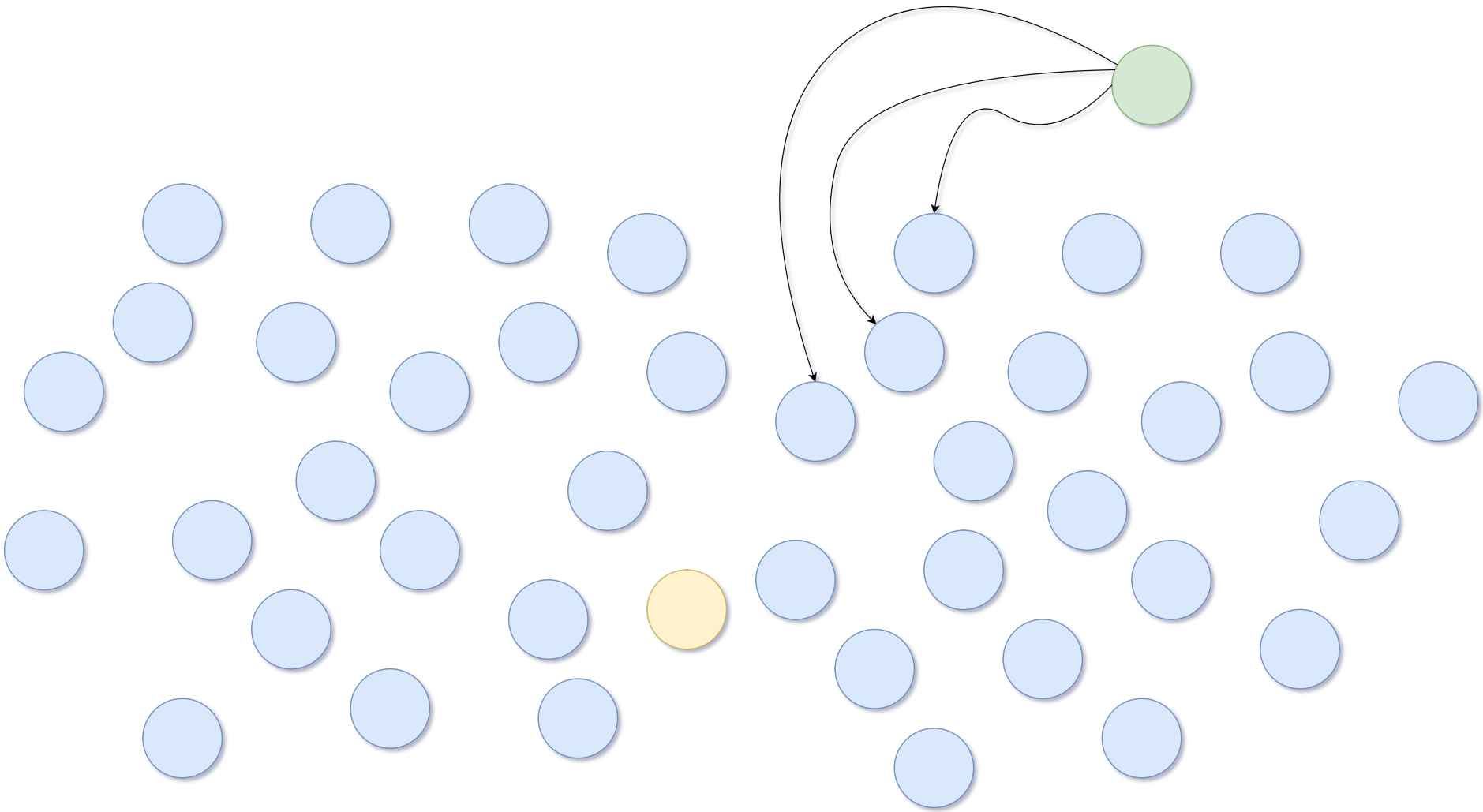

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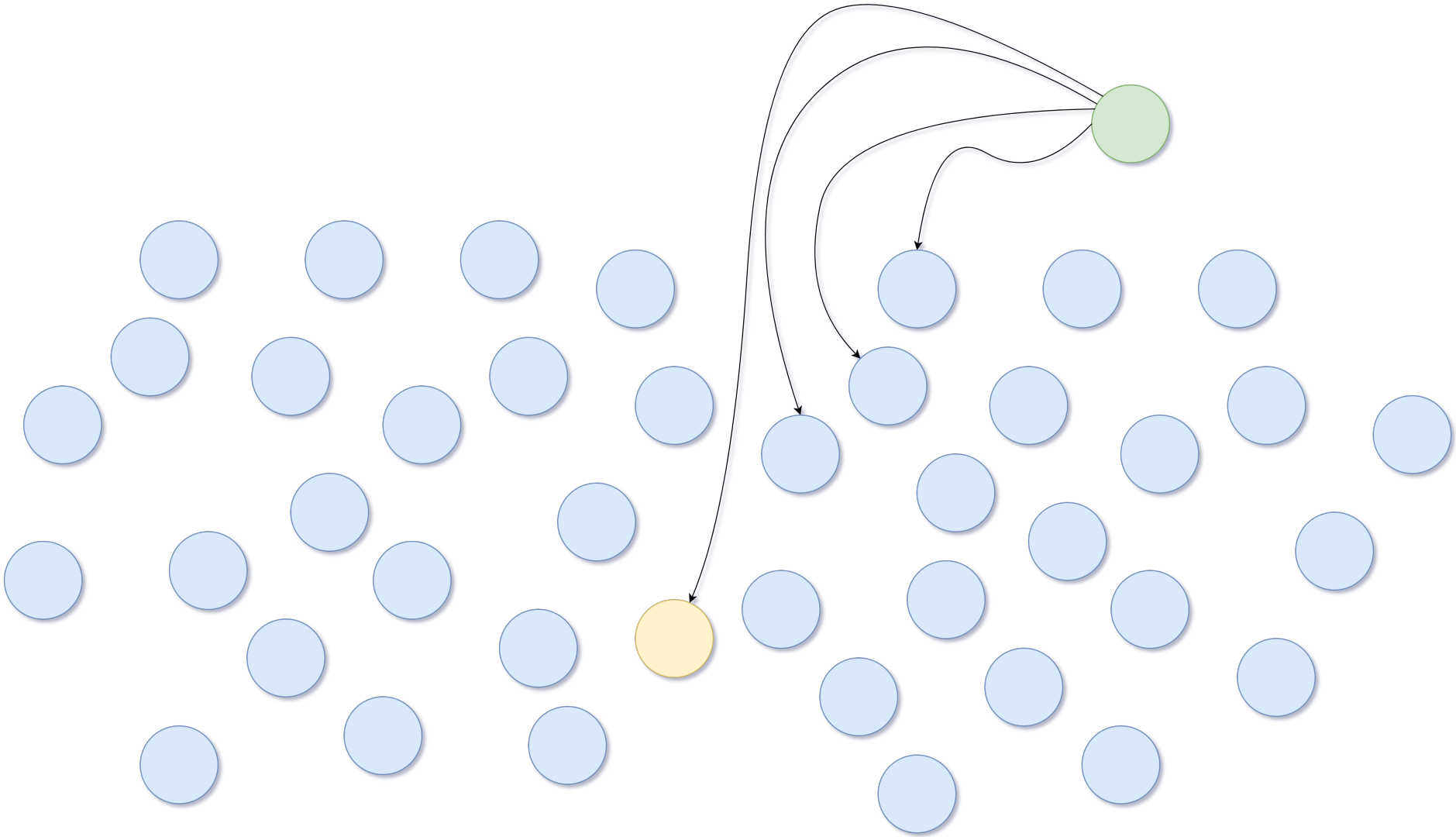


RPC

- For node communication, we defined an RPC protocol living on top of JeroMQ
- We define a multimethod to handle the dispatching of the message
- Kademlia mandates that you have the following RPC commands.
  - PING
  - STORE
  - GET
  - FIND

Section 6

NATs

NATs

- Network Address Translation
  - The feature of your router or firewall that allows you to share a single IP address across many devices.
  - Notoriously hard to work around when doing network applications.

NATs

Petar Maymounkov <petar@maymounkov.or… Mar 8, 2018, 5:53 PM

to me

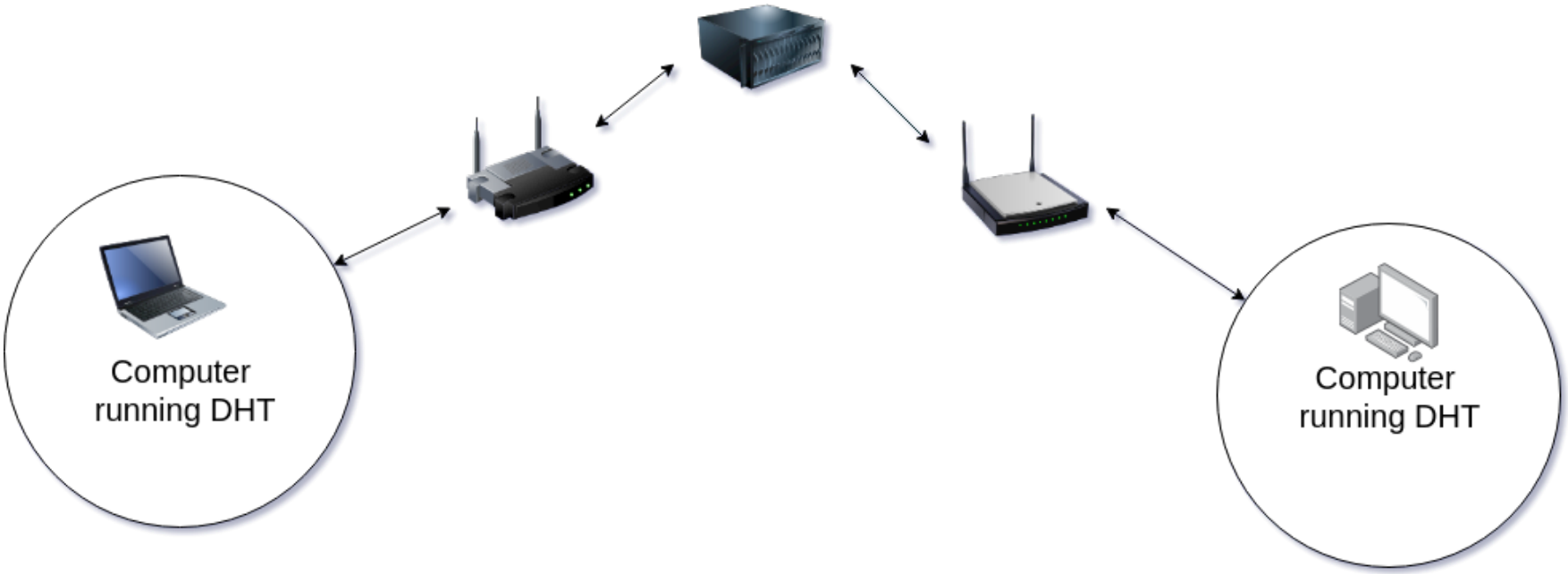
NATs are a hard problem. a few years ago there simply wasn't a good solution in oss. I don't know now. I actually still don't know of a solution on this.

Hole Punching

- External computers don't know how to talk directly to computers within NAT (without a port forward)

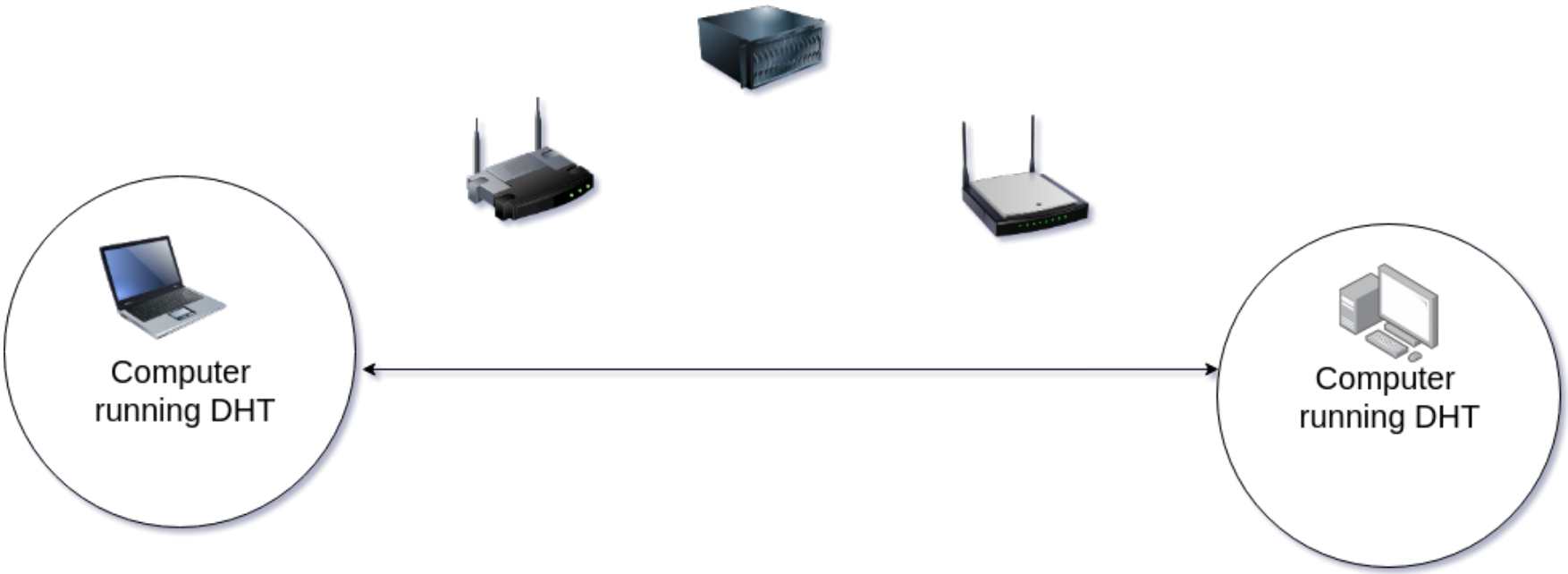
Hole Punching

- One solution, both computers connect to a server



Hole Punching

- Since the socket is open to both computers, the server can stich together a direct connection.



Hole Punching

- In order to keep this decentralized, we use the following algorithm.
  - Any node that has an open port gets priority on the routing table.
  - We maintain one constant connection to a node with an open port per bucket.
  - Each node will consistently publish any nodes with open ports that it has reference to as part of its metadata.
  - When trying to "get" from a closed node, a hole-punch will be attempted through a mutually connected node if it exists.

Changing Data

- It would be a bit of a lame user experience if we don't give the user the ability to update anything.
- Distributed systems can be really difficult to figure out which update happened most recently.

Vector Clock.

- Vector Clocks allow to create a partial ordering of data updates in a distributed system.
- Items are tagged with a counter (independent of wall-time), and this counter is incremented upon each time the information is touched by another entity.
- When two entities have created incompatible updates to data, a conflict is created and it must be resolved.
  - We cheat and during a conflict, we rely on wall-clock time and choose the latest from there.

Section 7

Frontend

A word on JavaScript

- I actually *like* JavaScript.
- JavaScript **punishes** the OOP programmer.
- Forced me to adopt functional programming techniques such as data/function seperation and composition.
- Has significant gaps though:
  - Large parts of the standard library focus around mutation
  - Missing pieces that should be a part of the language but aren't
  - "Pit of Despair" (classes, prototypical inheritence, null vs undefined)

Why ClojureScript?

- Fixes the problems I have with JavaScript while sharing similar philosophy and idioms:
  - Shared design ideology of working with many functions over relatively few data types
  - Embraces "dynamic programming" (dynamic typing, interactivity)
  - Has several useful features that JavaScript is trying to add

Future JavaScript today

- Optional Chaining (https://github.com/tc39/proposal-optional-chaining)
- Pattern Matching (https://github.com/tc39/proposal-pattern-matching)
- Pipeline Operator (https://github.com/tc39/proposal-pipeline-operator)
- Do Expressions (https://github.com/tc39/proposal-do-expressions)
- Protocols (https://github.com/michaelficarra/proposal-first-class-protocols)
- Macros (https://github.com/kentcdodds/babel-plugin-macros)

Other Niceties

- Immutability by default
- Expression-based
- Homoiconicity
- One null type
- No == vs ===

Reframe vs React

- HTML Templating:
  - React's JSX brings the pain of HTML into JavaScript
  - Awkward escapement rules trip up newbies
  - Reframe's use of native data structures largely sidesteps these issues
- State Management:
  - Reframe is a similar model to Redux, but with far less headaches
  - Out of the box support for returning effects, including async
  - Generally more consise and straightforward to write

Section 8

Roadmap

In Progress

- Formal verification of the system using TLA+.
- Tonika Routing to prevent against potential attacks.
- Allowing for "private" videos by employing the use of GPG.
- Using blockchain (or something similar) to incentivize people to open up ports and/or donate their CPU for more interesting computation tasks.

Section 9

Further Reading!

Links

Kademlia Paper

Feross Aboukhadijeh's talk

Contact

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  - gitlab.com/nrmisturak

Section 10

Demo

Demo