Collections, Part Two

Today

- Short Review From Last Week
- `Vector`
- `Grid`
- `Vector` Performance
- Containers: Common mistakes

From Last Week…

A **recursive solution** is a solution that is defined in terms of itself.

Recursion: Fibonacci Numbers

- Fibonacci Numbers
  - 0, 1, 1, 2, 3, 5, 8, 13, 21, …
  - Defined *recursively*:

$$fib(\mathrm{n}) = \begin{cases} \mathrm{n} & \text{if n = 0 or 1} \\ fib(\mathrm{n-1}) + fib(\mathrm{n-2}) & \text{otherwise} \end{cases}$$

Another View of Factorials

$$n! = \begin{cases} 1 & \text{if } n = 0 \\ n \times (n - 1)! & \text{otherwise} \end{cases}$$

```
int factorial(int n) {
    if (n == 0) {
        return 1;
    } else {
        return n * factorial(n - 1);
    }
}
```

TokenScanner

- The **`TokenScanner`** class can be used to break apart a string into smaller pieces.
- Construct a `TokenScanner` to piece apart a string as follows:

```
TokenScanner scanner(str);
```

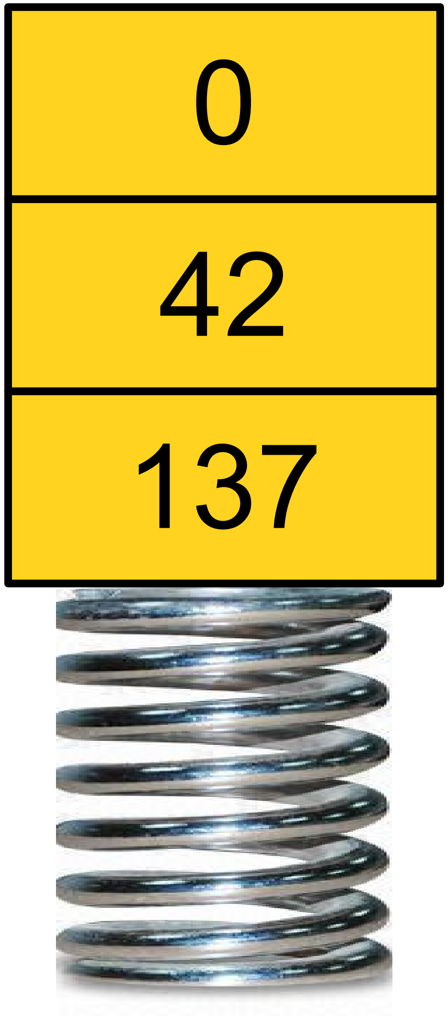
- Configure options (ignore comments, ignore spaces, add operators, etc.)
- Use the following loop to read tokens one at a time:

```
while (scanner.hasMoreTokens()) {
    string token = scanner.nextToken();
    /* … process token … */
}
```

- Check the documentation for more details; there are some really cool tricks you can do with the `TokenScanner`!

Stack

- A **`Stack`** is a data structure representing a stack of things.
- Objects can be **pushed** on top of the stack or **popped** from the top of the stack.
- Only the top of the stack can be accessed; no other objects in the stack are visible.
- Example: Function calls



Vector

Vector

- The **`Vector`** is a collection class representing a list of things.
  - Similar to Java's `ArrayList` type.
- Probably the single most commonly used collection type in all programming.

Example: Cell Tower Purchasing

Buying Cell Towers

137

42

95

272

52

Buying Cell Towers

137	42	95	272	52

Buying Cell Towers

14 22 13 25 30 11 9

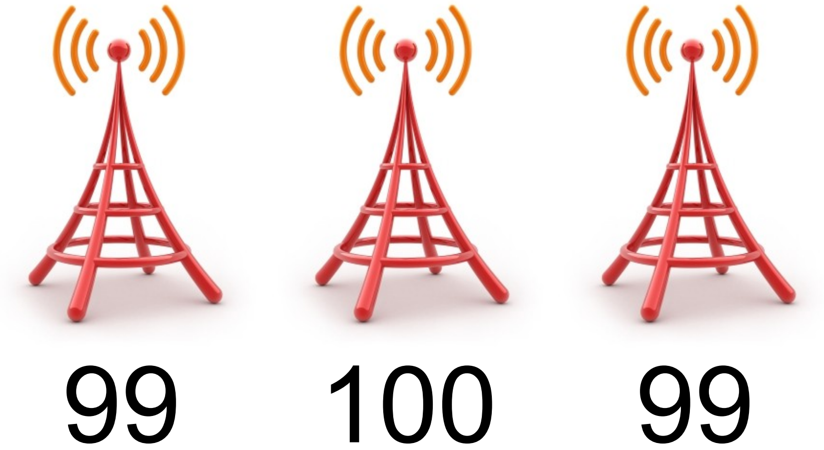
Buying Cell Towers

🟩 14	🟥 22	🟩 13	🟥 25	🟩 30	🟥 11	🟩 9

Buying Cell Towers

- Given the populations of each city, what is the largest number of people you can provide service to given that no two cell towers are adjacent?
- Proposed Algorithm: Iteratively pick the “largest population” cell towers from the set of remaining towers we can select
  - Problems with this algorithm?

Proposed Algorithm: Problem



Proposed Algorithm: Problem

🟩 99	🟥 100	🟩 99

Buying Cell Towers

- Our proposed algorithm won't always give us the correct answer!
- Correct algorithm is best explained pictorially...

14

22

13

25

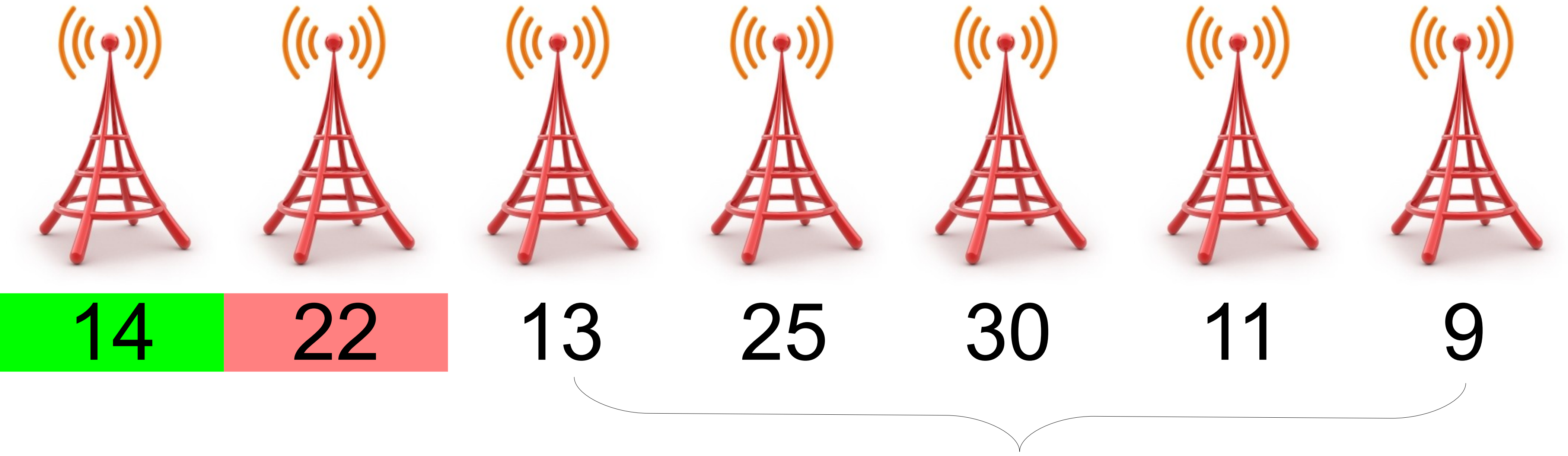
30

11

9

14	22	13	25	30	11	9

14	22	13	25	30	11	9



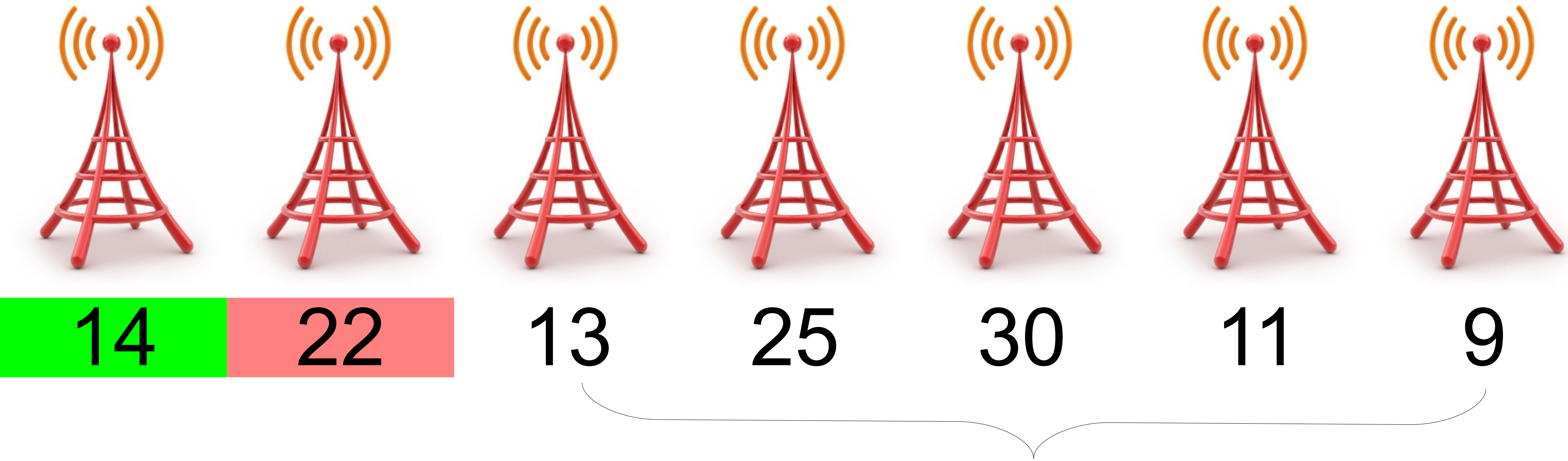
14	22	13	25	30	11	9

Maximize what's left in here.

14	22	13	25	30	11	9

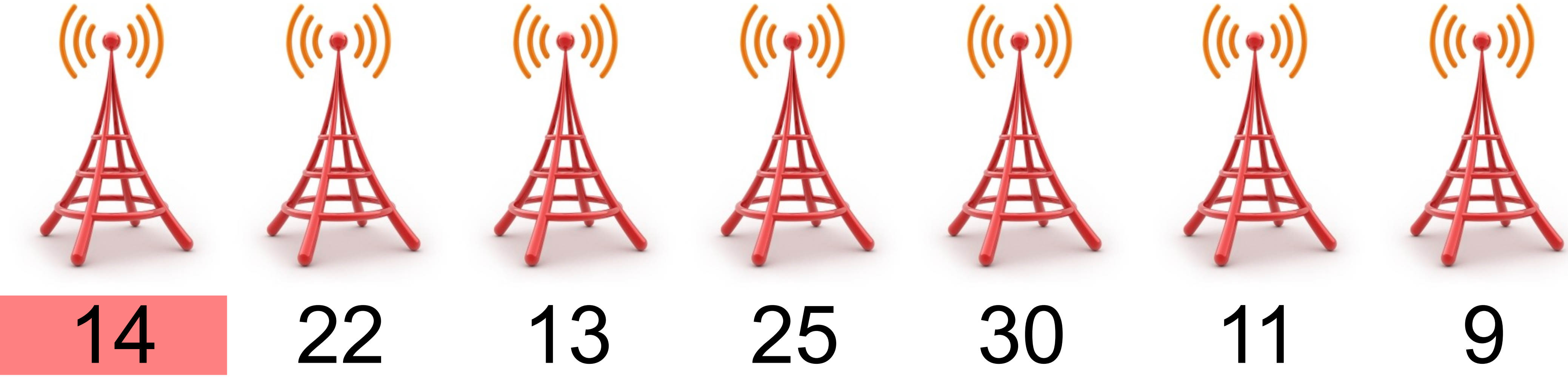
Maximize what's left in here.

14	22	13	25	30	11	9

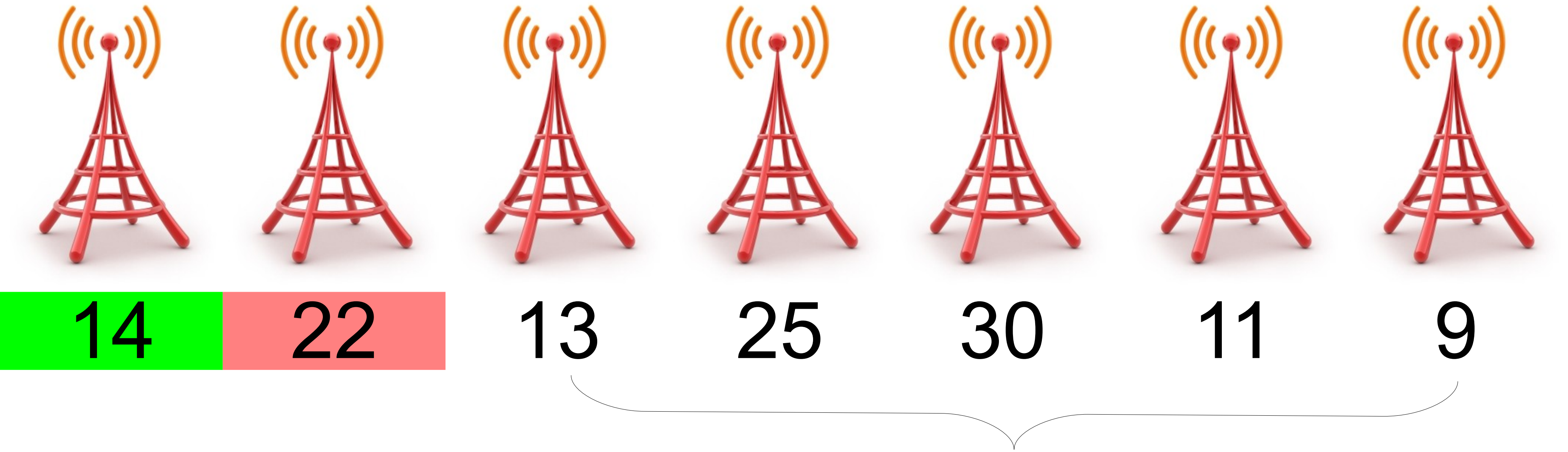


🟩 14	🟥 22	13	25	30	11	9

Maximize what's left in here.

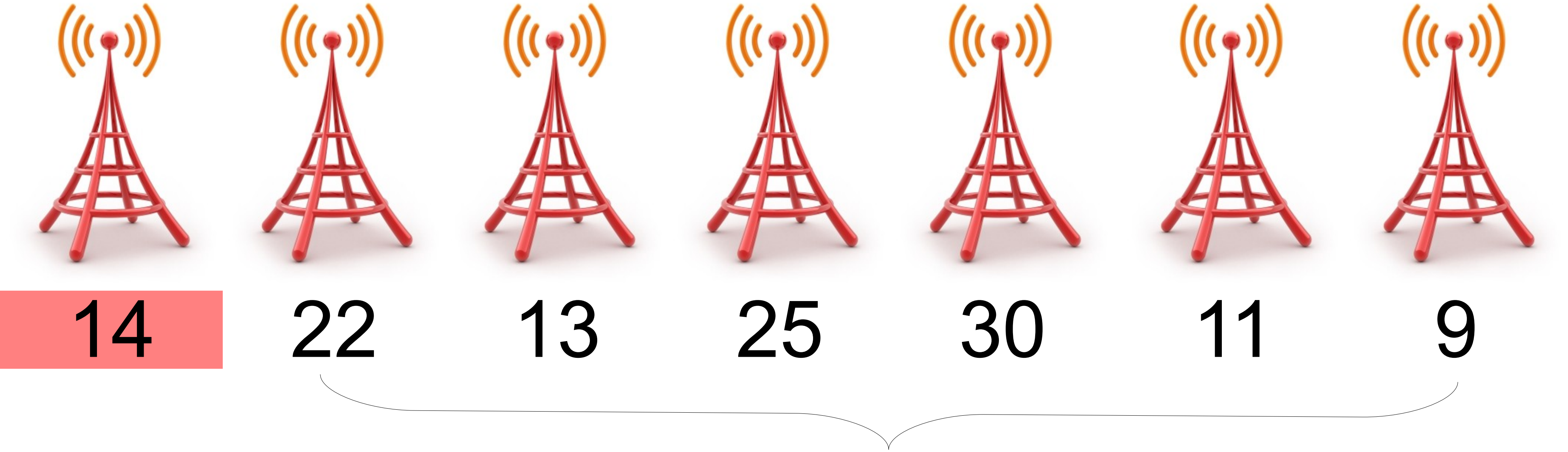


🟥 14	22	13	25	30	11	9



14 22 13 25 30 11 9

Maximize what's left in here.



14 22 13 25 30 11 9

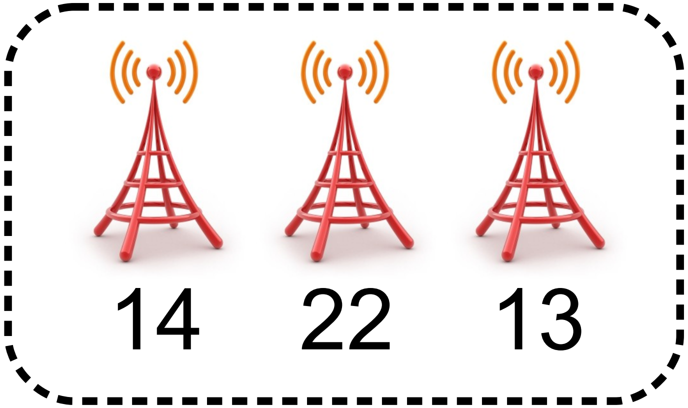
Maximize what's left in here.

`Cell-towers` Pseudocode (On Board)

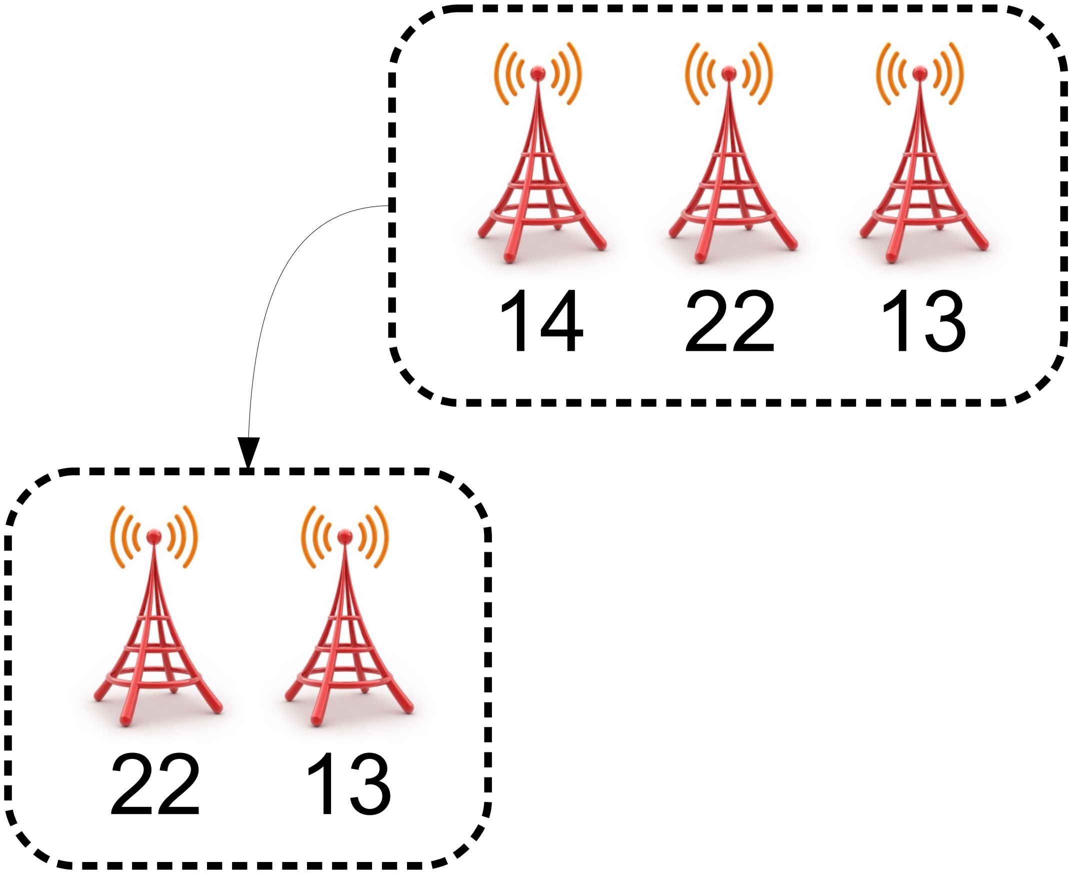
`cell-towers.cpp`

(On Computer)

How the Recursion Works



How the Recursion Works



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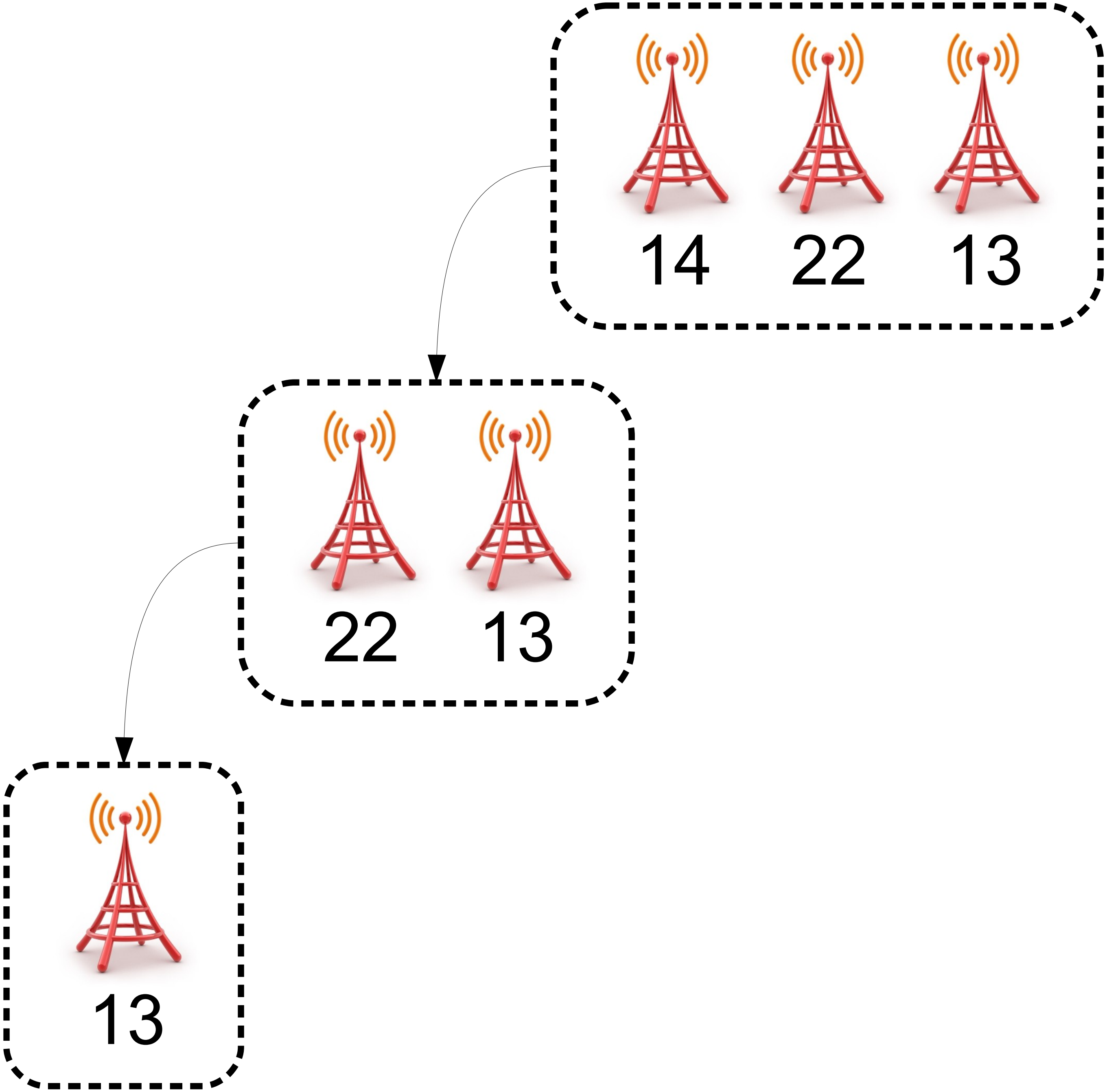

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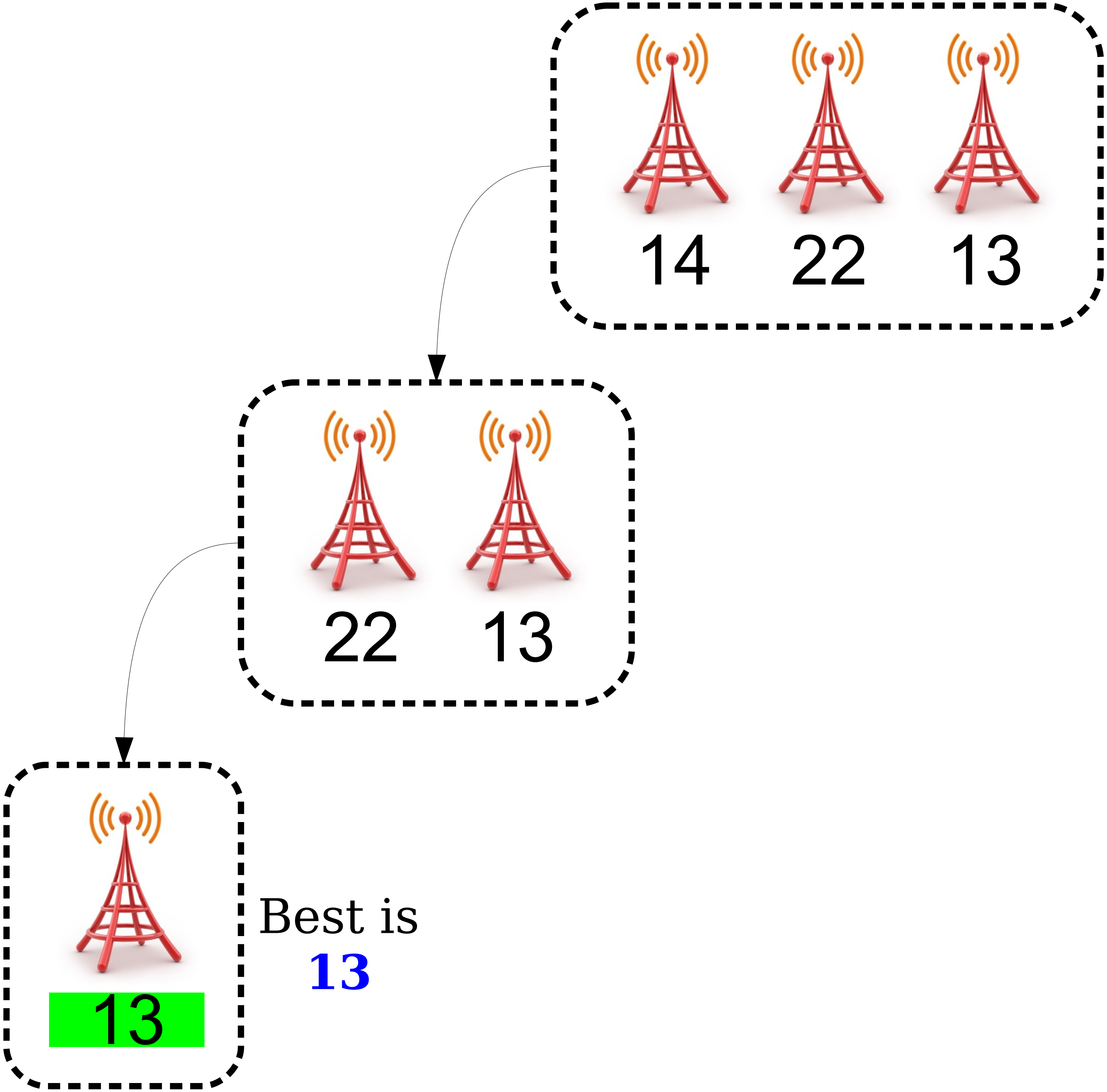
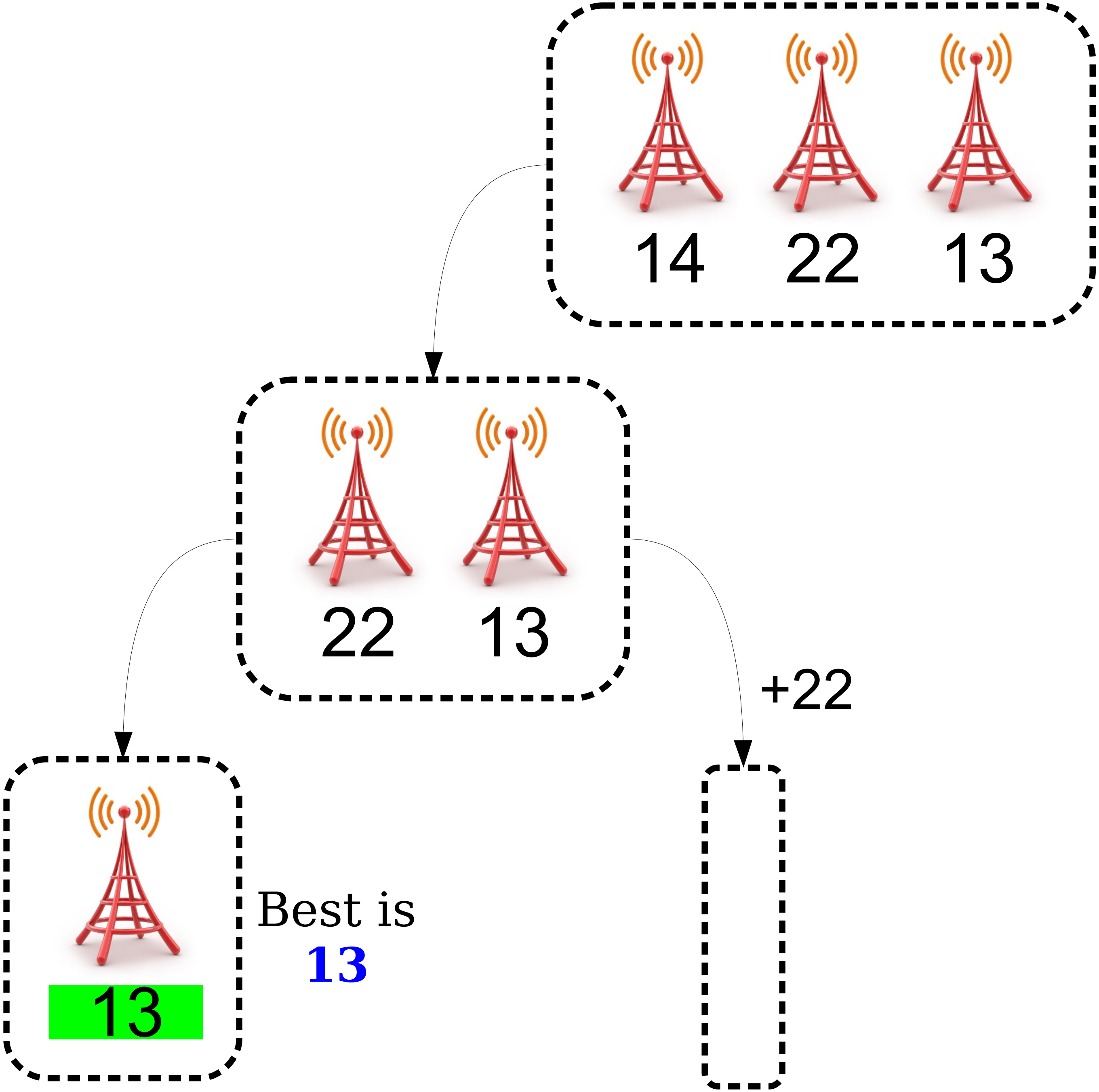


Best is
13

How the Recursion Works



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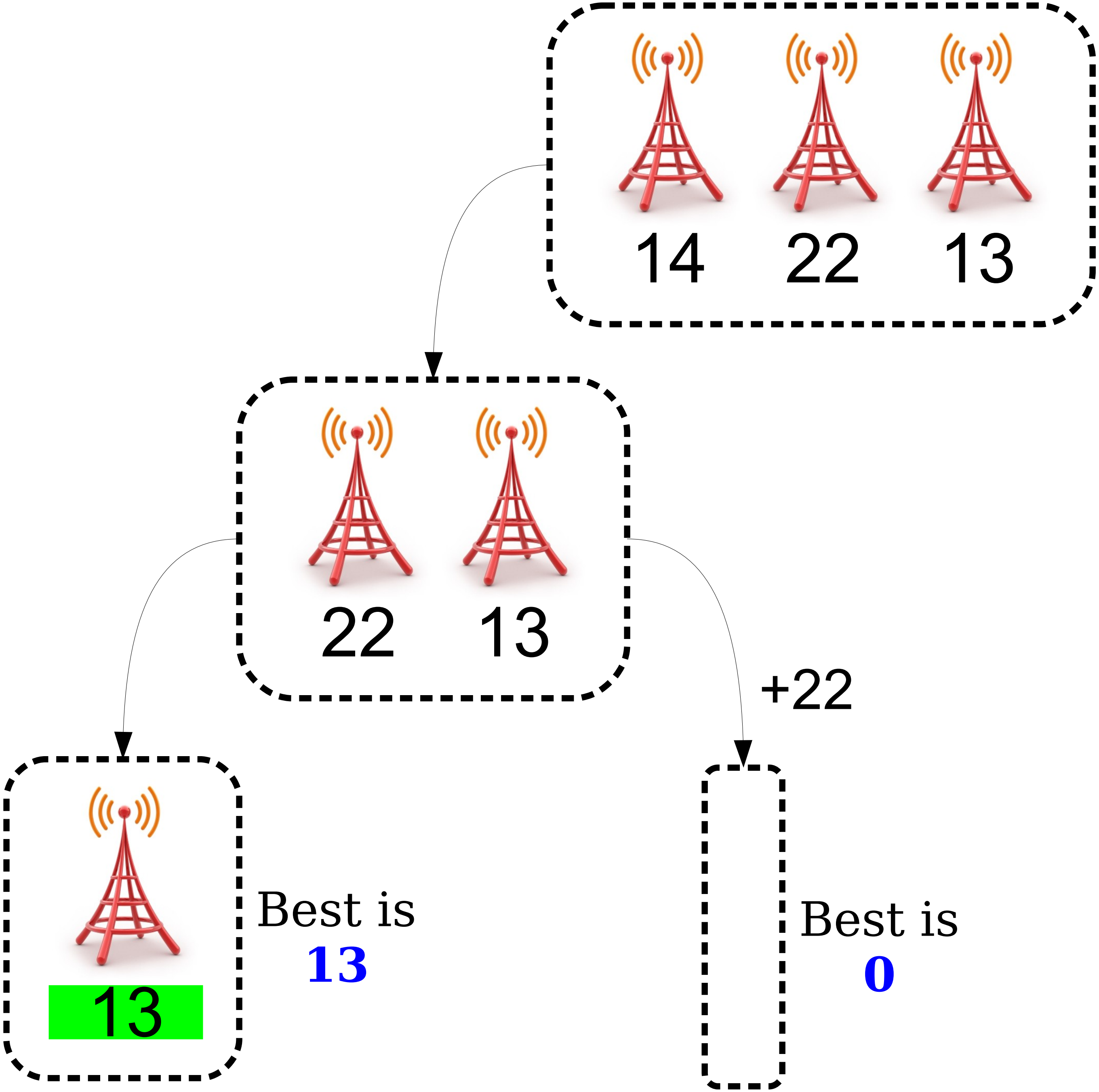


14 22 13

22 13

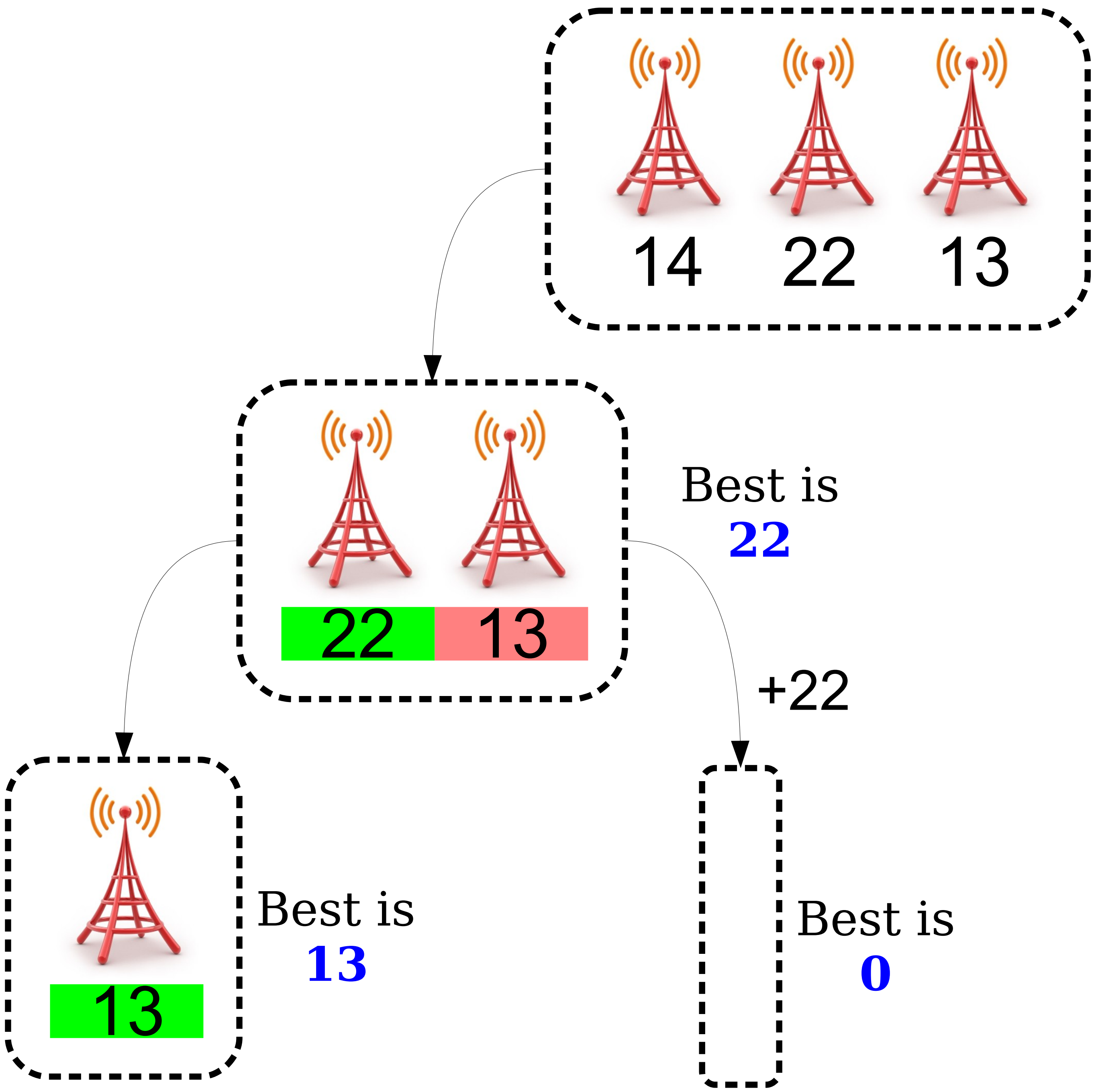
+22

13

Best is
13

Best is
0

How the Recursion Works



14 22 13

22 13

Best is
22

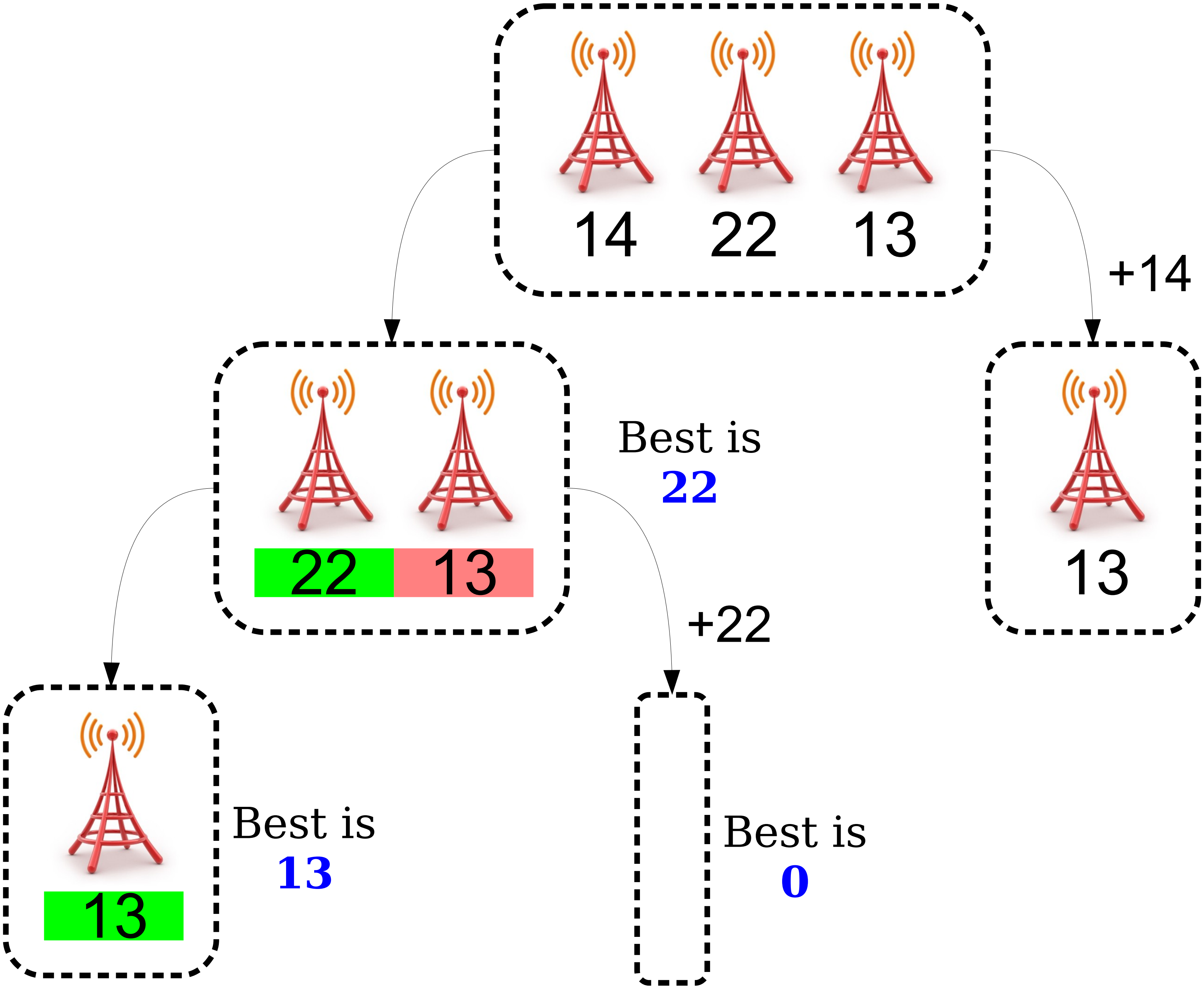
+22

13

Best is
13

Best is
0

How the Recursion Works



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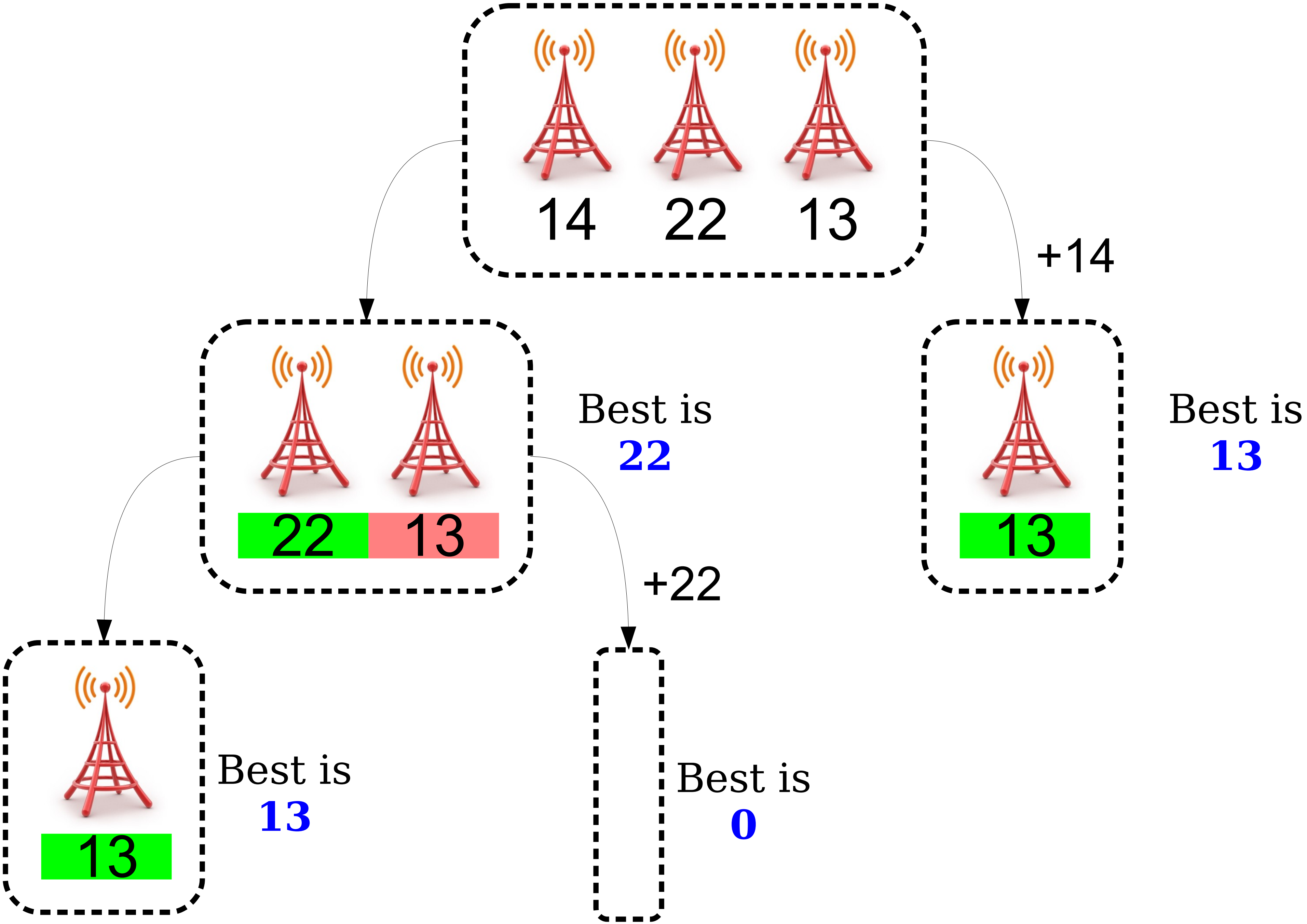


14 22 13

+14

22 13

Best is
22

13

Best is
13

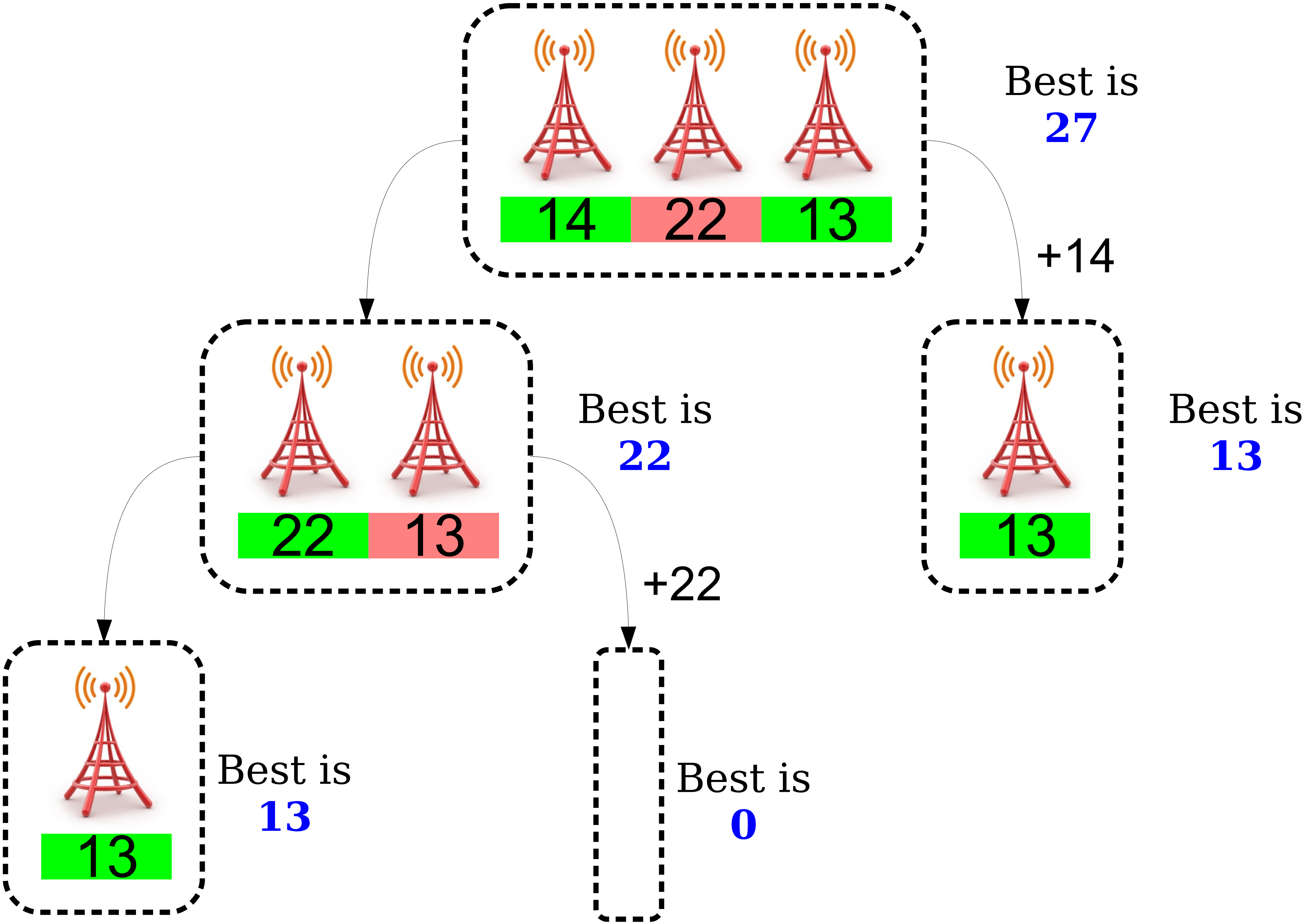
+22

13

Best is
13

Best is
0

How the Recursion Works



14 22 13

Best is
27

+14

22 13

Best is
22

13

Best is
13

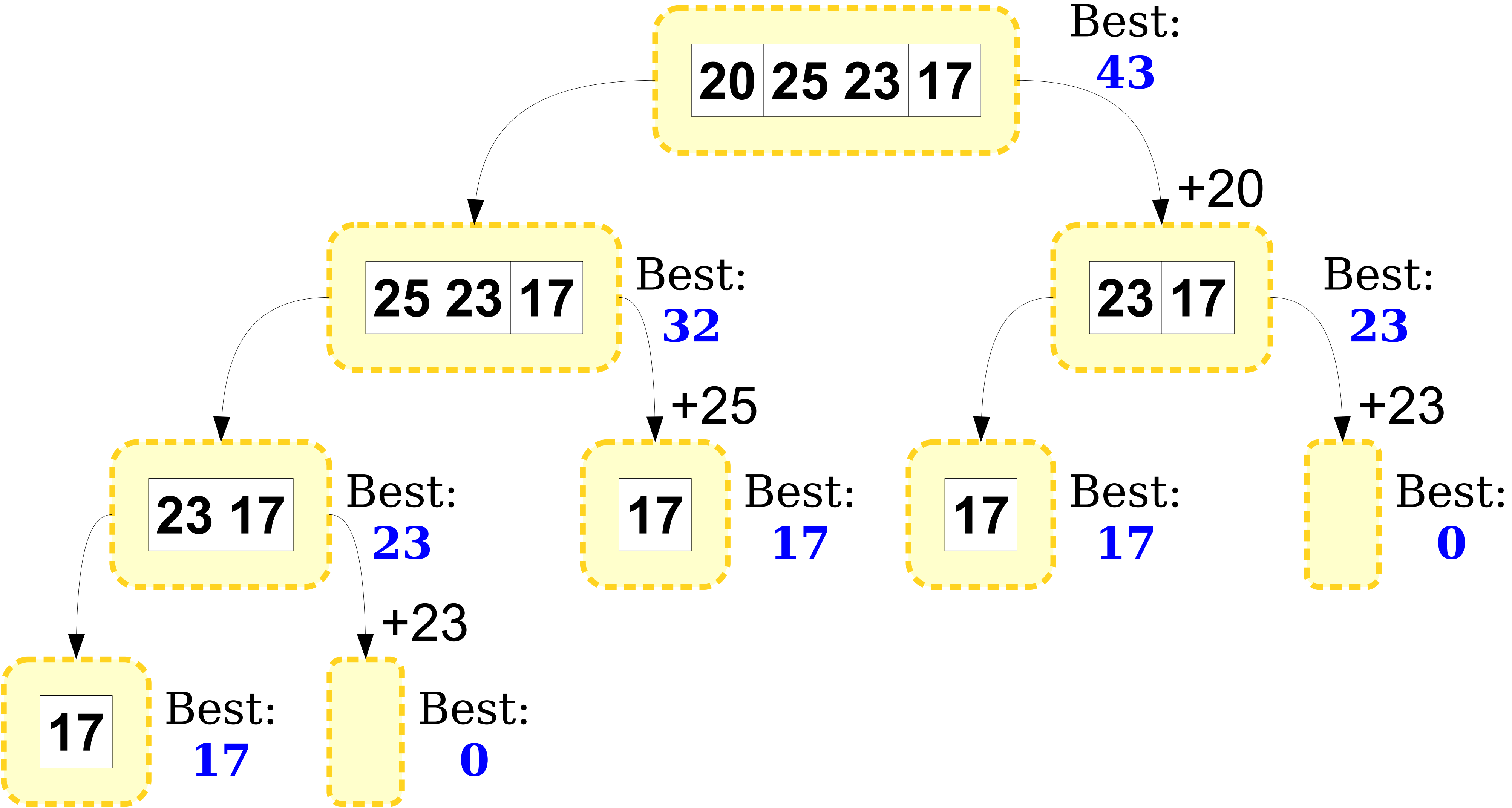
+22

13

Best is
13

Best is
0

How the Recursion Works



Pass-by-Reference and Objects

- Recall: In C++, *all* parameters are passed by value unless specified otherwise.
- Passing by value makes a *copy* of the parameter
- When using container types (**`Stack`**, **`Vector`**, etc.) it is often useful to use pass-by-reference for efficiency reasons.
  - Takes a *long* time to make a copy of a large collection!
  - Let's see what happens when we do this for `cell-towers.cpp`!

`Vector` or `Stack`?

- Any `Stack` can be replaced with a `Vector` with which we only add and remove from the back.
    - So why should we ever use a `Stack`?
    - Hint: It's not for performance reasons

`Vector` or `Stack`?

- Reason 1: It makes your code easier to read
  - Someone reading your code knows that you are only going to read and add to the top of the `Stack`.
- Reason 2: It protects you from making mistakes
  - If you use a `Vector`, you might accidentally add/read/remove from the middle instead of the end.
- Summary: Use `Stack` when the algorithm lets you, otherwise use `Vector`

Grid

Two-Dimensional Data

- The **`Grid`** type can be used to store two-dimensional data.
  - e.g. matrices, scrabble boards, etc.
- Can construct a grid of a certain size by writing

```
Grid<Type> g(numRows, numCols);
```

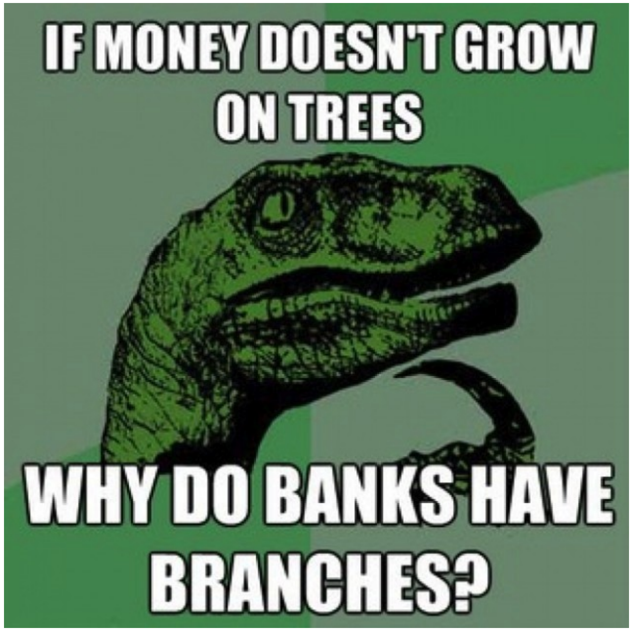
- Can access individual elements by writing

```
g[rows][cols]
```

Stanford is not as safe as it seems…

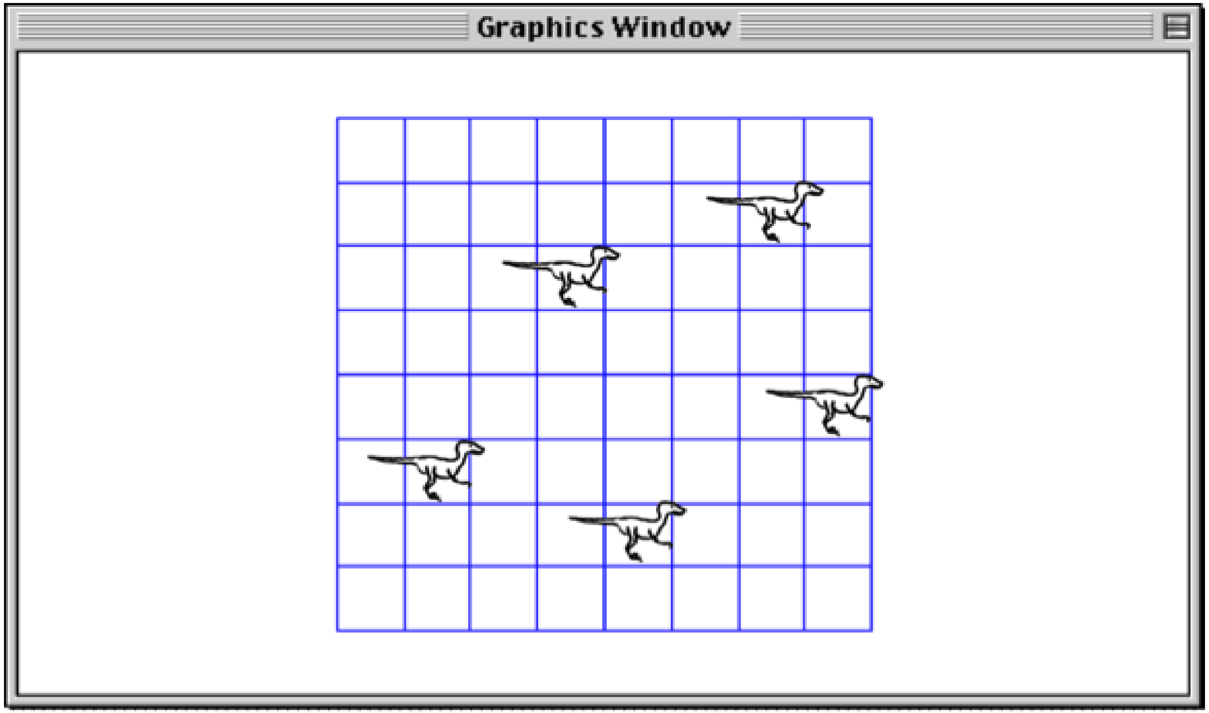
Velociraptors Spotted on Campus!

- Everyone knows how dangerous velociraptors are, but not everyone knows how to survive an attack.



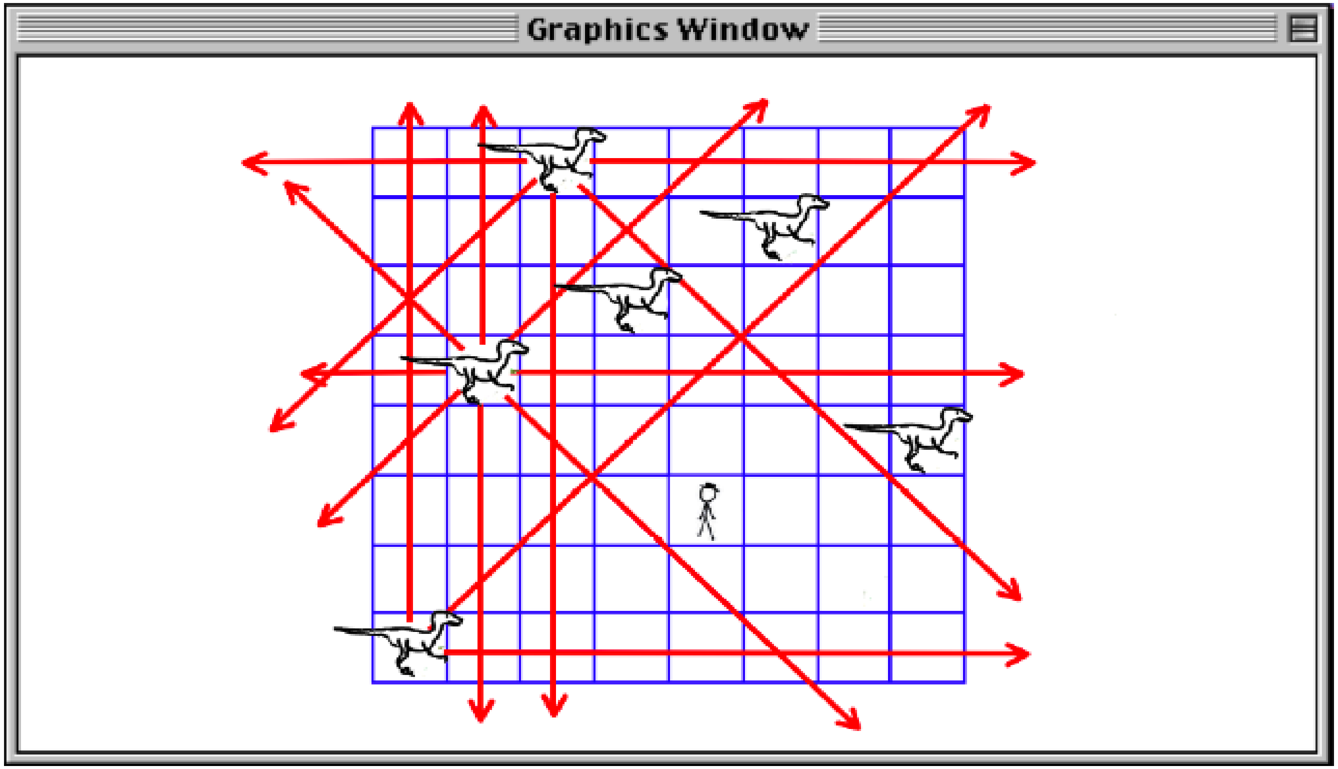
Good News

- Luckily, velociraptors are constrained to exist on cells of a Grid!



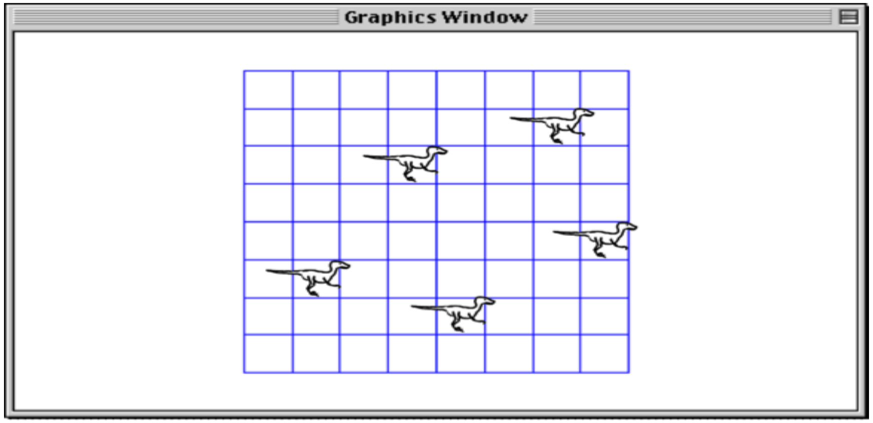
Good News

- Also, velociraptors can only move in the 8 cardinal and ordinal directions



Good News

- A natural question arises – given a grid of locations of velociraptors, is there a position on the grid that is safe?



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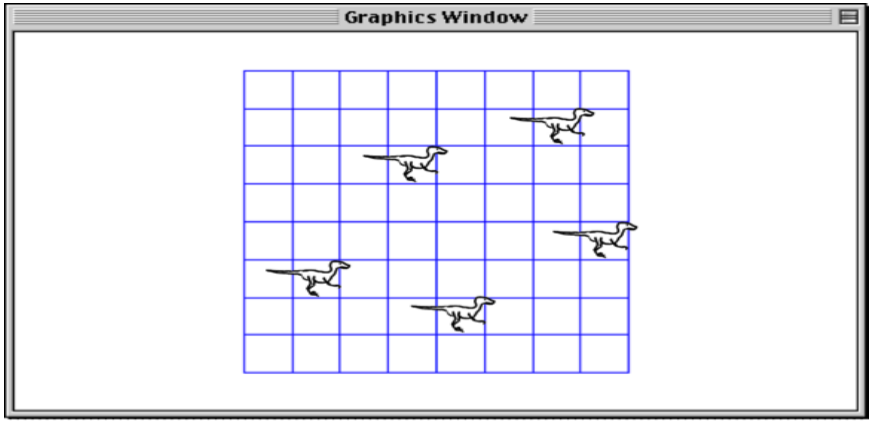
- A natural question arises – given a grid of locations of velociraptors, is there a position on the grid that is safe?
- Represent the grid with...a **`Grid<bool>`** where **`true`** indicates that a velociraptor is there.



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- Represent the grid with…a **`Grid<bool>`** where **`true`** indicates that a velociraptor is there.

F	F	F	F	F	F	F	F
F	F	F	F	F	F	T	F
F	F	F	T	F	F	F	F
F	F	F	F	F	F	F	F
F	F	F	F	F	F	F	T
F	T	F	F	F	F	F	F
F	F	F	F	T	F	F	F
F	F	F	F	F	F	F	F

`raptor-defense.cpp`
(Computer)

`Grid` or `Vector<Vector >`?

- Any `Grid` can be replaced with a `Vector<Vector >` in which we make the length of the “inner vectors” equal
  - So why should we ever use a `Grid`?
- For reasons similar to the “`Vector` or `Stack`” decision:
  - Easier to read.
  - Less likely to make a mistake.

`Vector` Performance

- Where you add/remove from a `Vector` can have a huge performance impact

Vector Performance?

```
Vector<int> myVector;
for (int i = 0; i < 1000; i++)
  myVector[i] = 0;
```

vs

```
Vector<int> myVector;
for (int i = 0; i < 1000; i++)
  myVector.insert(0,i);
```

Vector Performance

- Why was this?
  - When you remove (or insert) at the beginning of a **`Vector`**, all the other elements in the **`Vector`** must be shifted over
  - This can have big performance consequences
    - We will learn about other data structures that solve this
- It turns out, reading from a **`Vector`** takes the same amount of time no matter where you read from
  - We'll learn why later in the quarter

Collections: Common Pitfall 1

```
Vector numbers;
```

Collections: Common Pitfall 1

```
Vector<int> numbers;
```

Collections: Common Pitfall 2

```
Vector<Vector<int>> numbers;
```

Collections: Common Pitfall 2

```
Vector<Vector<int> > numbers;
```

Collections: Common Pitfall 3

```
void myFunction(Grid<bool> bigGrid);
```

Collections: Common Pitfall 3

```
void myFunction(Grid<bool> &bigGrid);
```

Next Time

- **`Map`**
  - A collection for storing associations between elements.
- **`Set`**
  - A collection for storing an unordered group of elements.
- **`Lexicon`**
  - A special kind of **`Set`**.