Faster Applications

Minko Gechev

rhyme

Minko Gechev

mgechev

Functional time traveler.

California, USA

http://blog.mgechev.com/

Organizations

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angular-style-guide

Set of best practices for Angular application development

★ 5k 744

angular-seed

Modular starter project for Angular 2 (and beyond) with statically typed build and AoT compilation

TypeScript ★ 4.5k 1.7k

codelyzer

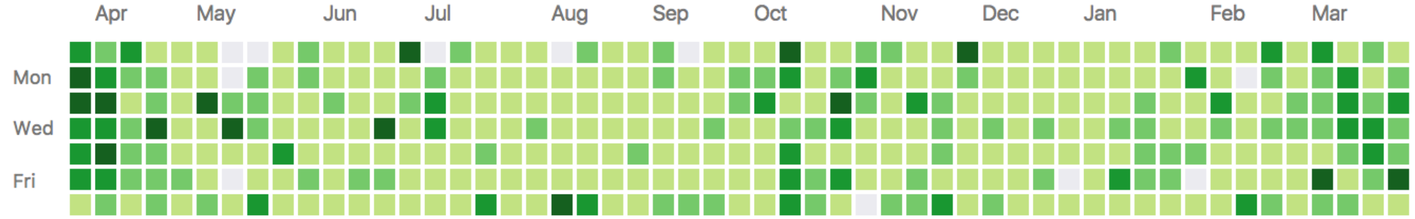
Linting for Angular projects.

TypeScript ★ 1.4k 133

angular/mobile-toolkit

JavaScript implementation of different computer science algorithms.

TypeScript ★ 1,104 150



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github.com/**mgechev**


Minko Gechev
Foreword by Miško Hevery, Creator of AngularJS and Angular
Switching to Angular
Third Edition
Align with Google's long-term vision for Angular versi
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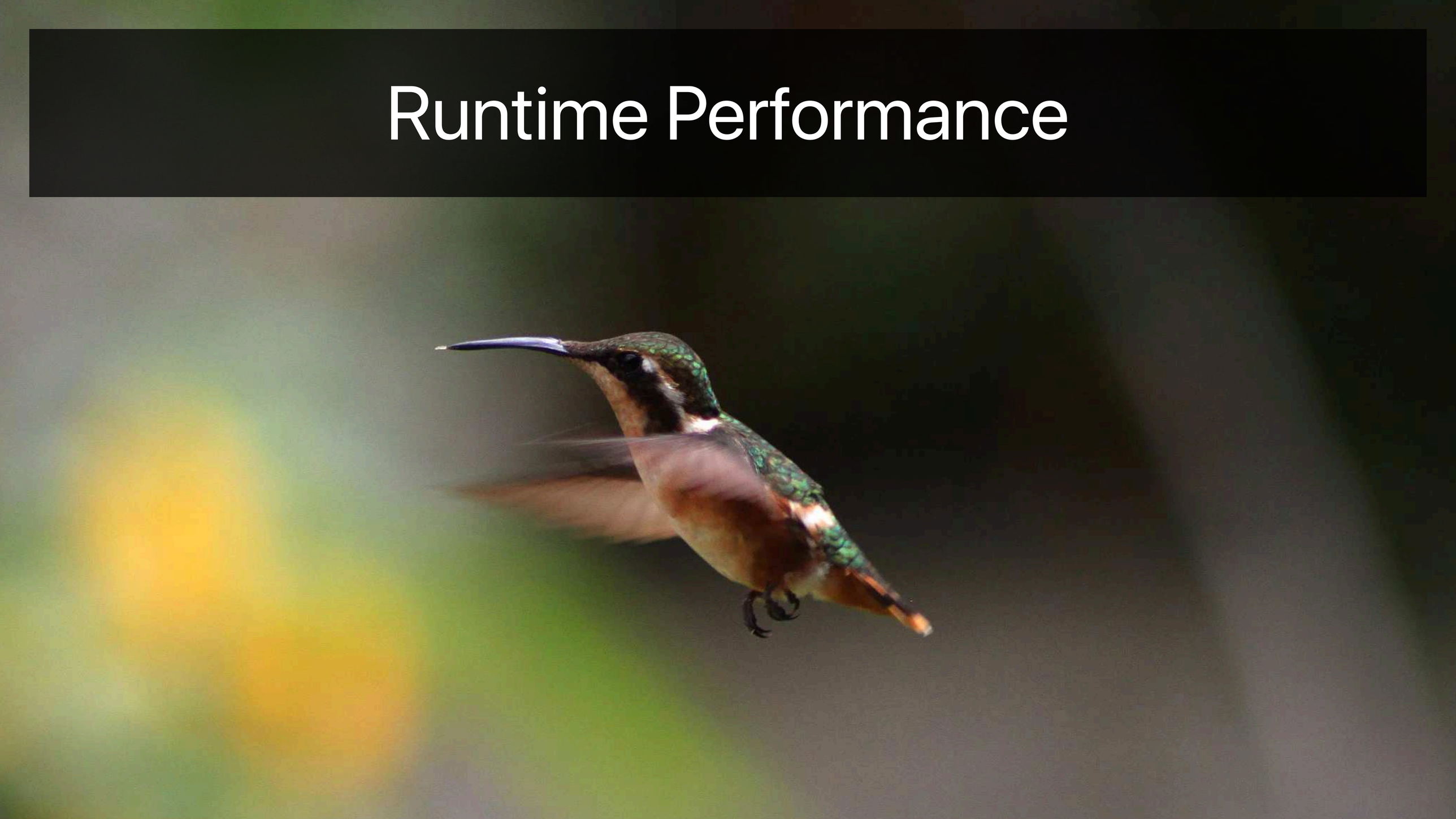
Runtime Performance



Simplified

Business application

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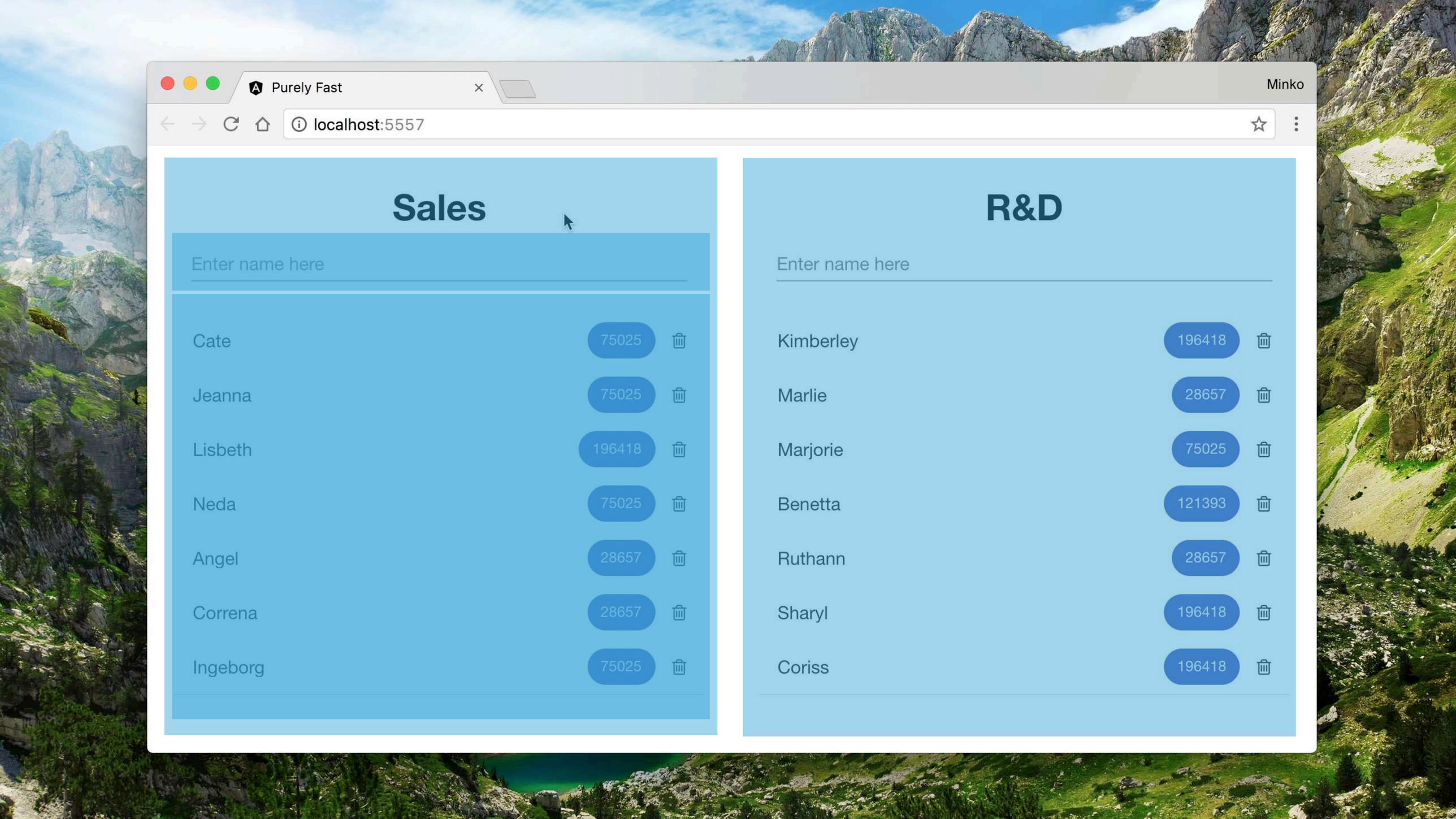
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Lisbeth 196418
Neda 75025
Angel 28657
Correna 28657
Ingeborg 75025
R&D
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Marlie 28657
Marjorie 75025
Benetta 121393
Ruthann 28657
Sharyl 196418
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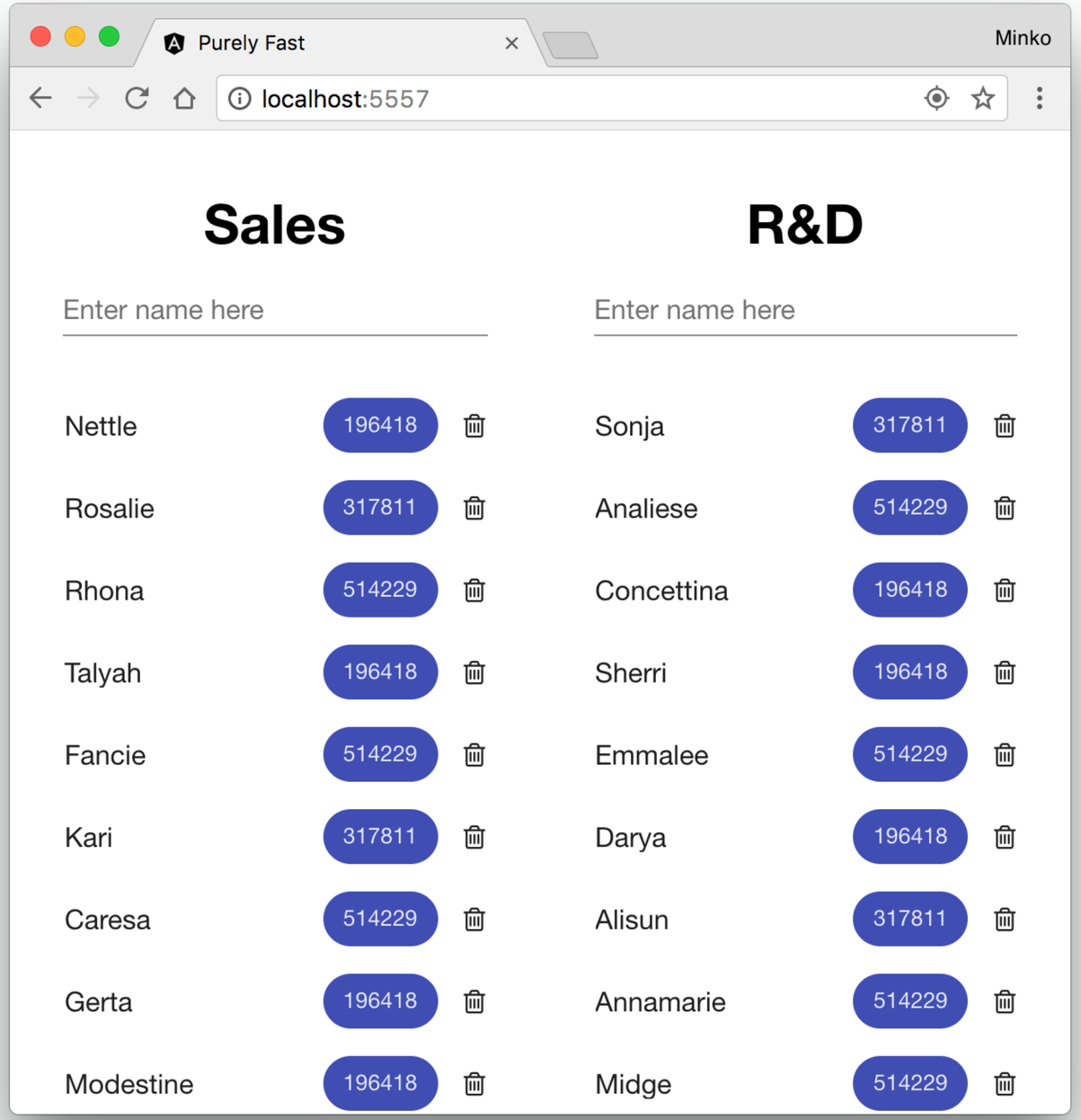
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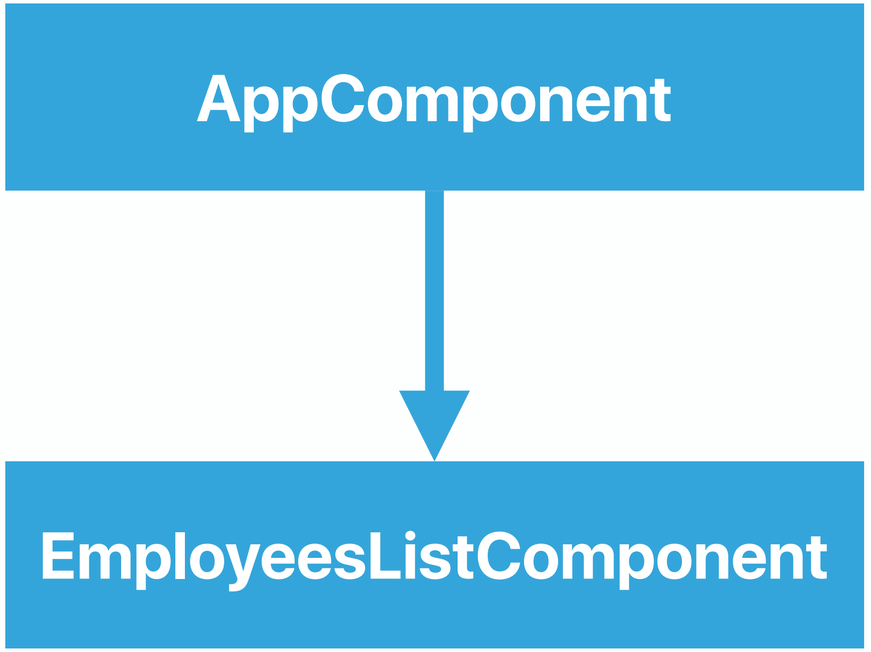
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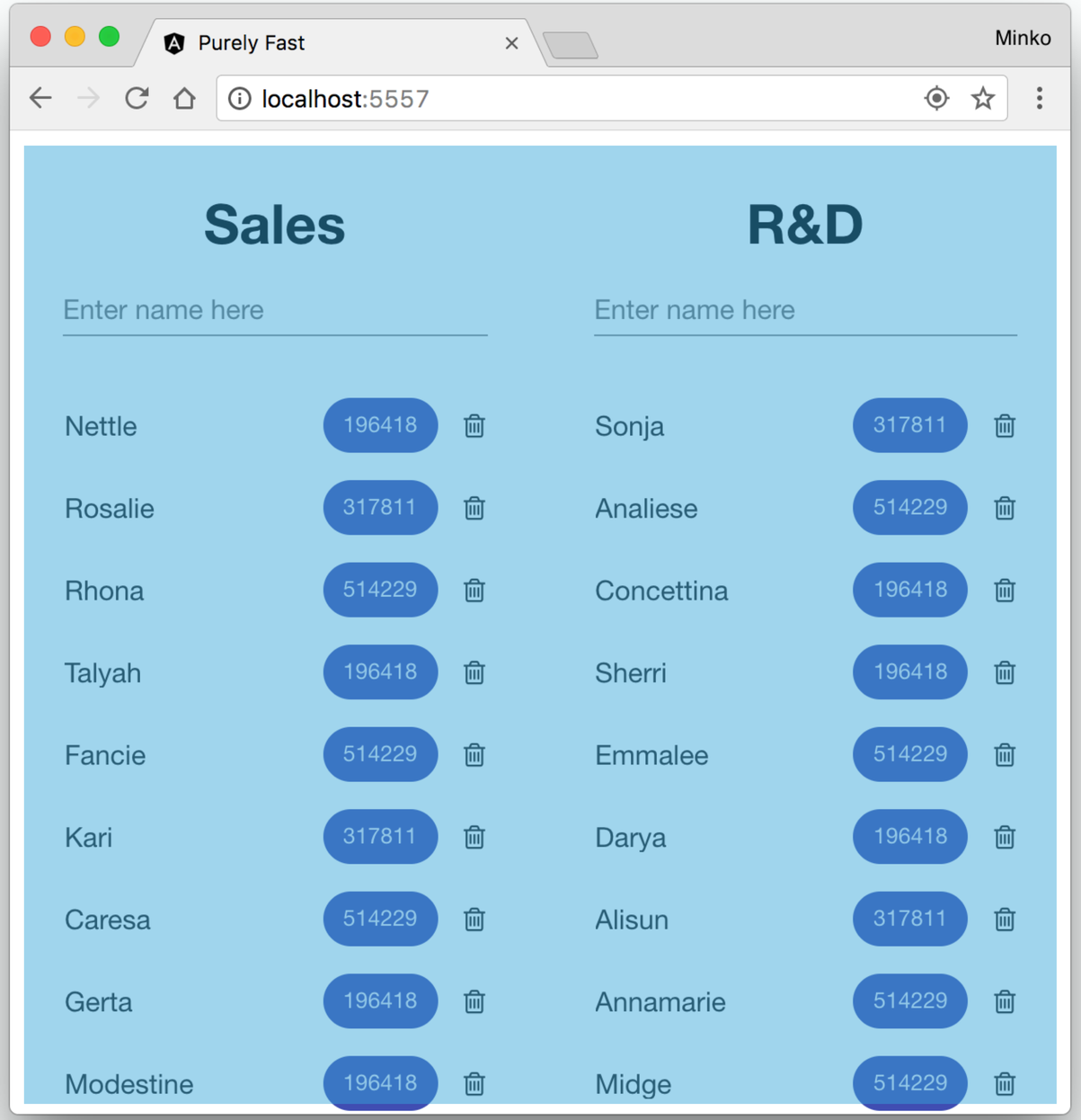
EmployeesListComponent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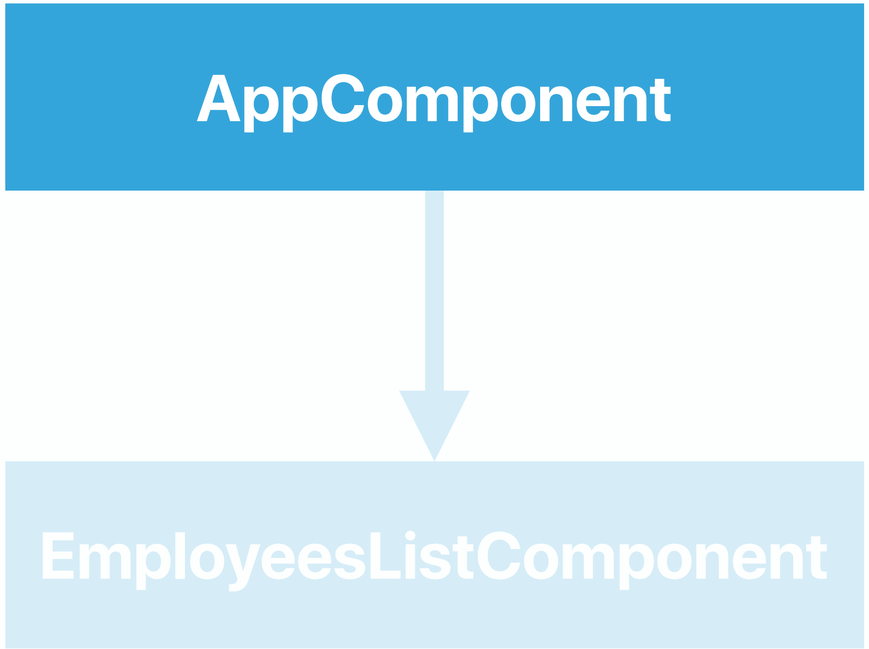
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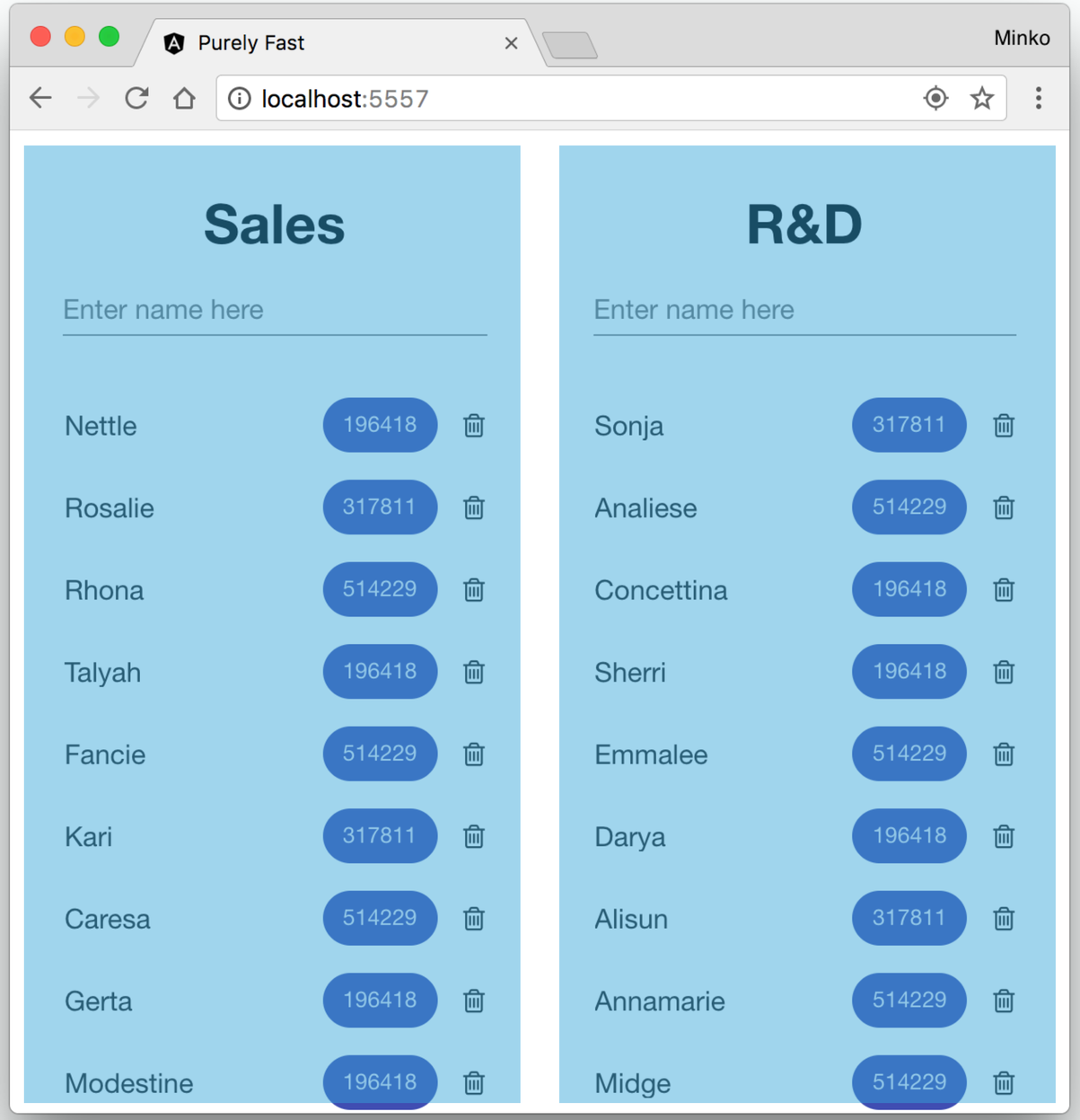
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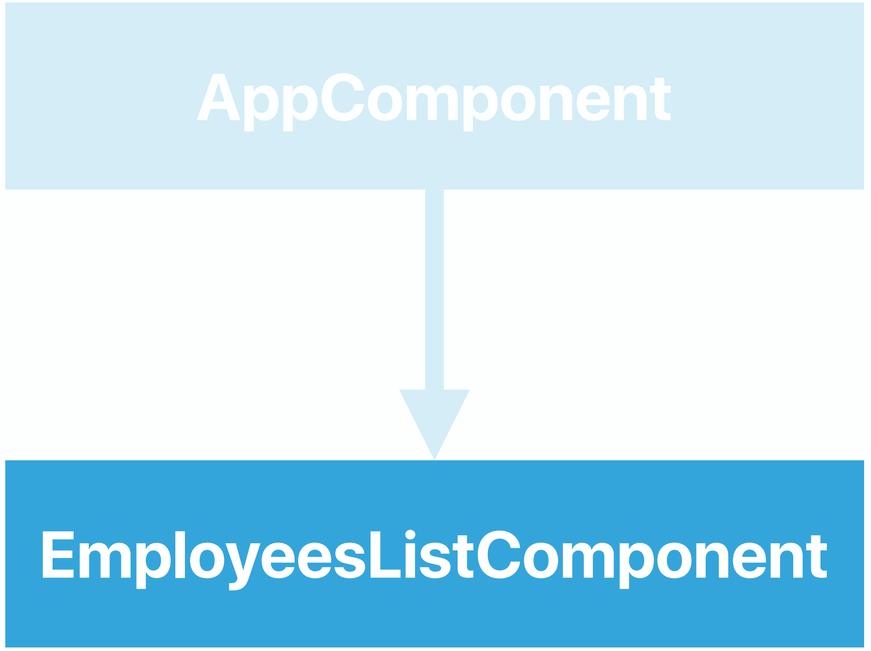

AppComponent
EmployeesListComponent

Sales

Enter name here

Jeanna	75025
Carla	196418
Ezmeralda	121393
Karena	196418
Birdie	28657
Angy	75025
Rennie	121393
Lidia	46368

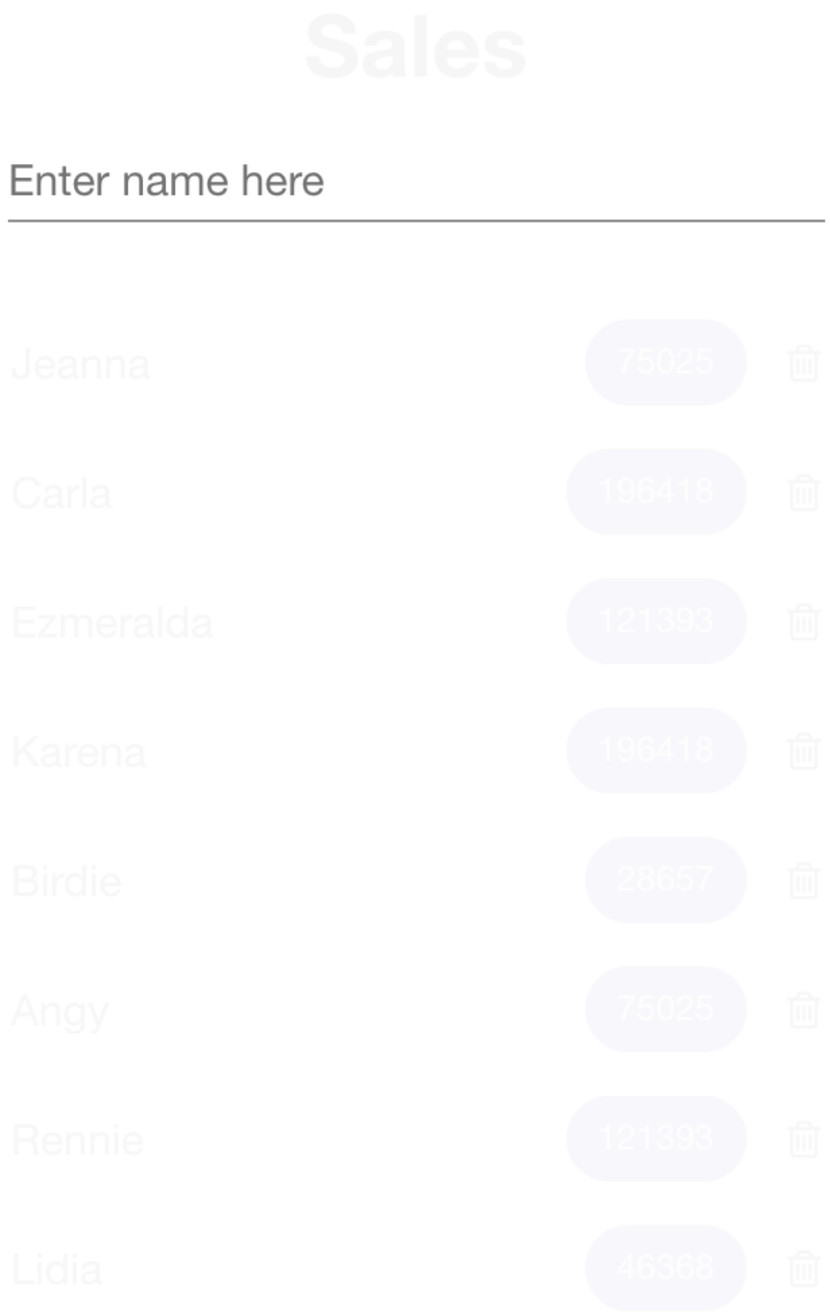
```
<input [(ngModel)]="label"
  (keydown)="handleKey($event)">

<mat-list-item
  *ngFor="let item of data">

  {{ item.label }}

  {{ calculate(item.num) }}

</mat-list-item>
```

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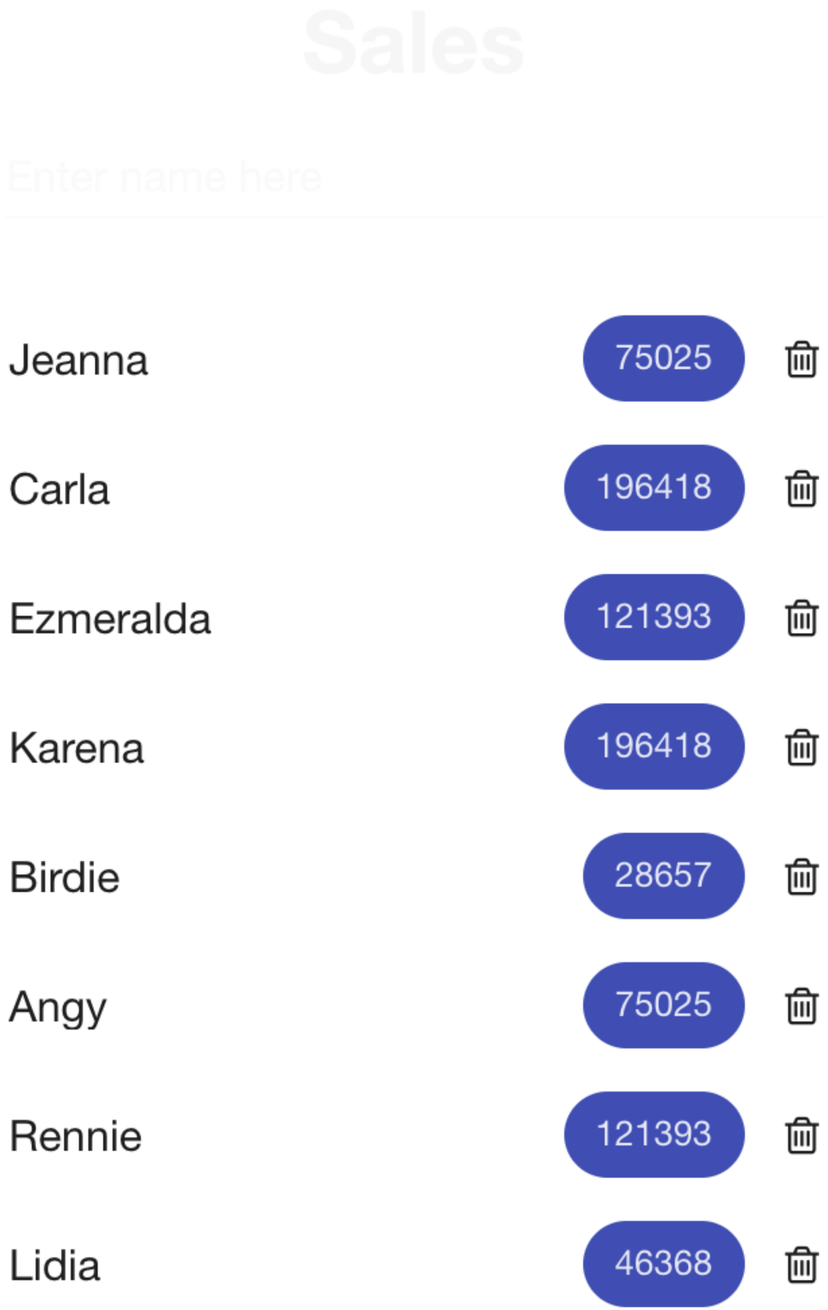


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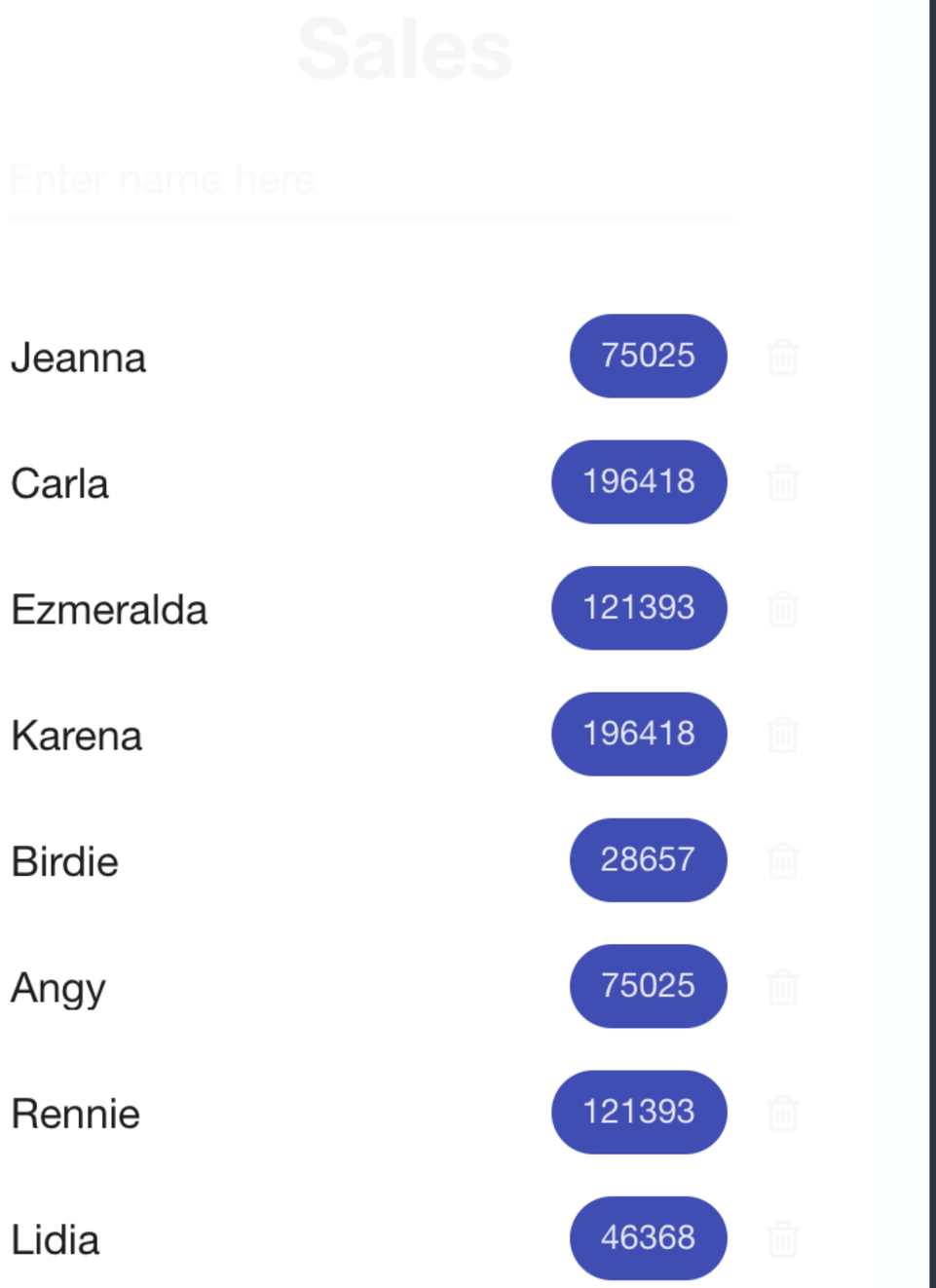


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  {{ calculate(item.num) }}

</mat-list-item>
```

```
@Component( ... )
export class EmployeeListComponent {
  @Input() data: EmployeeData[];

  @Output() remove = new EventEmitter<EmployeeData>();
  @Output() add = new EventEmitter<string>();

  handleKey(event: any) {  ...  }

  calculate(num: number) {
    return fibonacci(num);
  }
}
```

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export class EmployeeListComponent {
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  @Output() add = new EventEmitter<string>();

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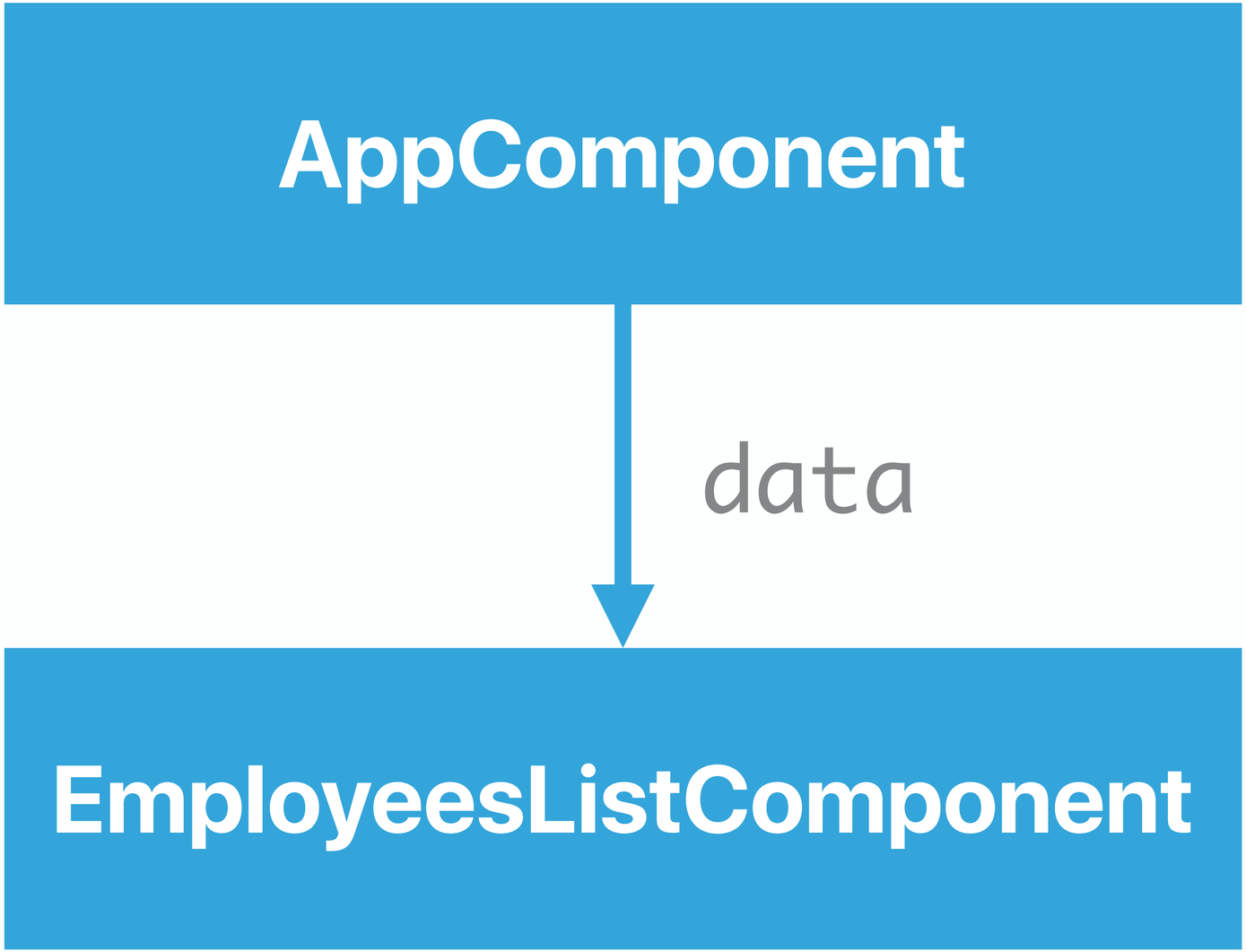
}
```


AppComponent
data
EmployeesListComponent

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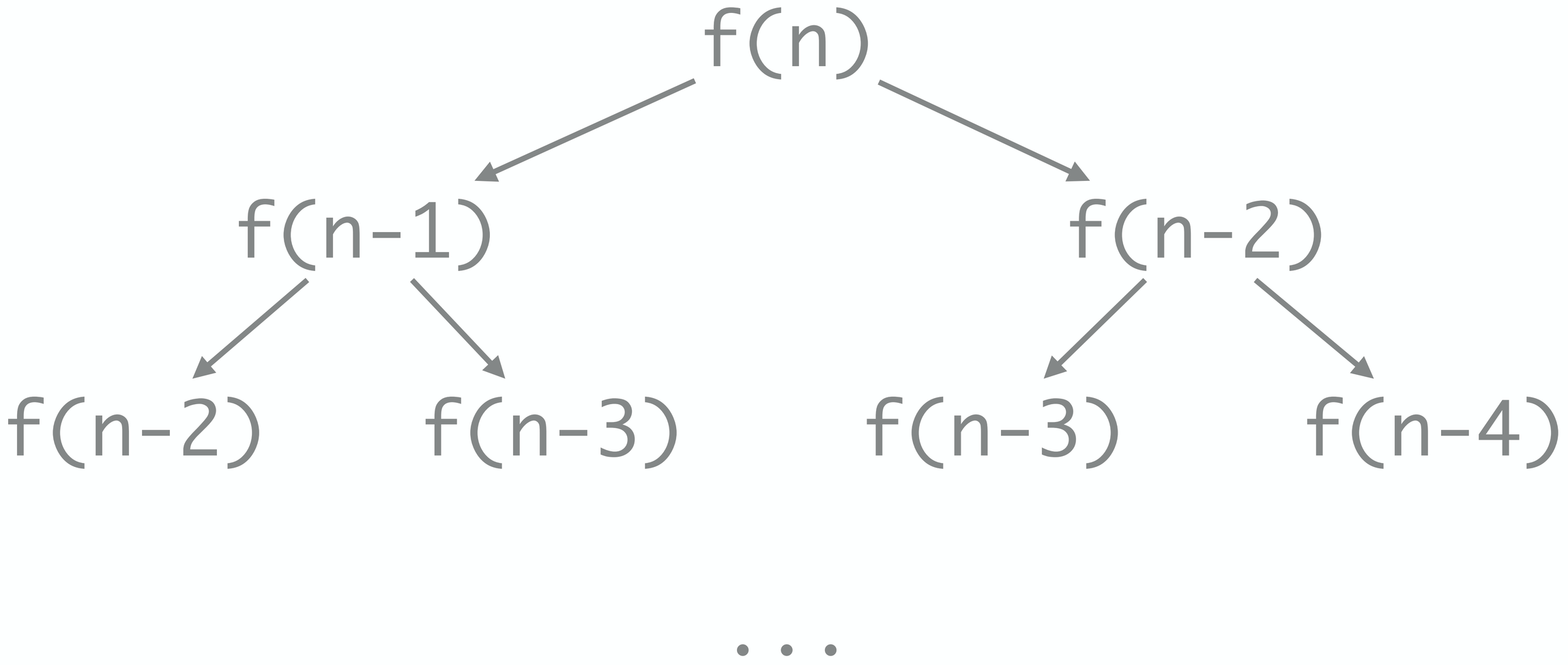
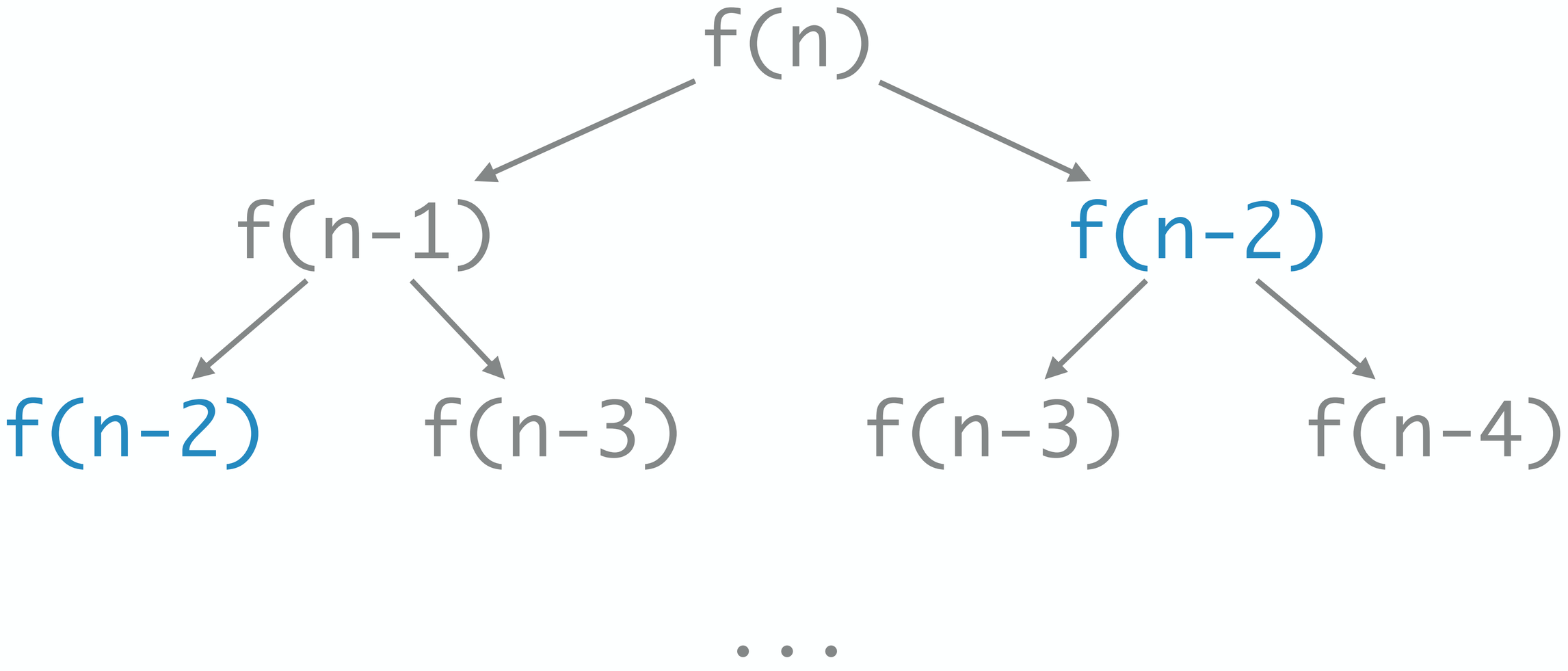
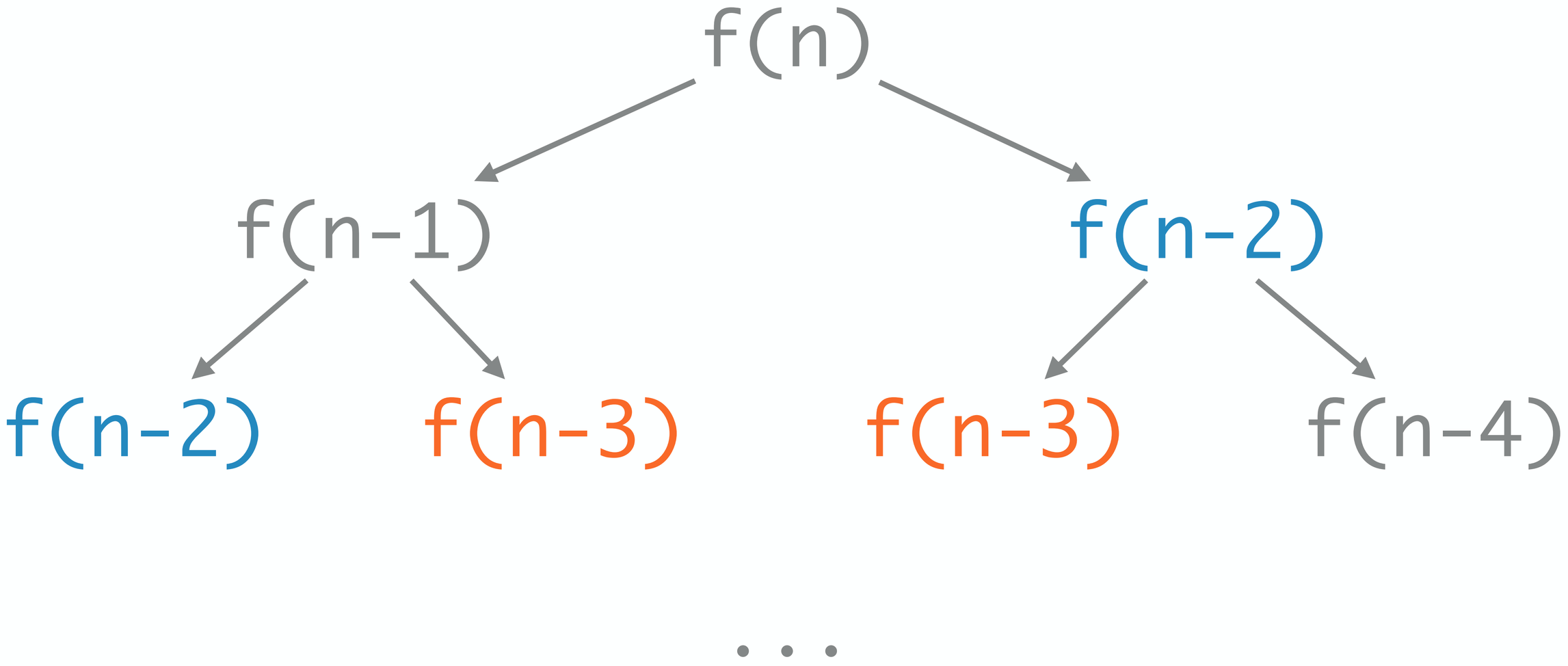
Karena	196418
Birdie	28657
Angy	75025
Rennie	121393
Lidia	46368

```
const fibonacci = n => {
  if (n === 1 || n === 2)
    return 1;
  return fibonacci(n - 1)
       + fibonacci(n - 2);
};
```


f(n)
f(n-1)
f(n-2)
f(n-2)
f(n-3)
f(n-3)
f(n-4)
. . .


f(n)
f(n-1)
f(n-2)
f(n-2)
f(n-3)
f(n-3)
f(n-4)
. . .

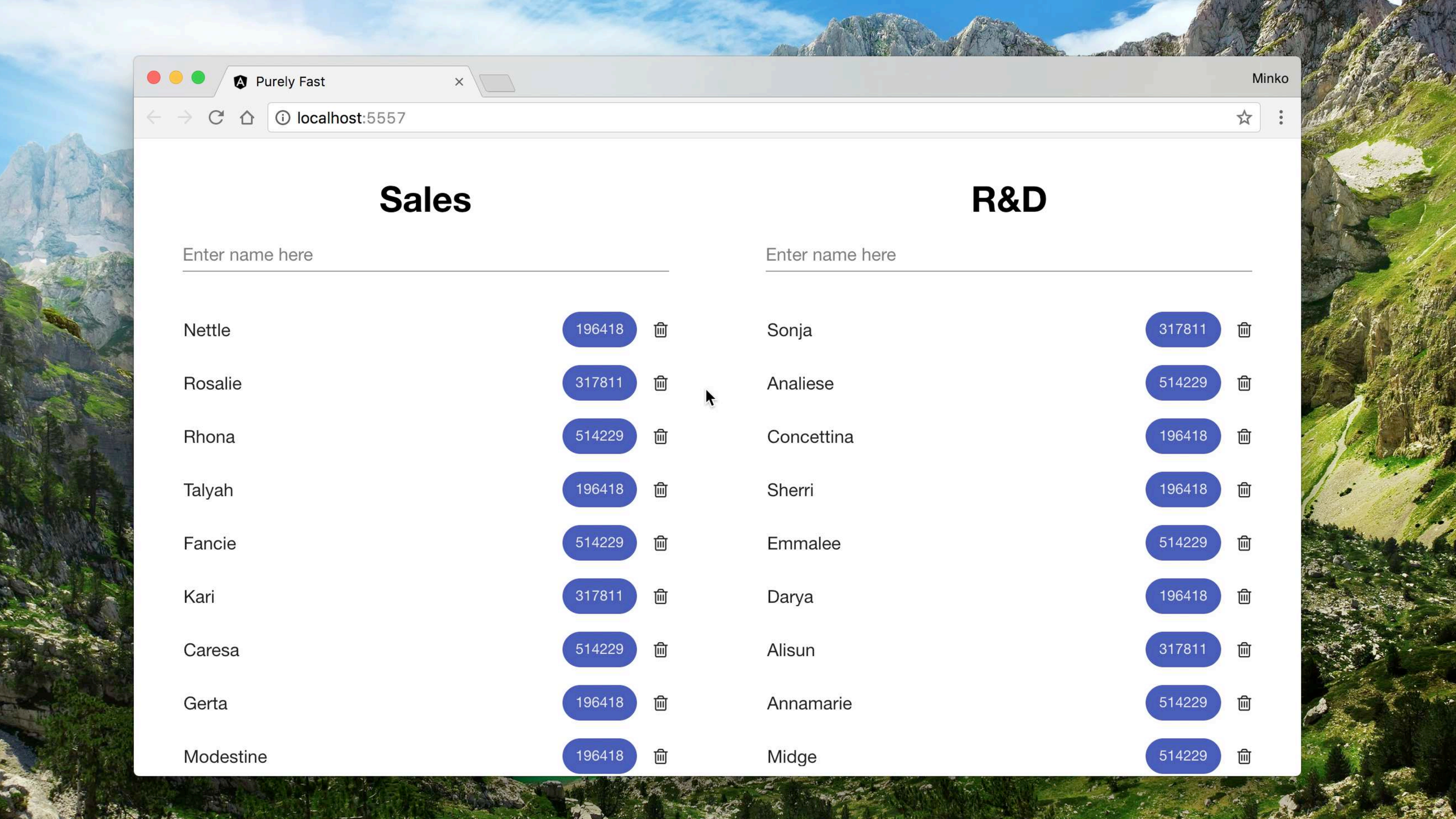

f(n)
f(n-1)
f(n-2)
f(n-2)
f(n-3)
f(n-3)
f(n-4)
. . .

Slowing it down artificially

Application Structure

- An application component
- Two list components
  - Slow computation for each entry

Real data...


Purely Fast
Minko
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Nettle 196418
Rosalie 317811
Rhona 514229
Talyah 196418
Fancie 514229
Kari 317811
Caresa 514229
Gerta 196418
Modestine 196418
R&D
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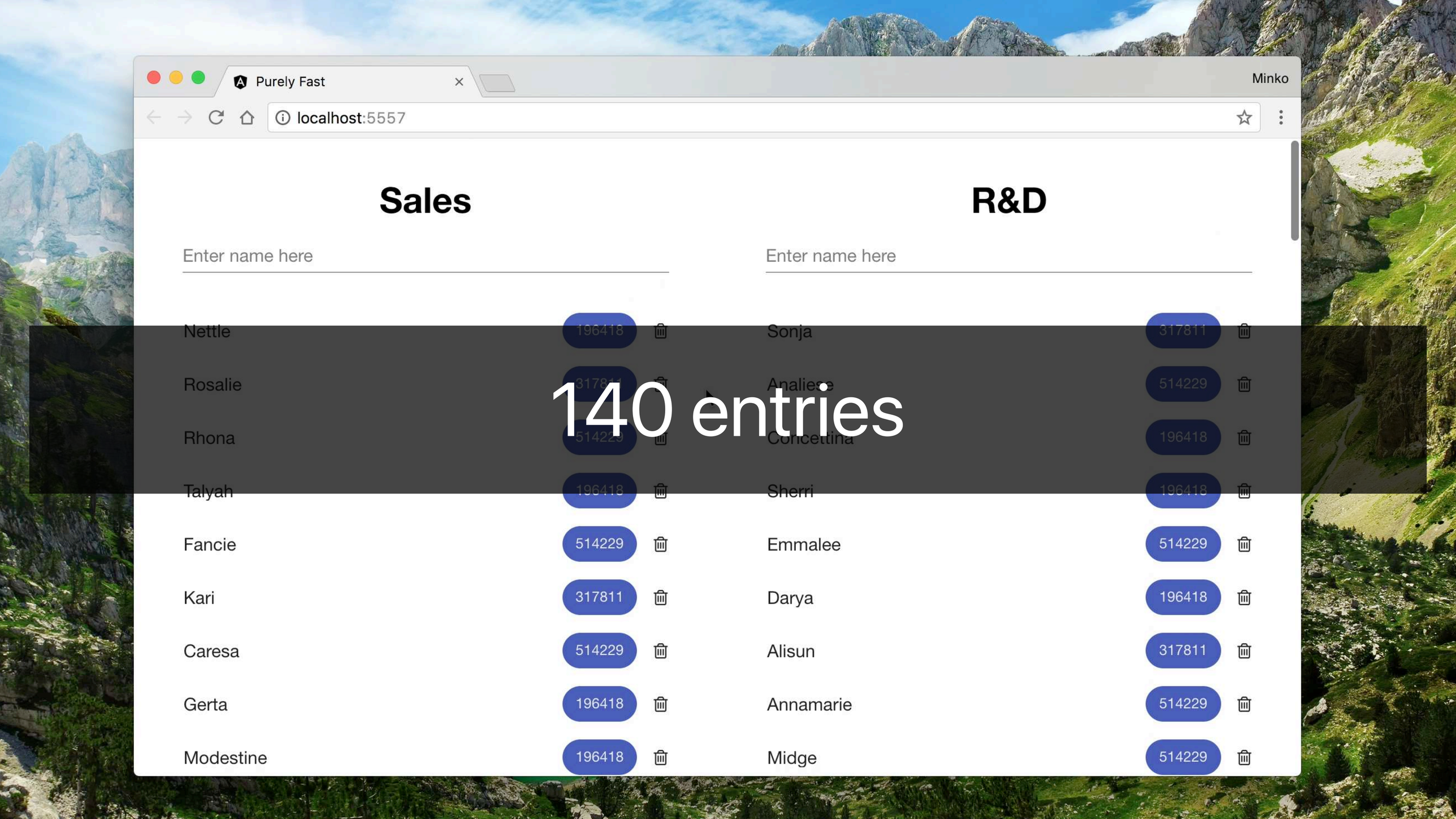
Midge 514229


Purely Fast
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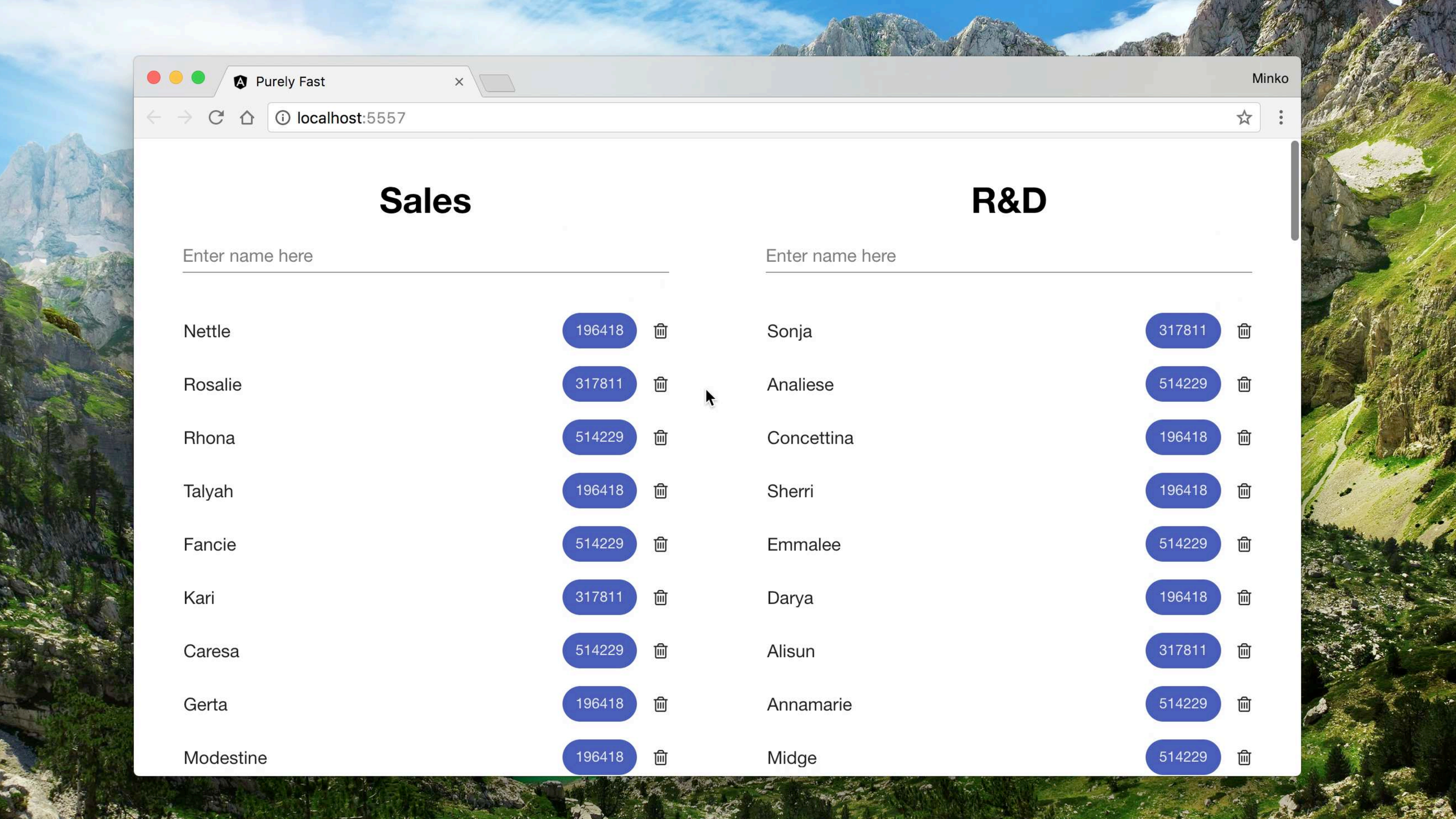
Sherri 196418
Emmalee 514229
Darya 196418
Alisun 317811
Annamarie 514229
Midge 514229
140 entries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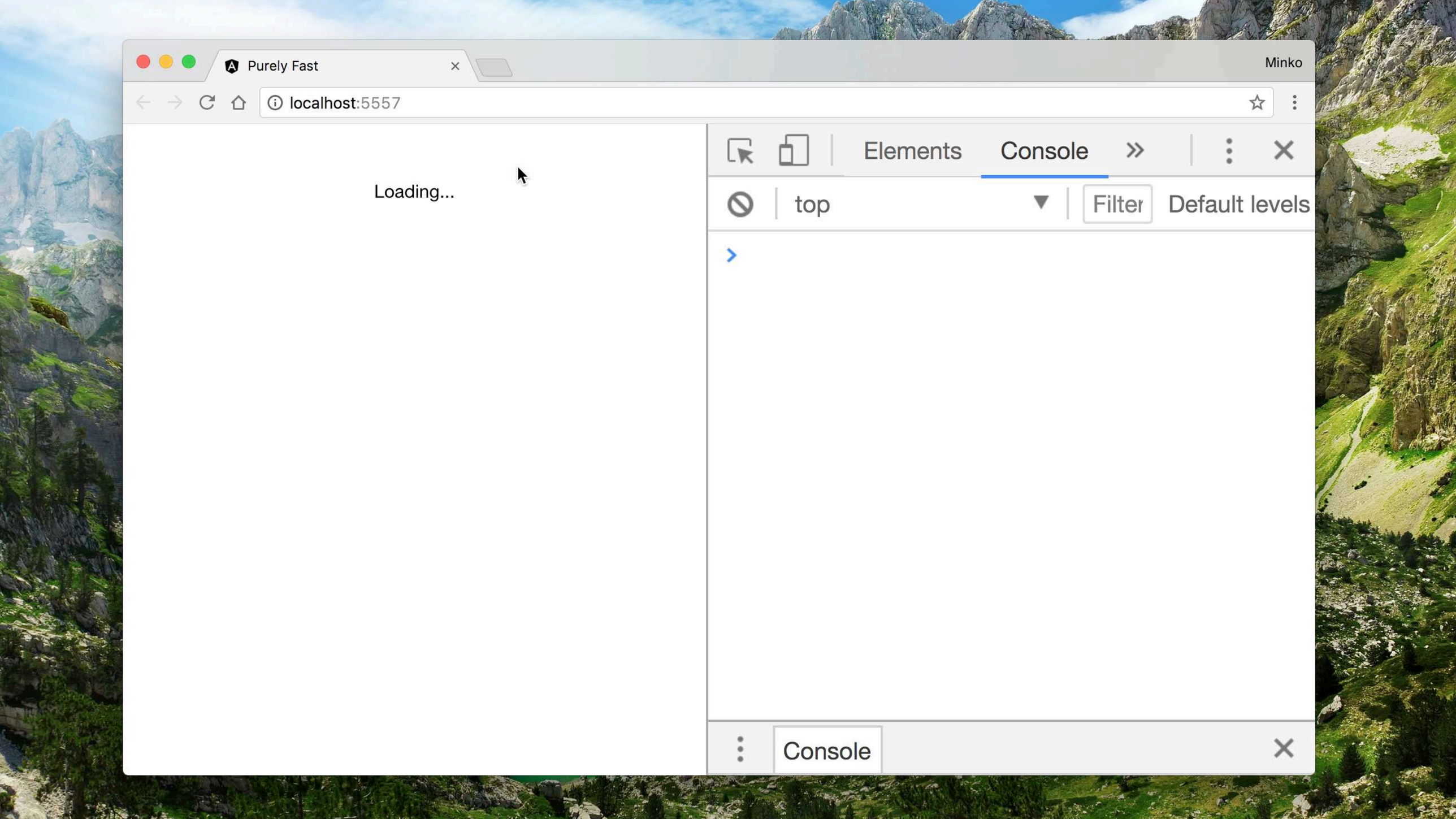
Alisun 317811
Annamarie 514229
Midge 514229

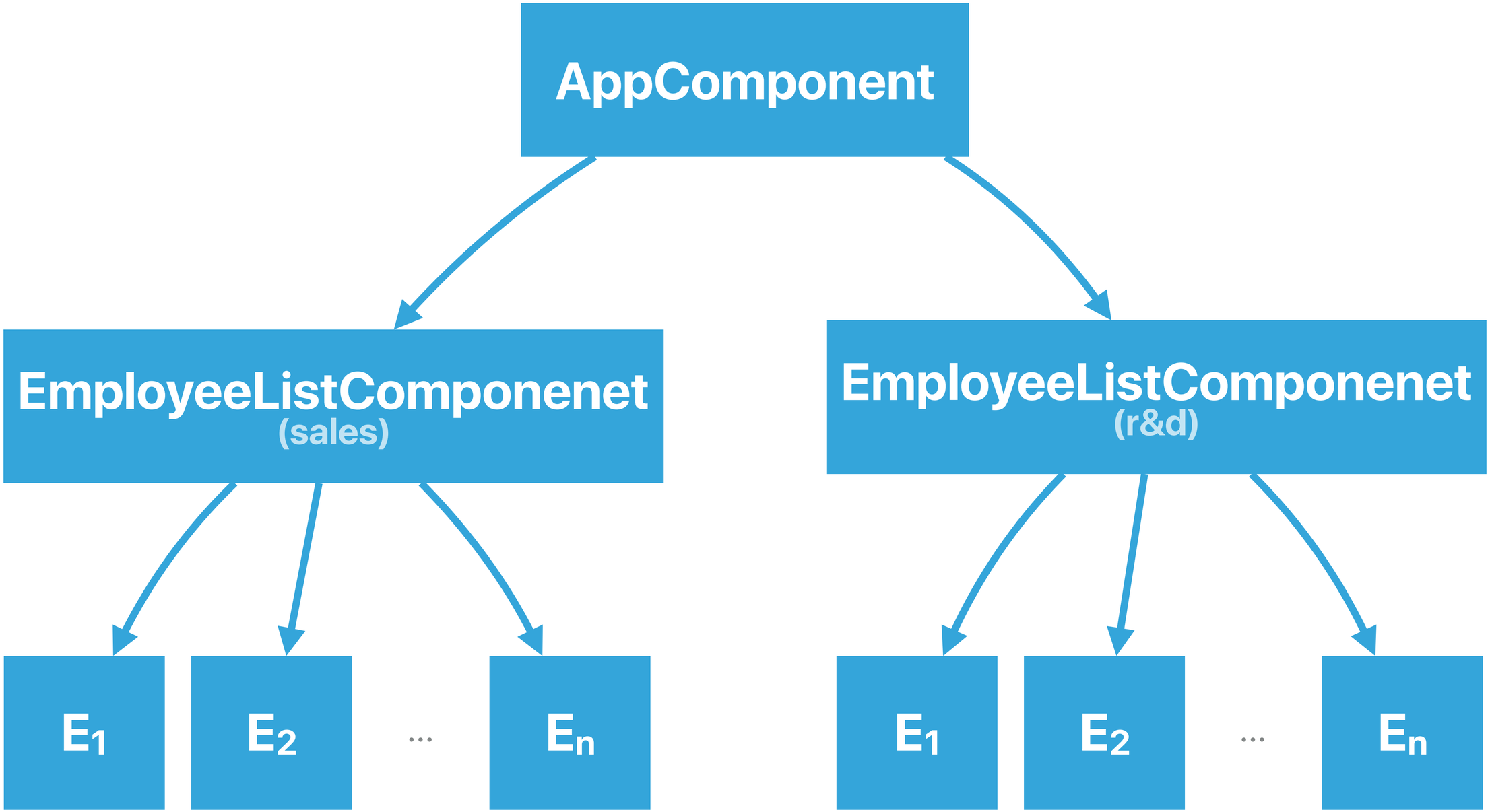
Why that slow?

Self Time	Total Time	Activity	
20671.2 ms 99.2 %	20671.2 ms 99.2 %	▶ fibonacci	employee-list.component.ts:5
22.5 ms 0.1 %	20797.2 ms 99.8 %	▶ Event	
21.1 ms 0.1 %	21.1 ms 0.1 %	▶ Update Layer Tree	
16.2 ms 0.1 %	16.2 ms 0.1 %	▶ Hit Test	
11.3 ms 0.1 %	20765.9 ms 99.6 %	▶ Function Call	
9.9 ms 0.0 %	9.9 ms 0.0 %	▶ Layout	
8.8 ms 0.0 %	20696.4 ms 99.3 %	▶ (anonymous)	EmployeeListComponent.ngfactory.js:77
8.2 ms 0.0 %	8.2 ms 0.0 %	▶ Paint	
8.0 ms 0.0 %	20728.7 ms 99.4 %	▶ execEmbeddedViewsAction	core.umd.js:12617
7.1 ms 0.0 %	20742.4 ms 99.5 %	▶ callViewAction	core.umd.js:12644
4.5 ms 0.0 %	4.6 ms 0.0 %	▶ execQueriesAction	core.umd.js:12713

```
@Component( ... )
export class EmployeeListComponent {
   ...
   calculate(num: number) {
     console.log('Computing for entry in',
         this.department);
     return fibonacci(num);
   }
}
```


Purely Fast
Minko
localhost:5557
Loading...
Elements
Console
top
Filter
Default levels
Console

Ignored details for simplicity



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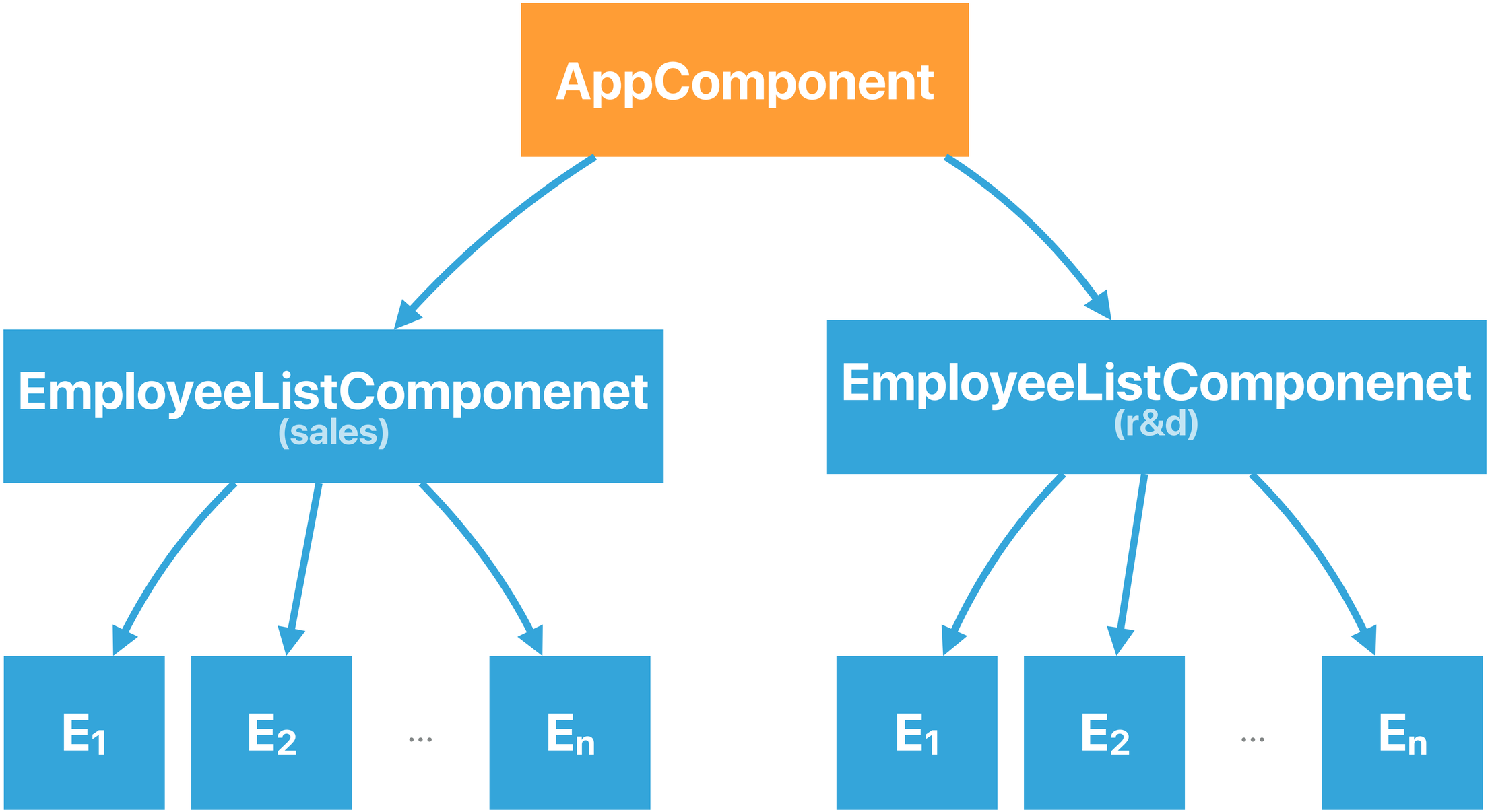

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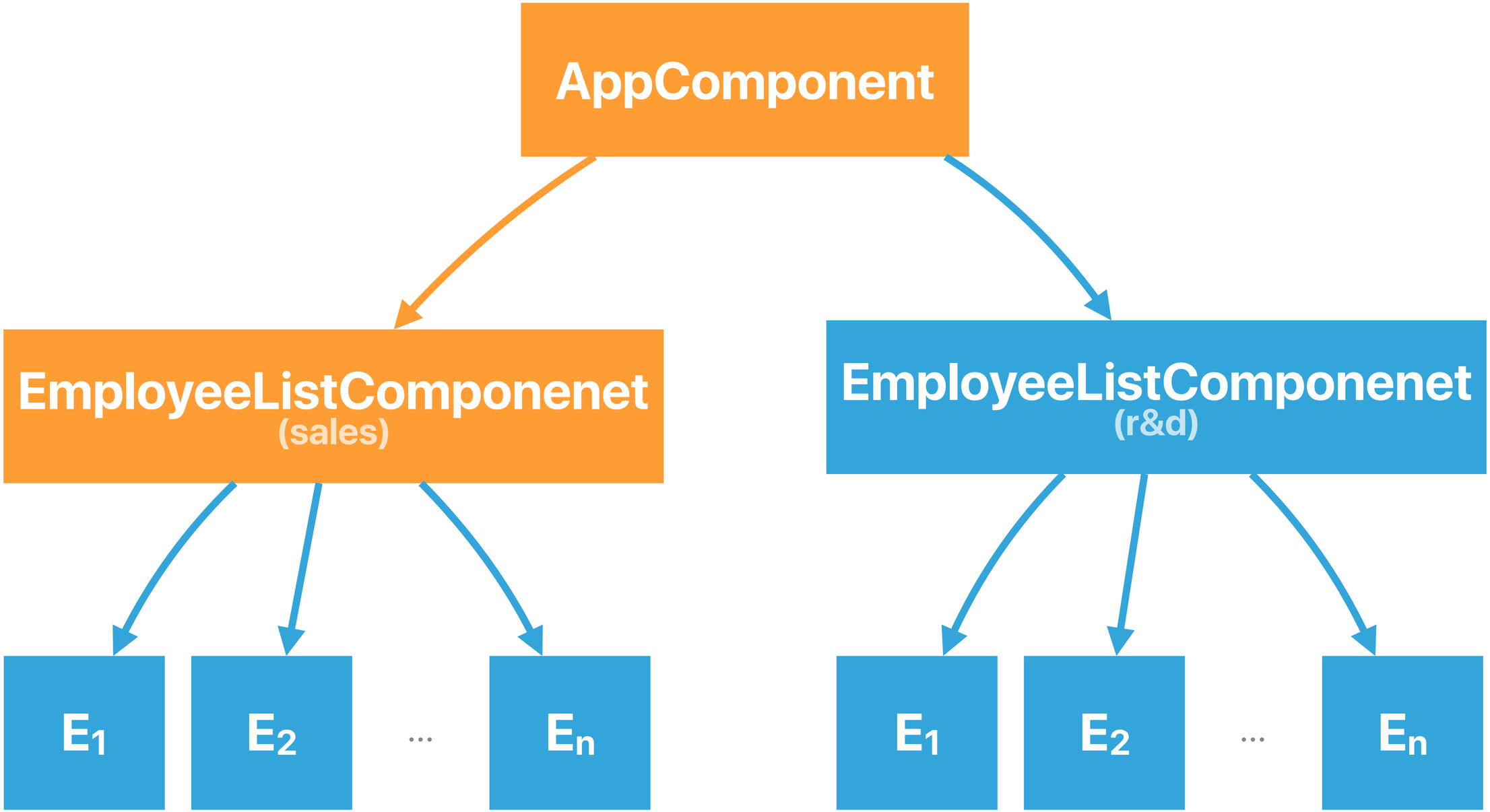

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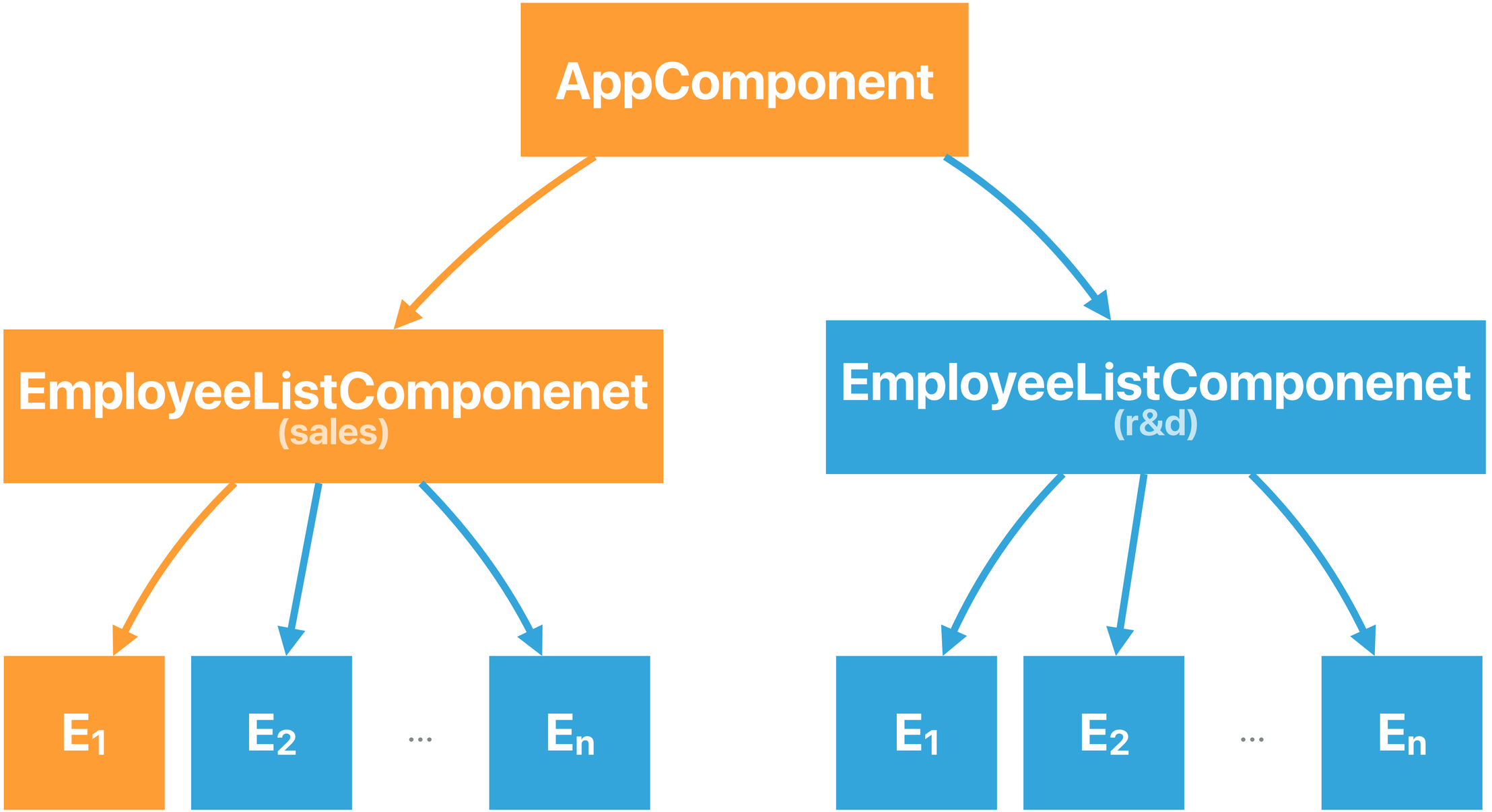

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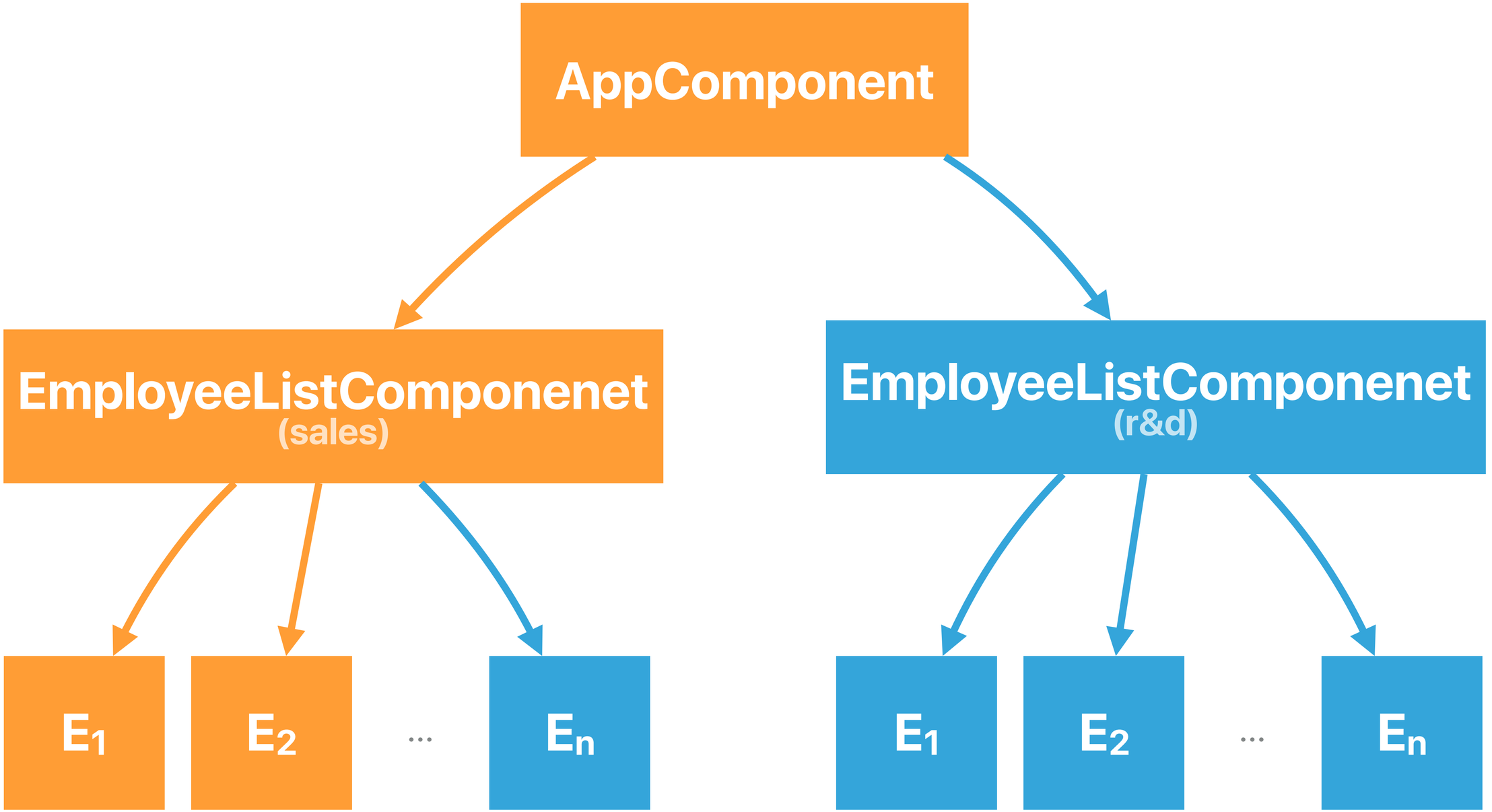

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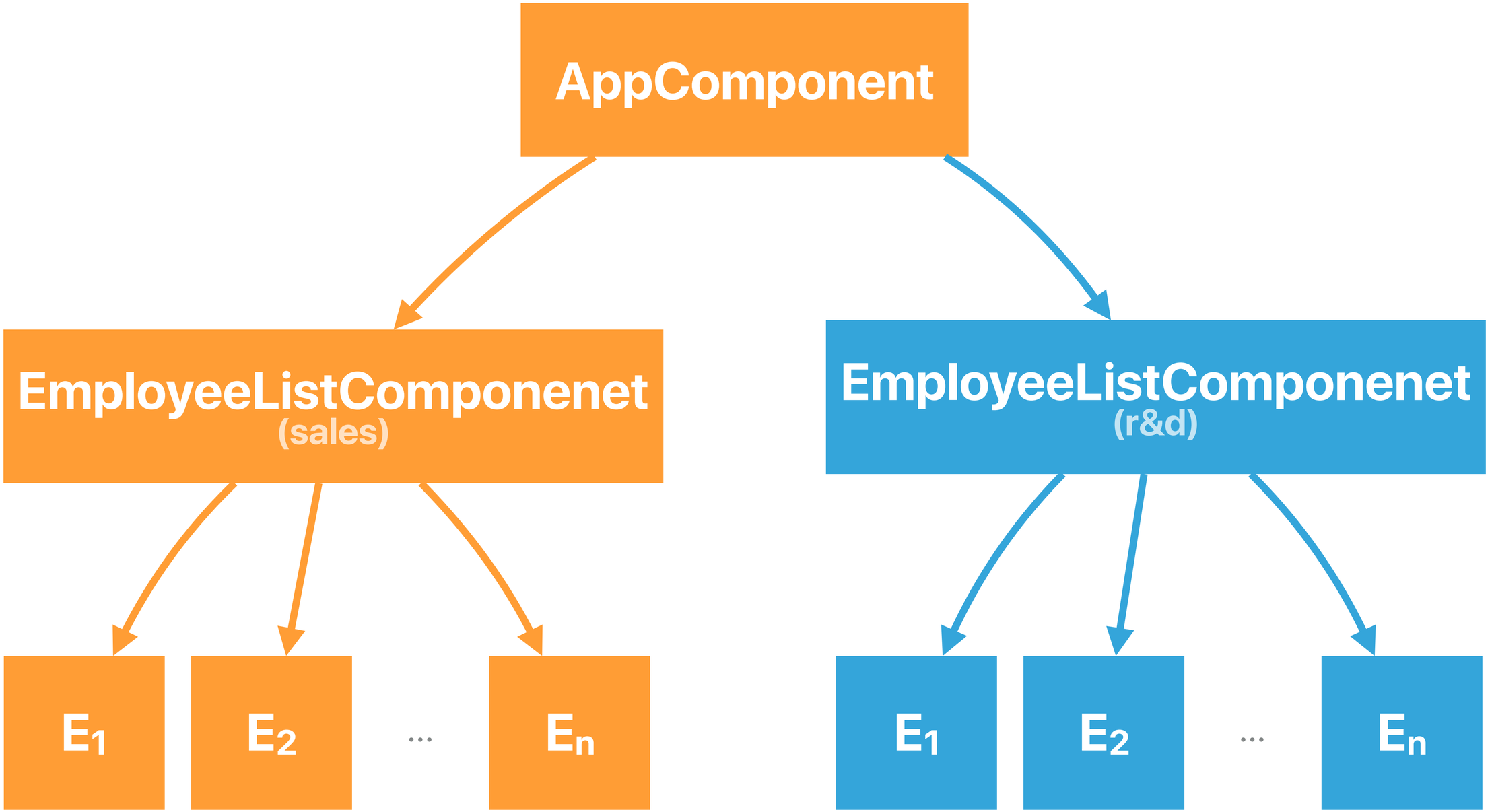

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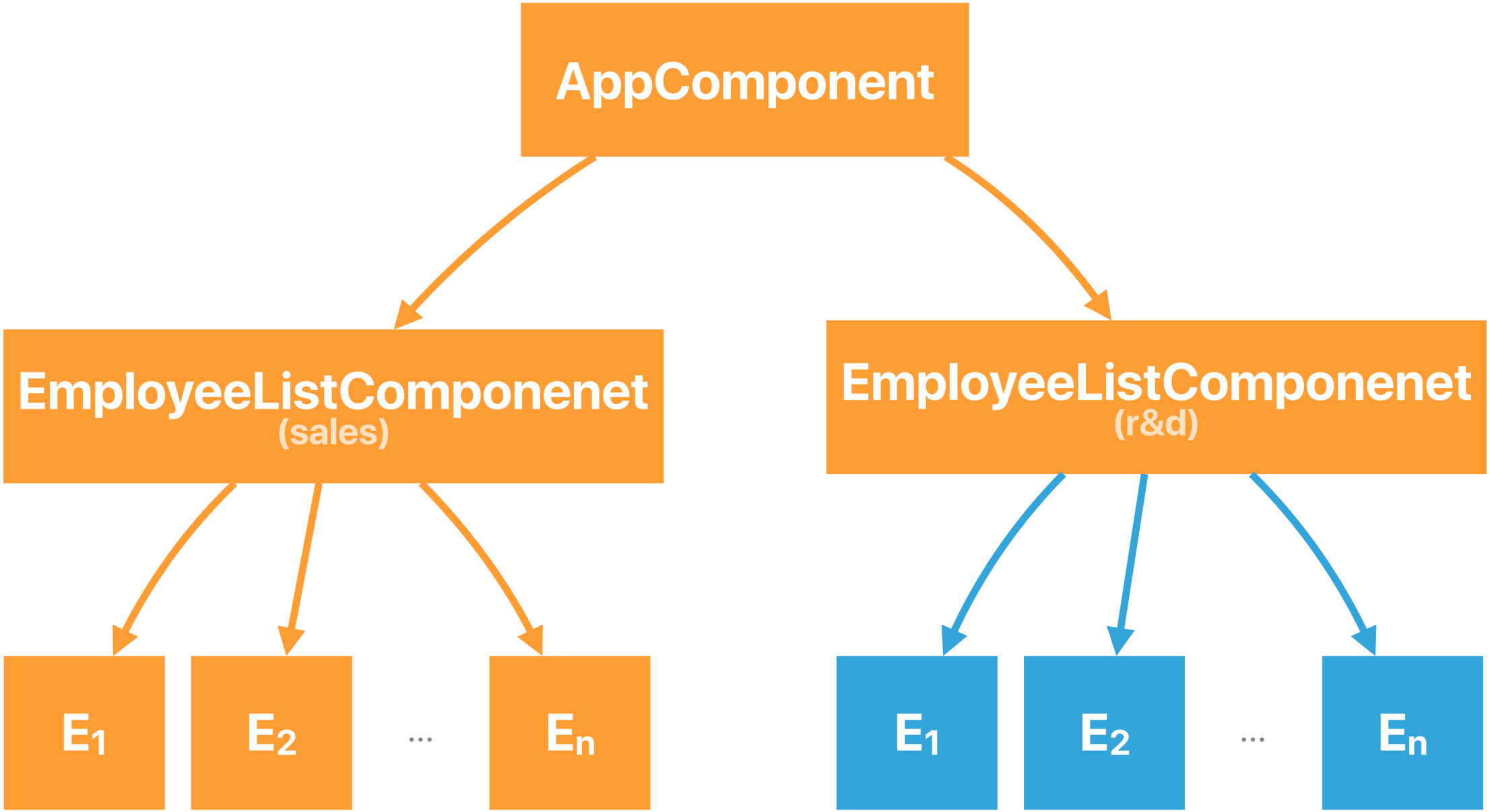

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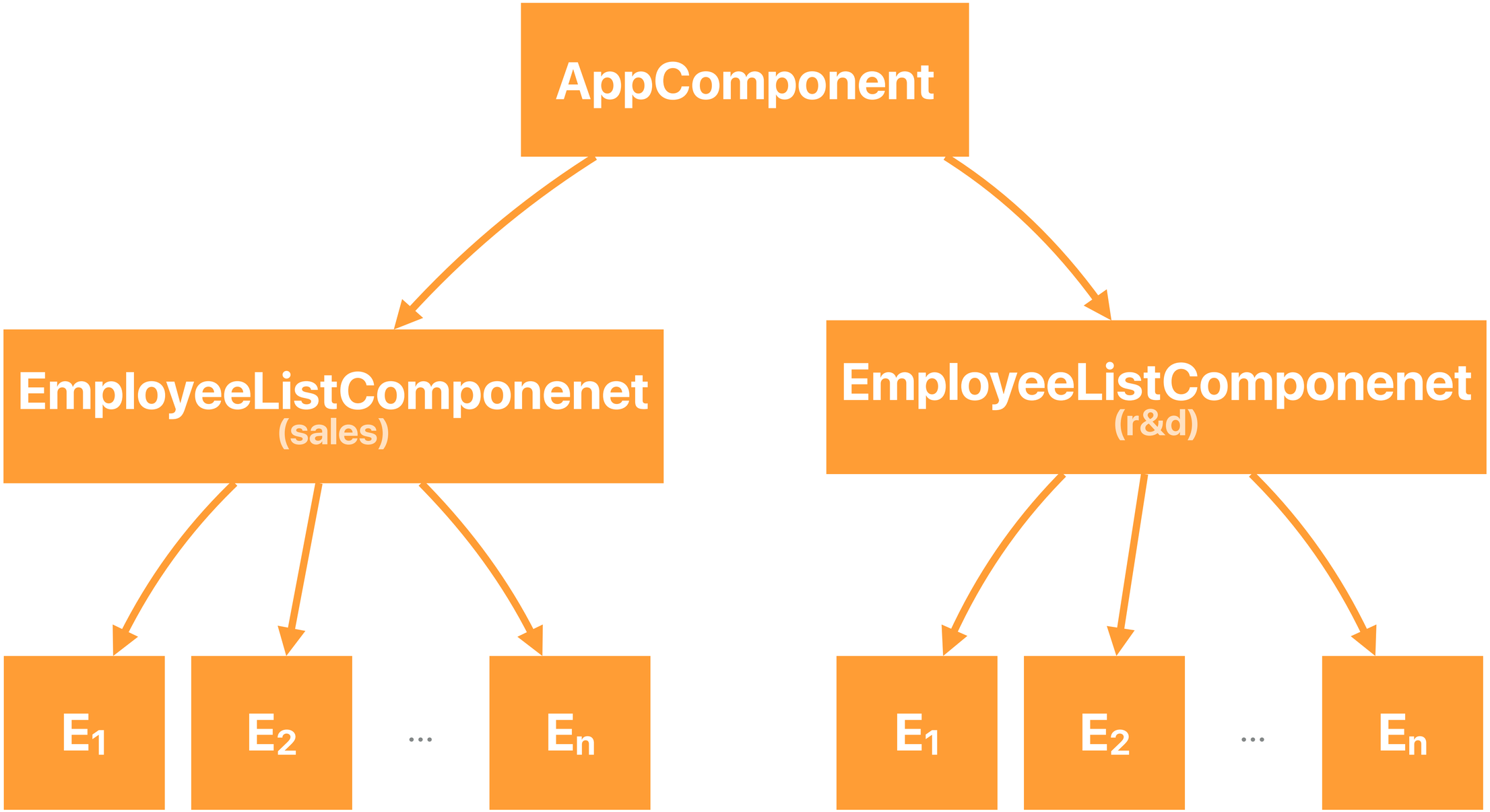

Ideas for optimization?

OnPush

Change Detection Strategy

twitter.com/mgechev

With `OnPush` change detection will be triggered when the framework, with reference check, determines that any of the inputs of a component has changed...

What does this mean?

Lets think of EmployeeListComponent as a function, where:

- Inputs are function's arguments
- Rendered component is function's result

Pseudo code (not Angular)

```
const f = EmployeeListComponent;
const data = [e1];

// Will trigger CD
f({ data: data });

data.push(e2);
// Will not trigger CD
f({ data: data });

// Will trigger CD
f({ data: data.slice() });
```

Pseudo code (not Angular)

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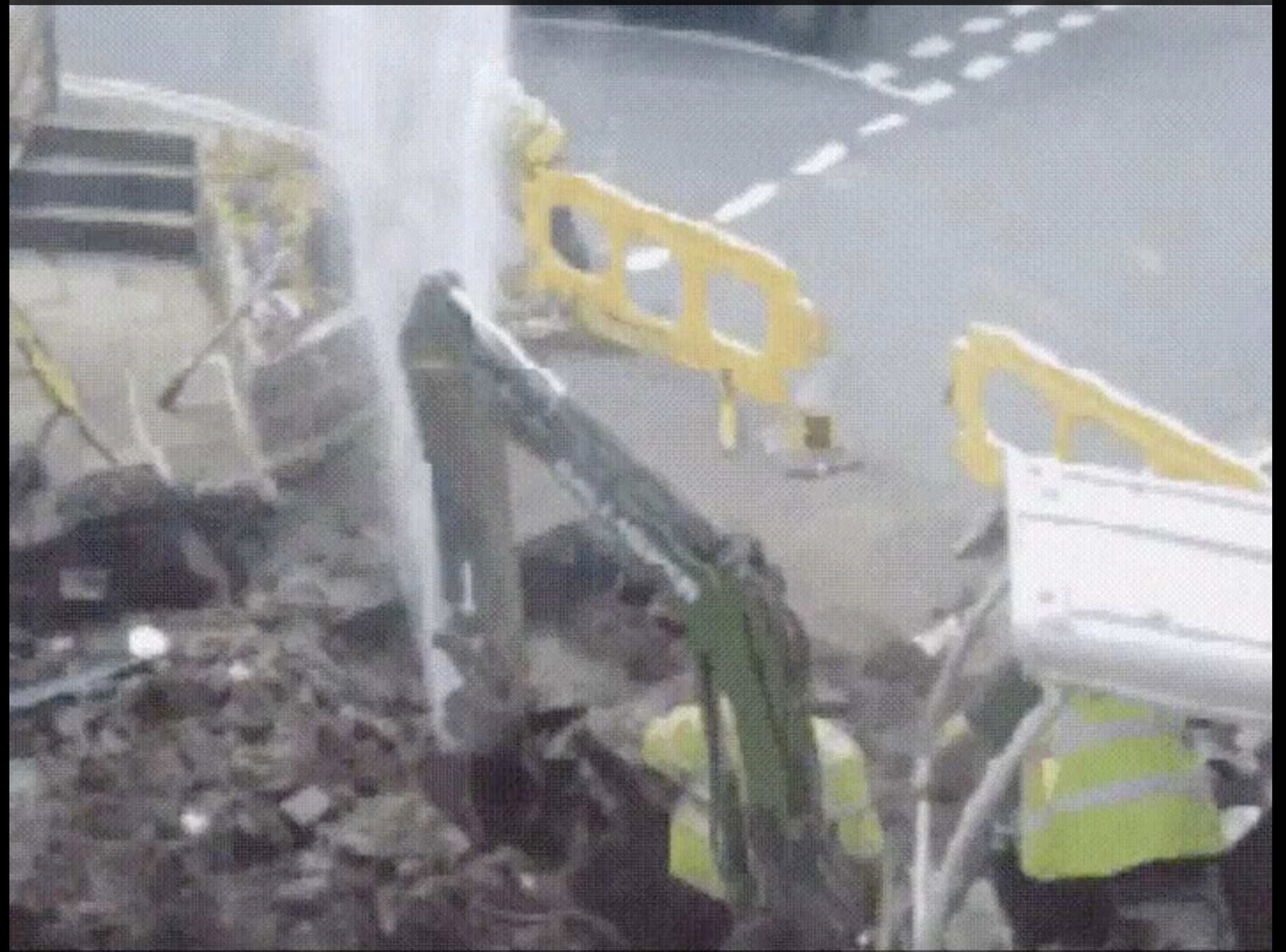
Passing new reference

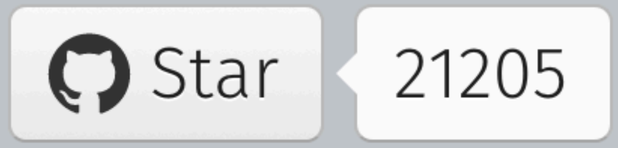
triggers the change detection

Should we copy the array every time?

Why would we do that...?



IMMUTABLE



Immutable.js helps:

- We get a new reference on change
- We do not copy the entire data structure

```
@Component({
  template: `
    <sd-employee-list
      [data]="list"
      (add)="list = add(list, $event)"
      (remove)="list = remove(list, $event)"
    ></sd-employee-list>
  `
})
export class AppComponent implements OnInit {
  list: List<EmployeeData>;

  add(list: List<EmployeeData>, name: string) {
    return list.unshift({ label: name, num:  ... });
  }

  remove(list: List<EmployeeData>, node: EmployeeData) {
    return list.splice(list.indexOf(node), 1);
  }
}
```

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  template: `
    <sd-employee-list
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    return list.splice(list.indexOf(node), 1);
  }
}
```

Lets see how fast it is now!

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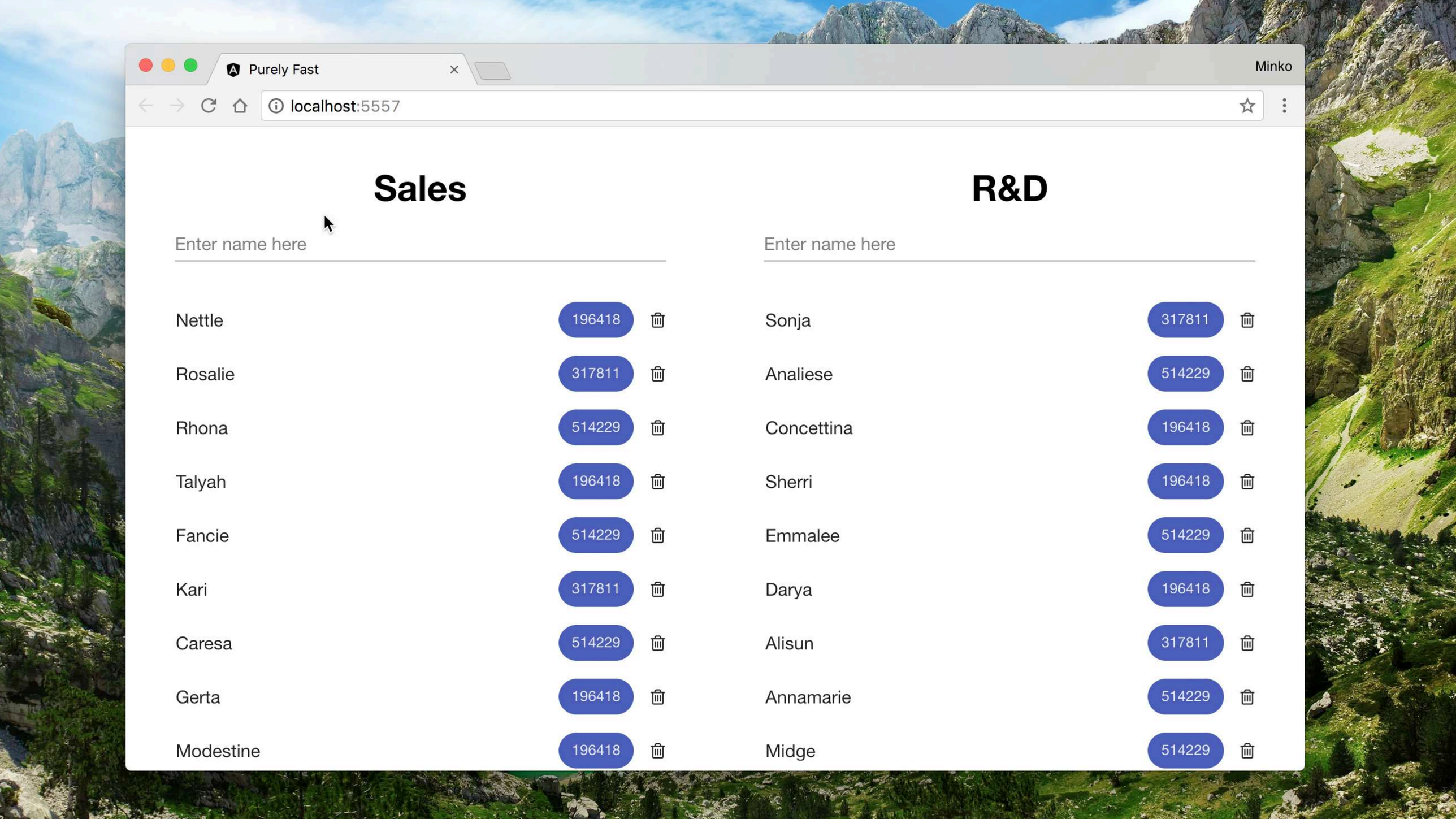
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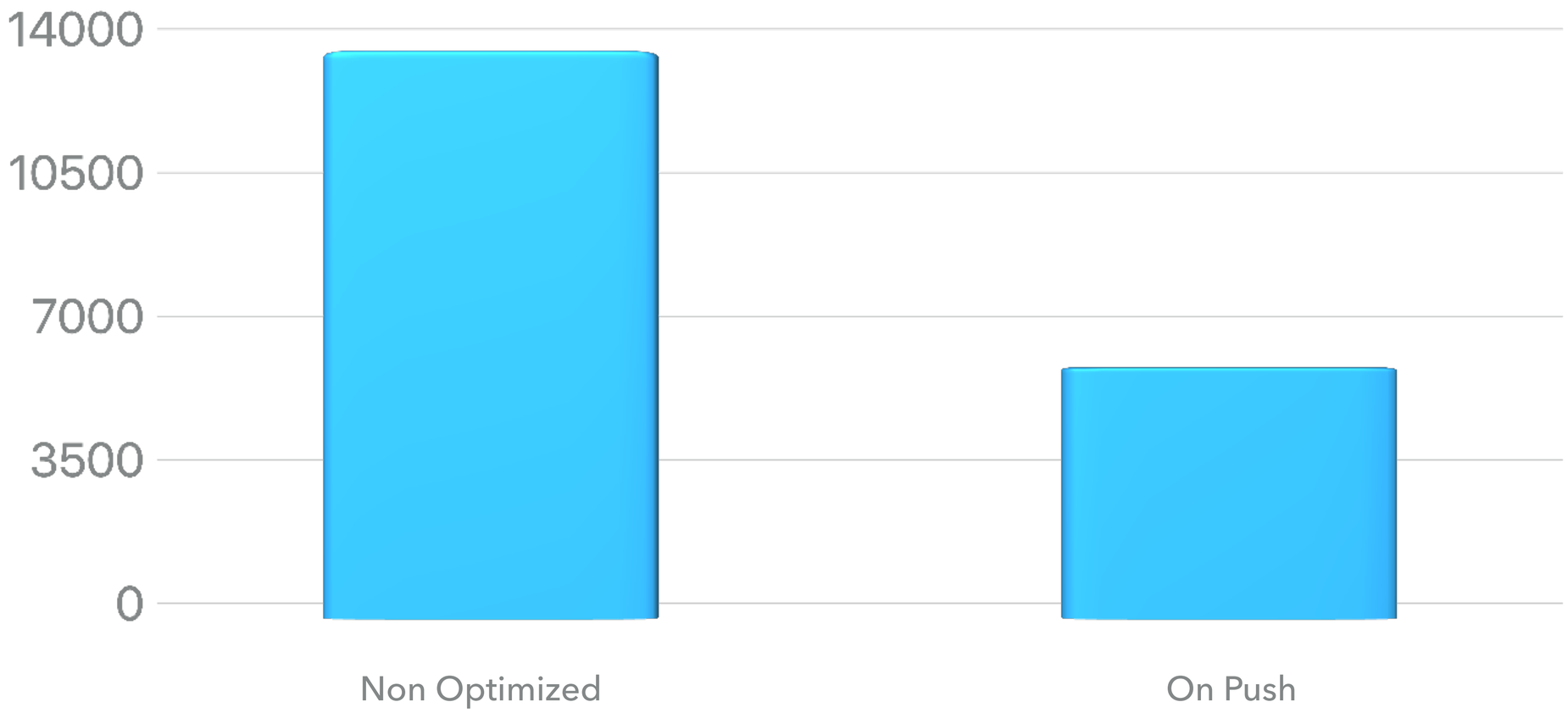
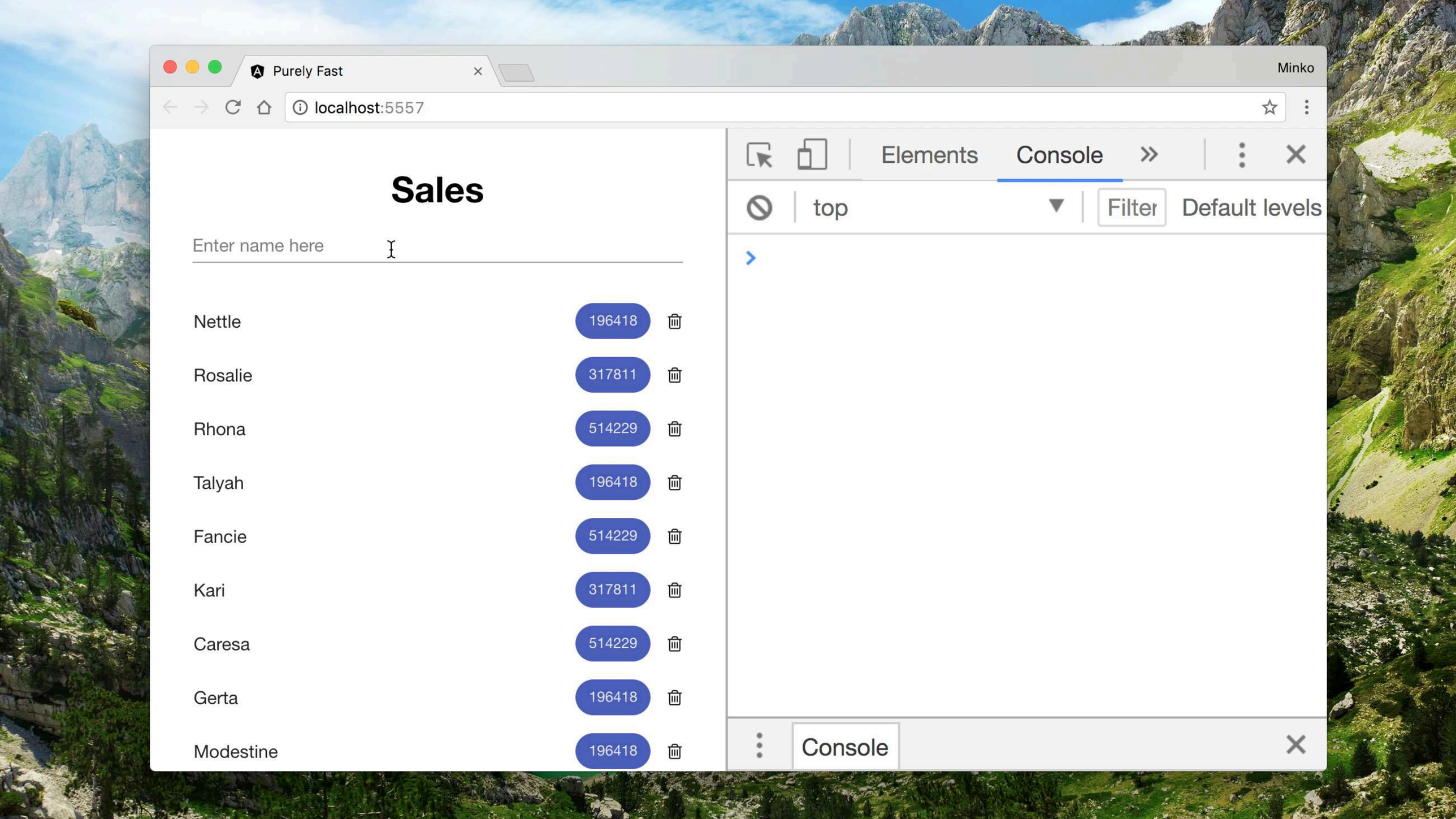
Talyah 196418
Fancie 514229
Kari 317811
Caresa 514229
Gerta 196418
Modestine 196418
R&D
Enter name here
Sonja 317811
Analiese 514229
Concettina 196418
Sherri 196418
Emmalee 514229
Darya 196418
Alisun 317811
Annamarie 514229
Midge 514229

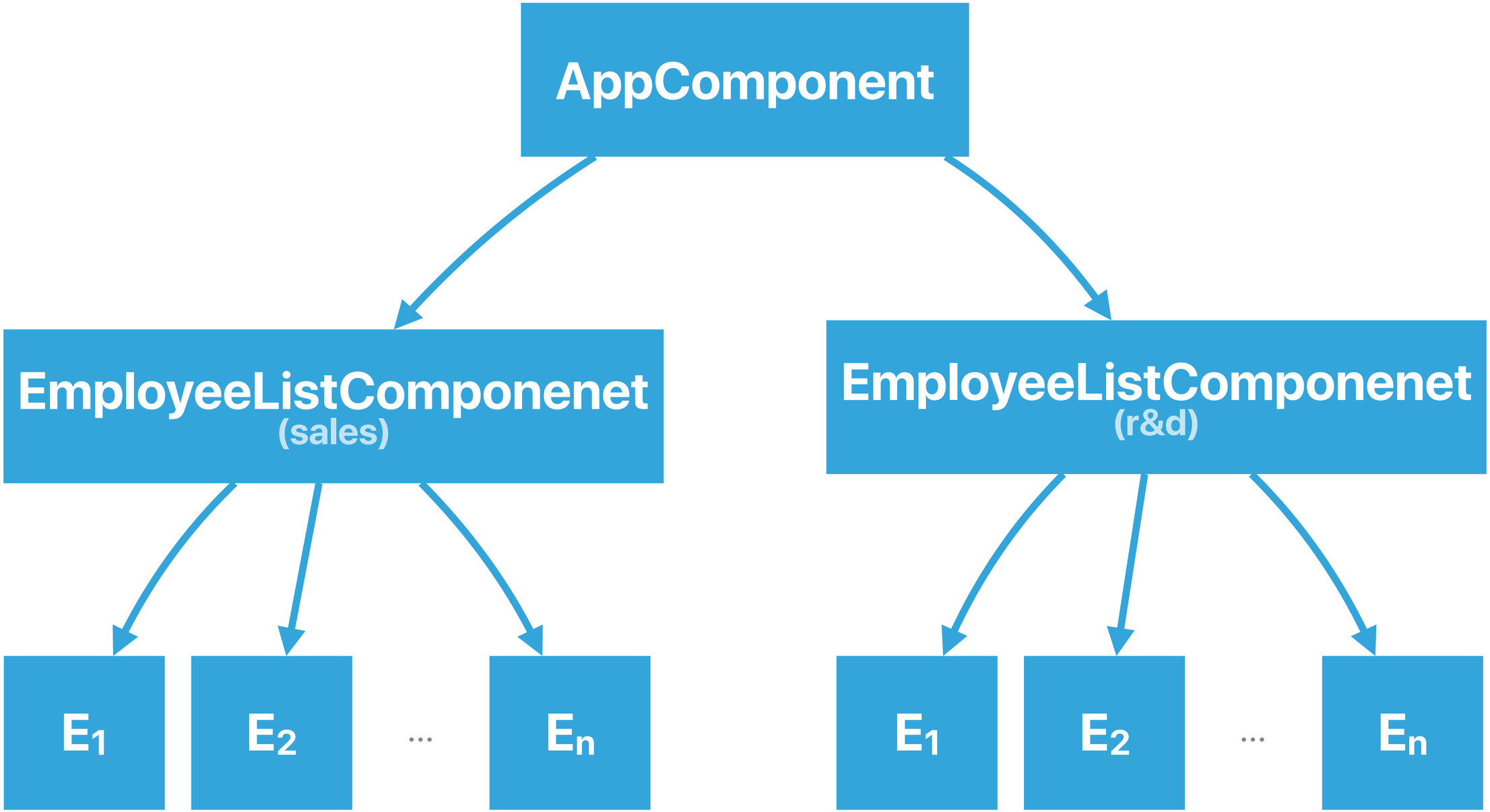
Typing Speed



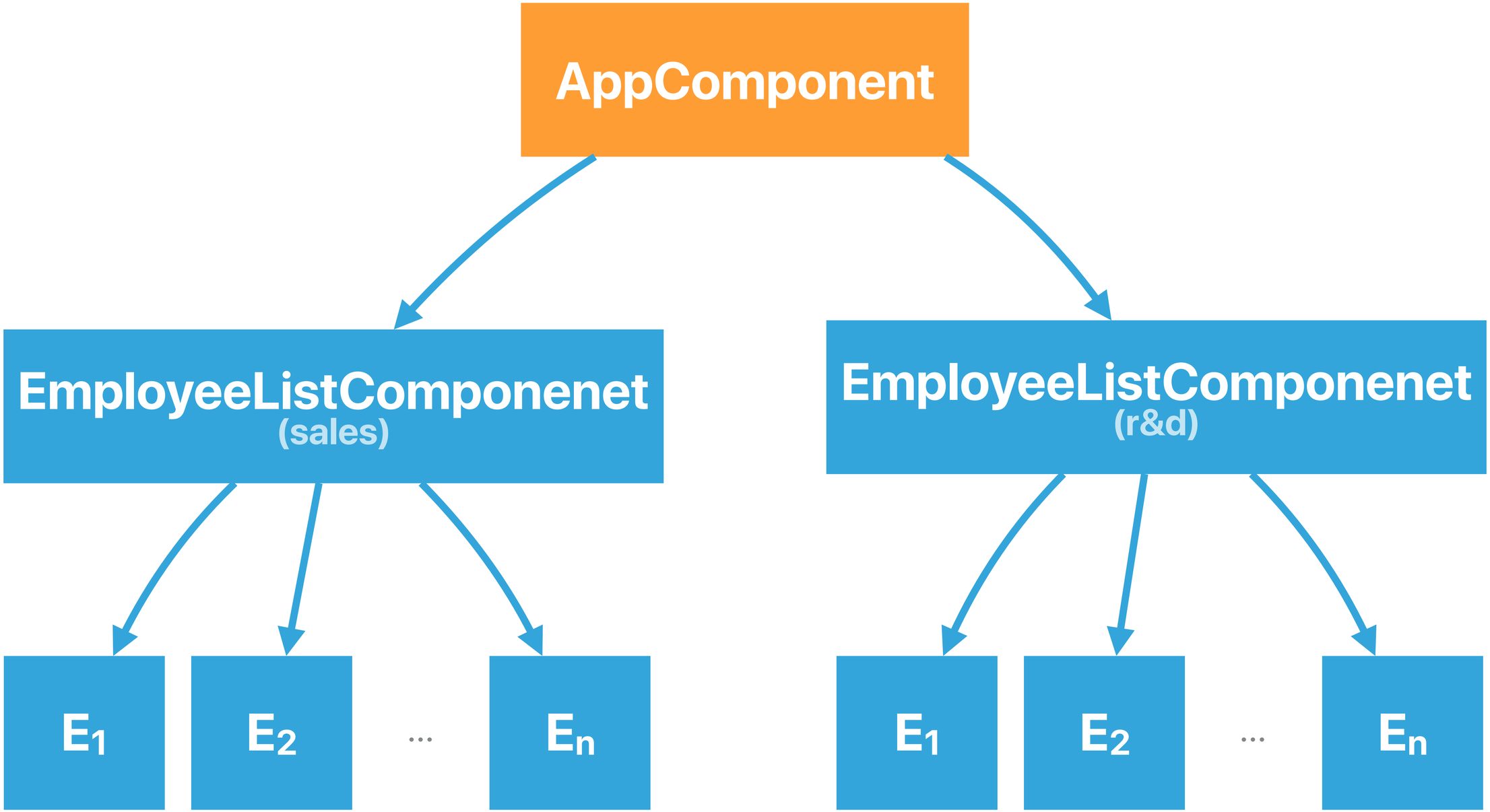
2x faster but still slow...


Purely Fast
Minko
localhost:5557
Sales
Enter name here
Nettle 196418
Rosalie 317811
Rhona 514229
Talyah 196418
Fancie 514229
Kari 317811
Caresa 514229
Gerta 196418
Modestine 196418
Elements
Console
top
Filter
Default levels
Console

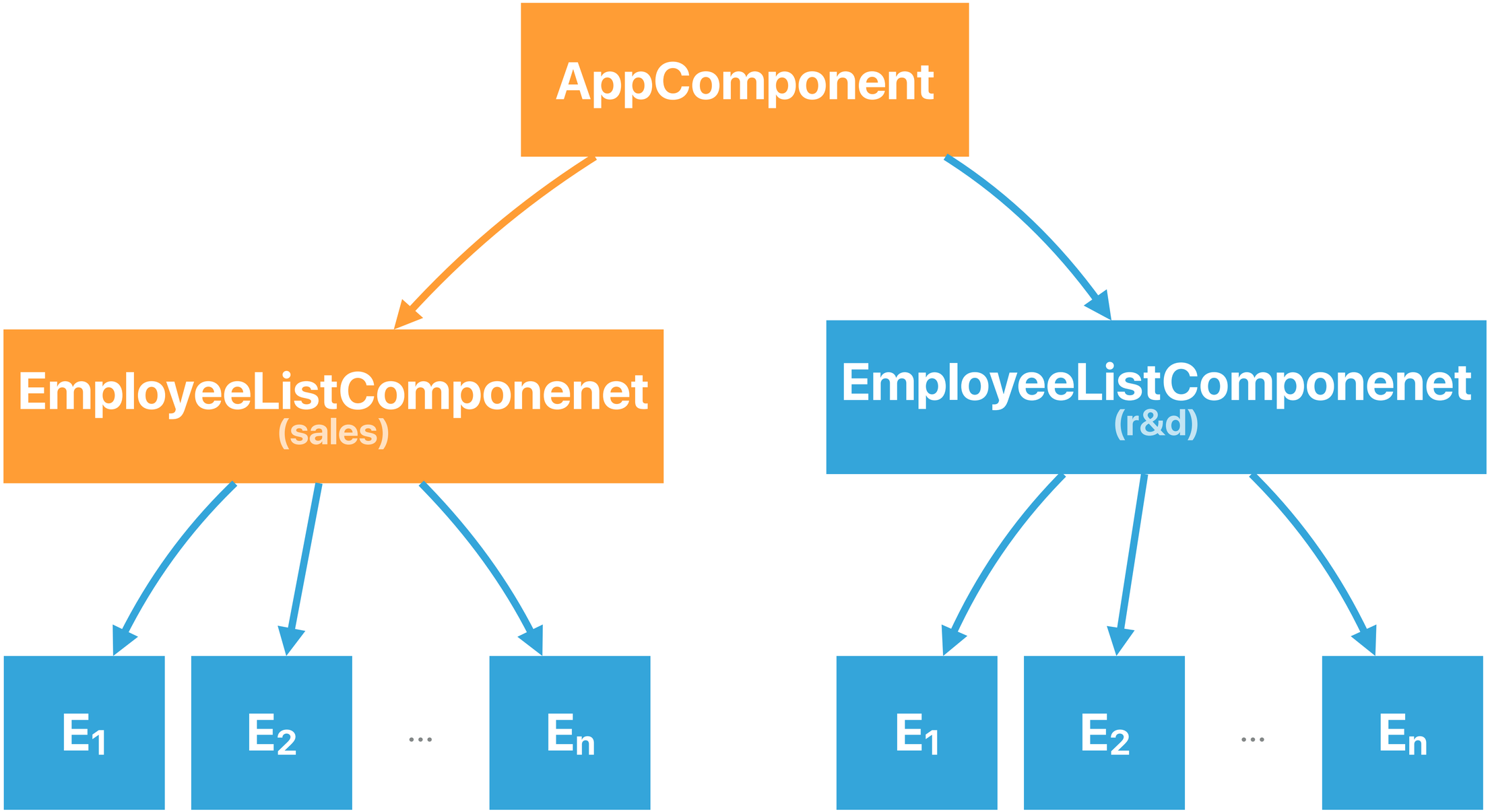
Ignored details for simplicity



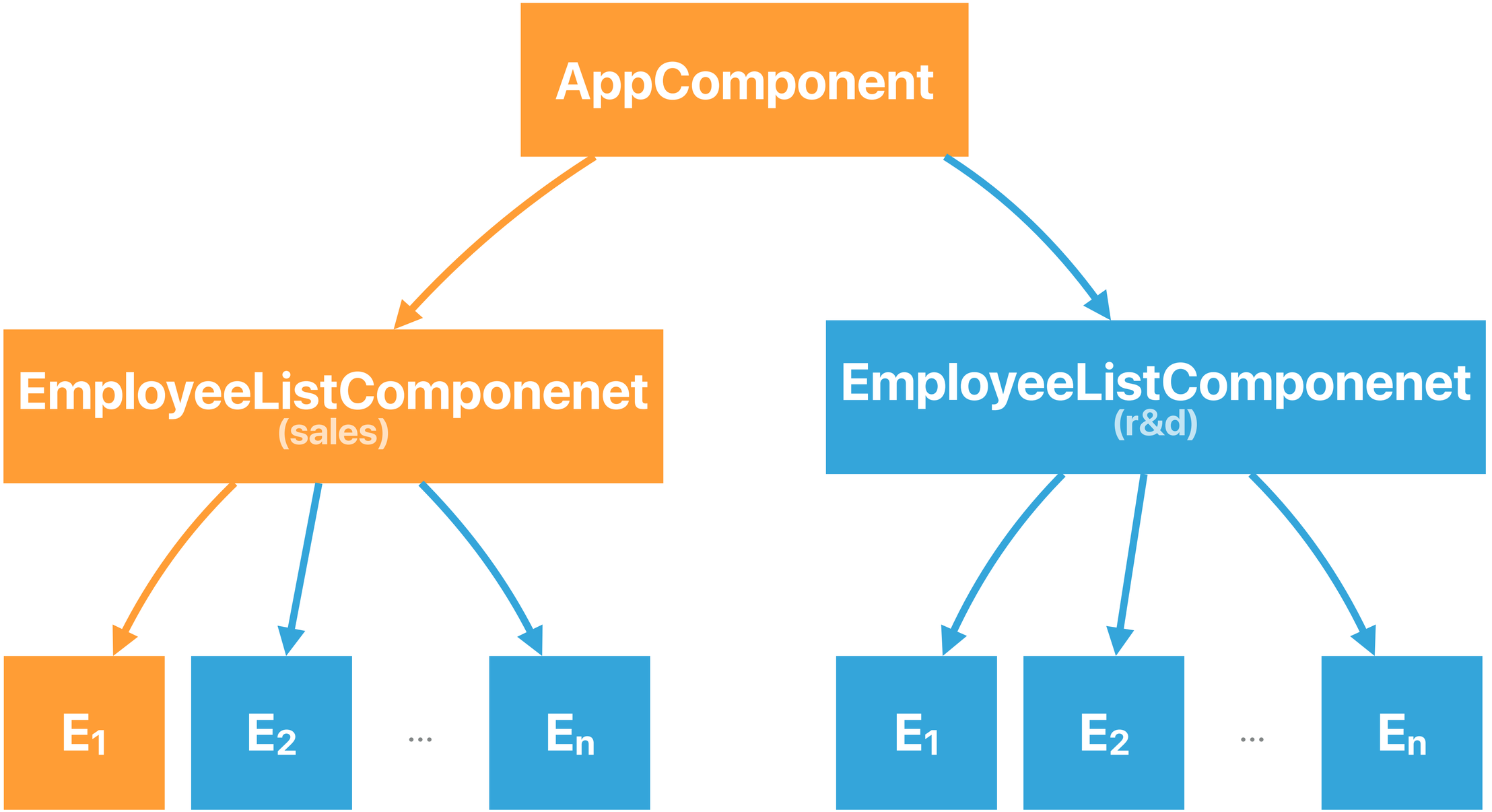
Ignored details for simplicity



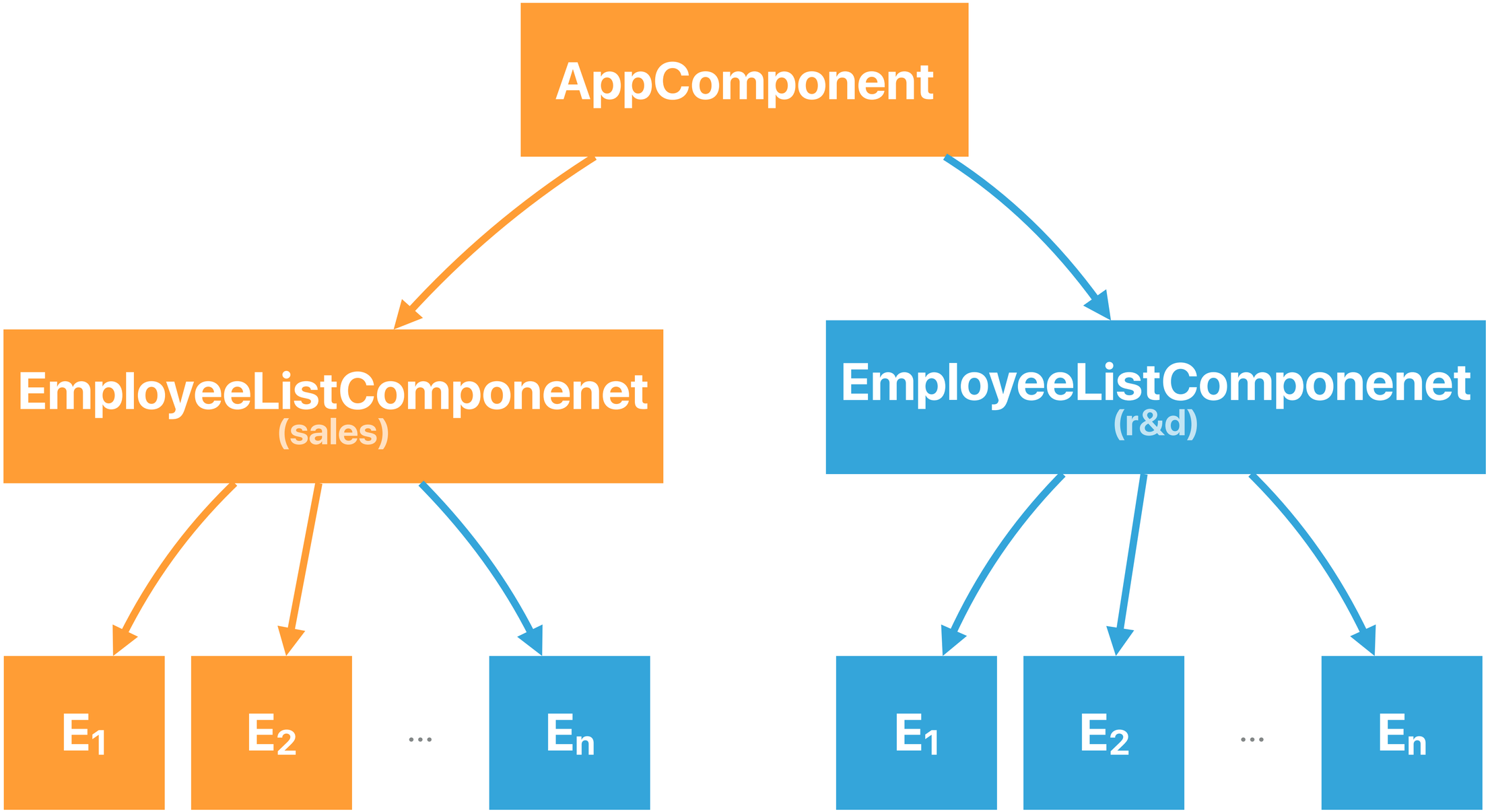
Ignored details for simplicity



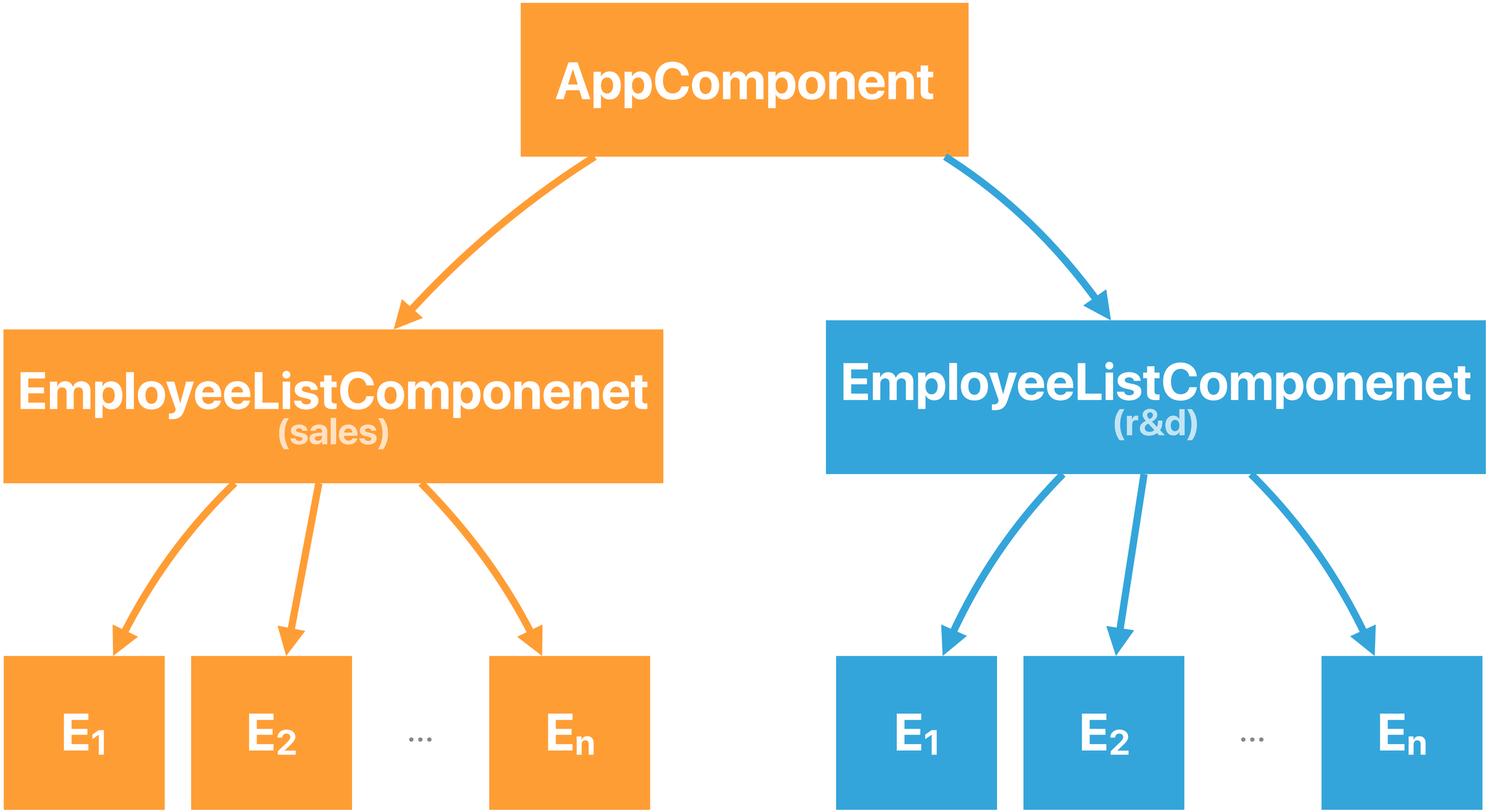
Ignored details for simplicity



Ignored details for simplicity

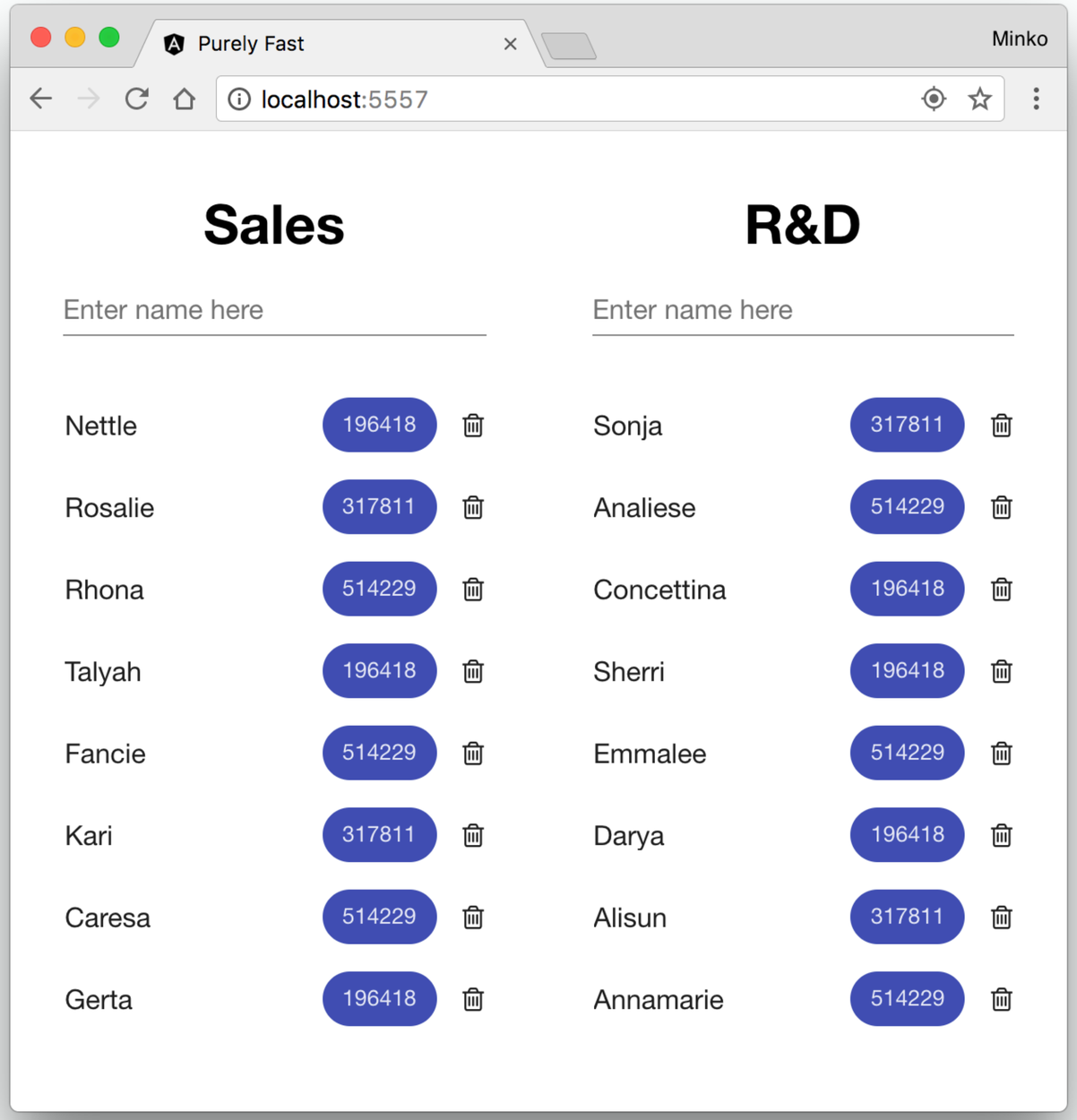


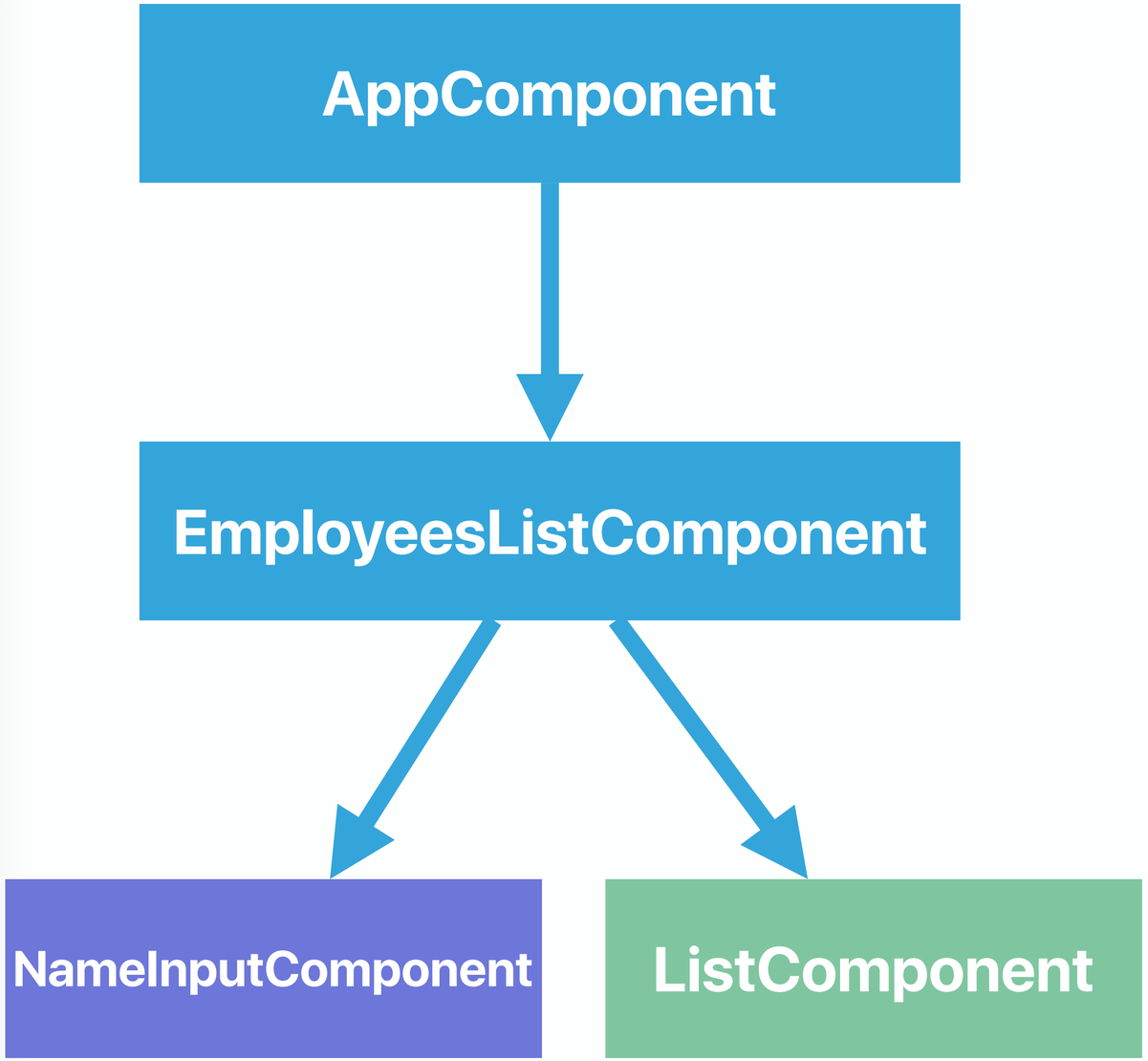
Ignored details for simplicity

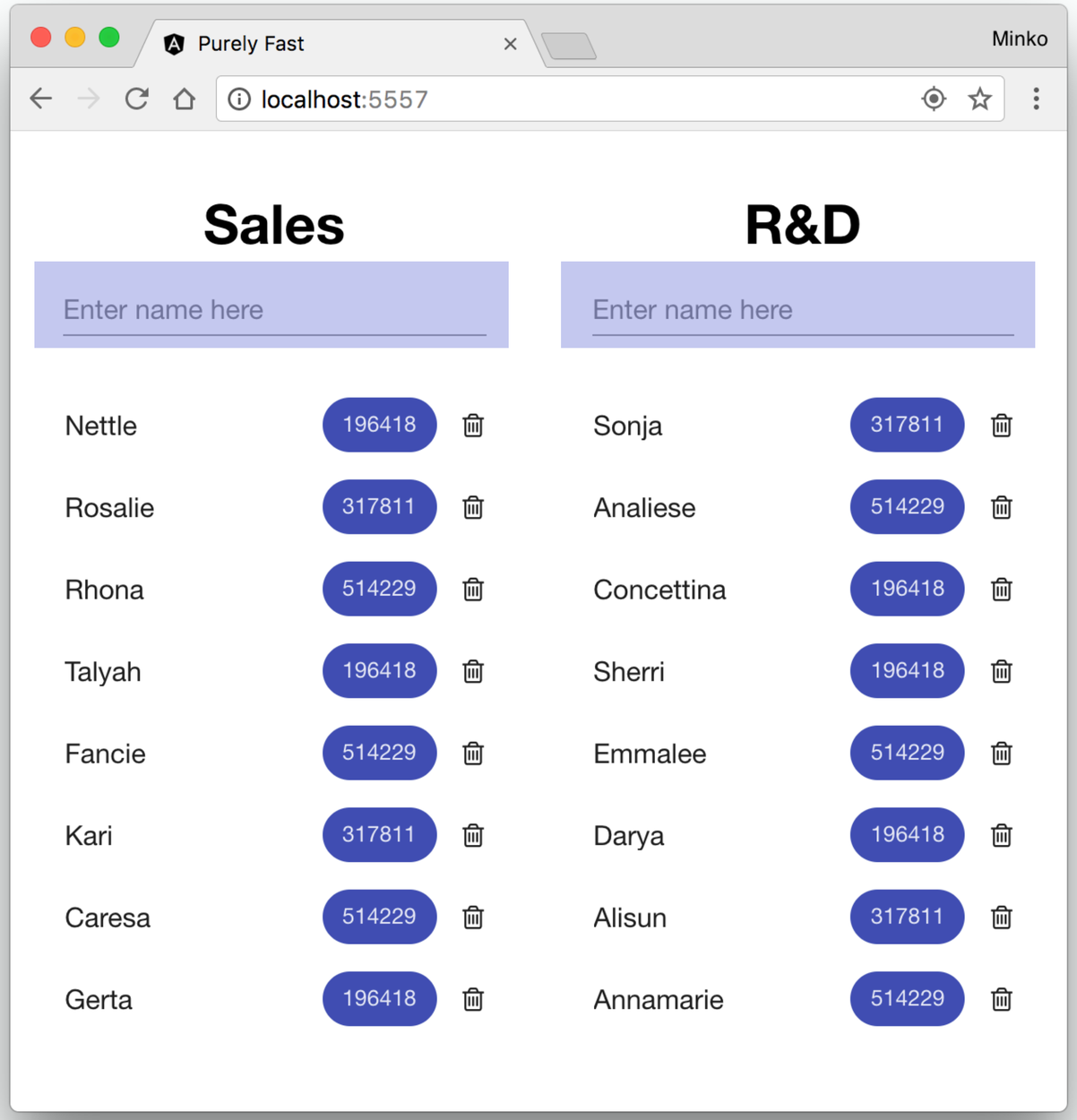


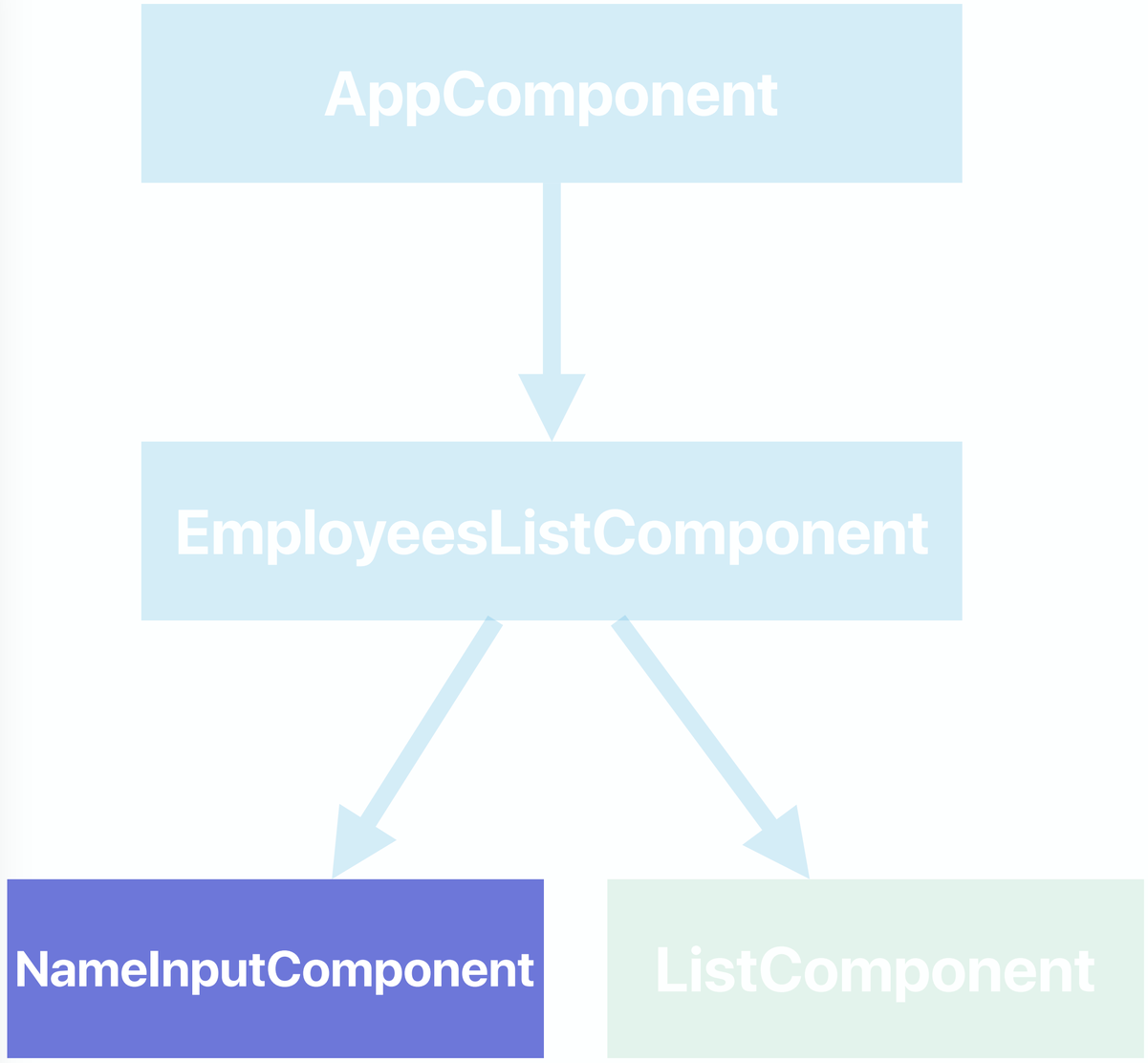
With `OnPush` change detection will be triggered when the framework, with reference check, determines that any of the inputs of a component has changed...**or when an event in the component is triggered**

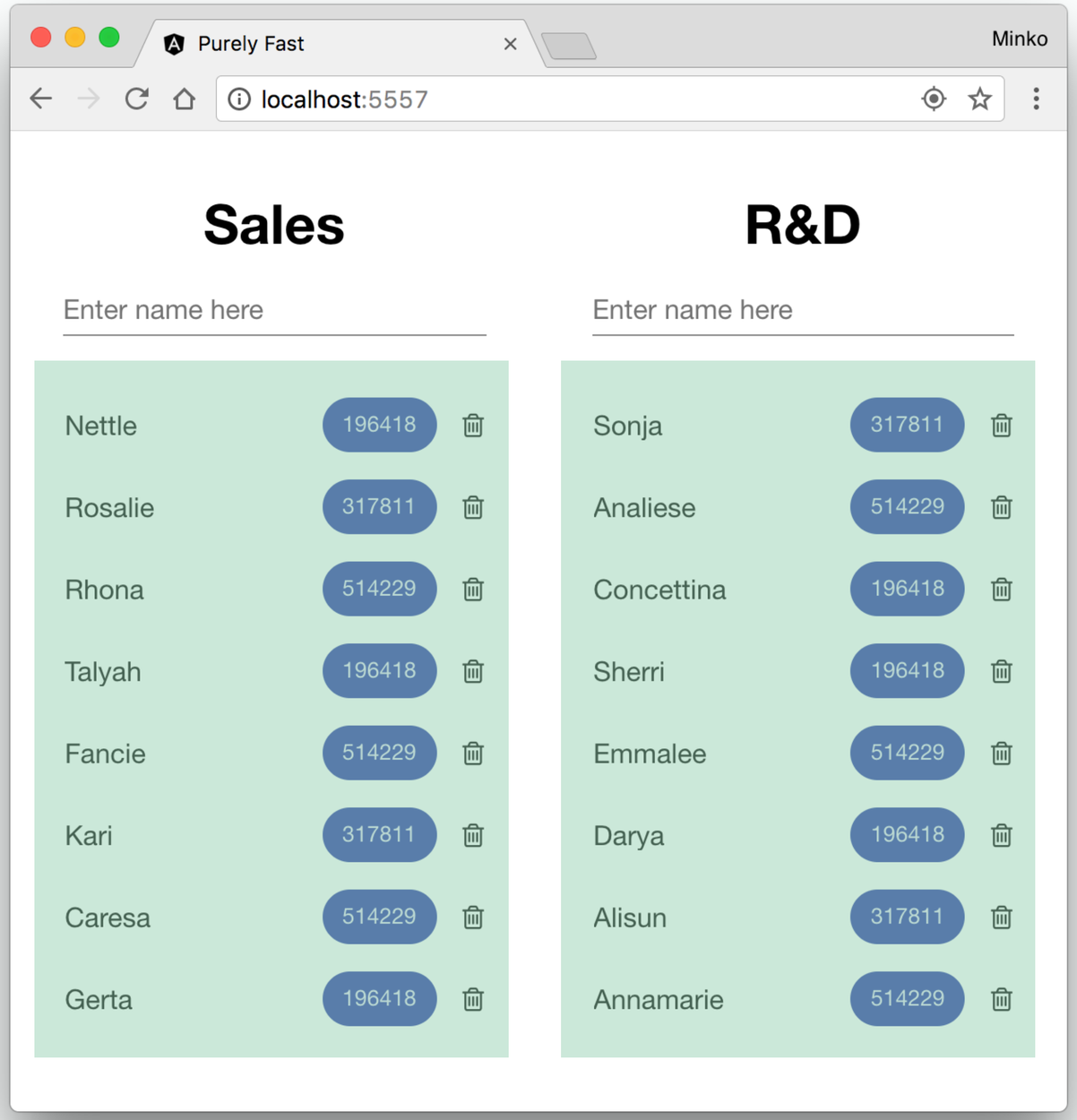
Lets do some refactoring!

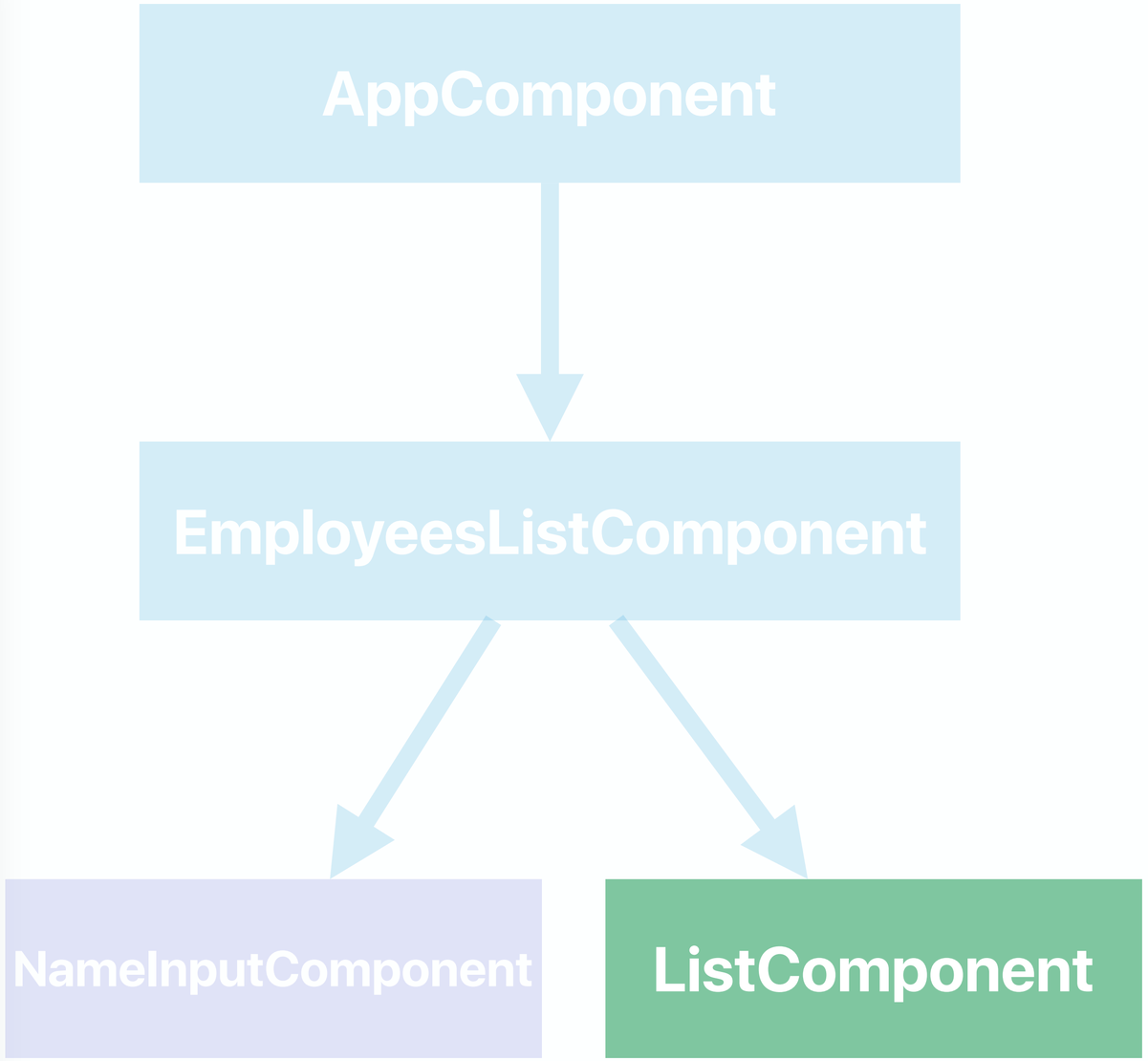

Purely Fast
Minko
localhost:5557
Sales
Enter name here
Nettle 196418
Rosalie 317811
Rhona 514229
Talyah 196418
Fancie 514229
Kari 317811
Caresa 514229
Gerta 196418
R&D
Enter name here
Sonja 317811
Analiese 514229
Concettina 196418
Sherri 196418
Emmalee 514229
Darya 196418
Alisun 317811
Annamarie 514229

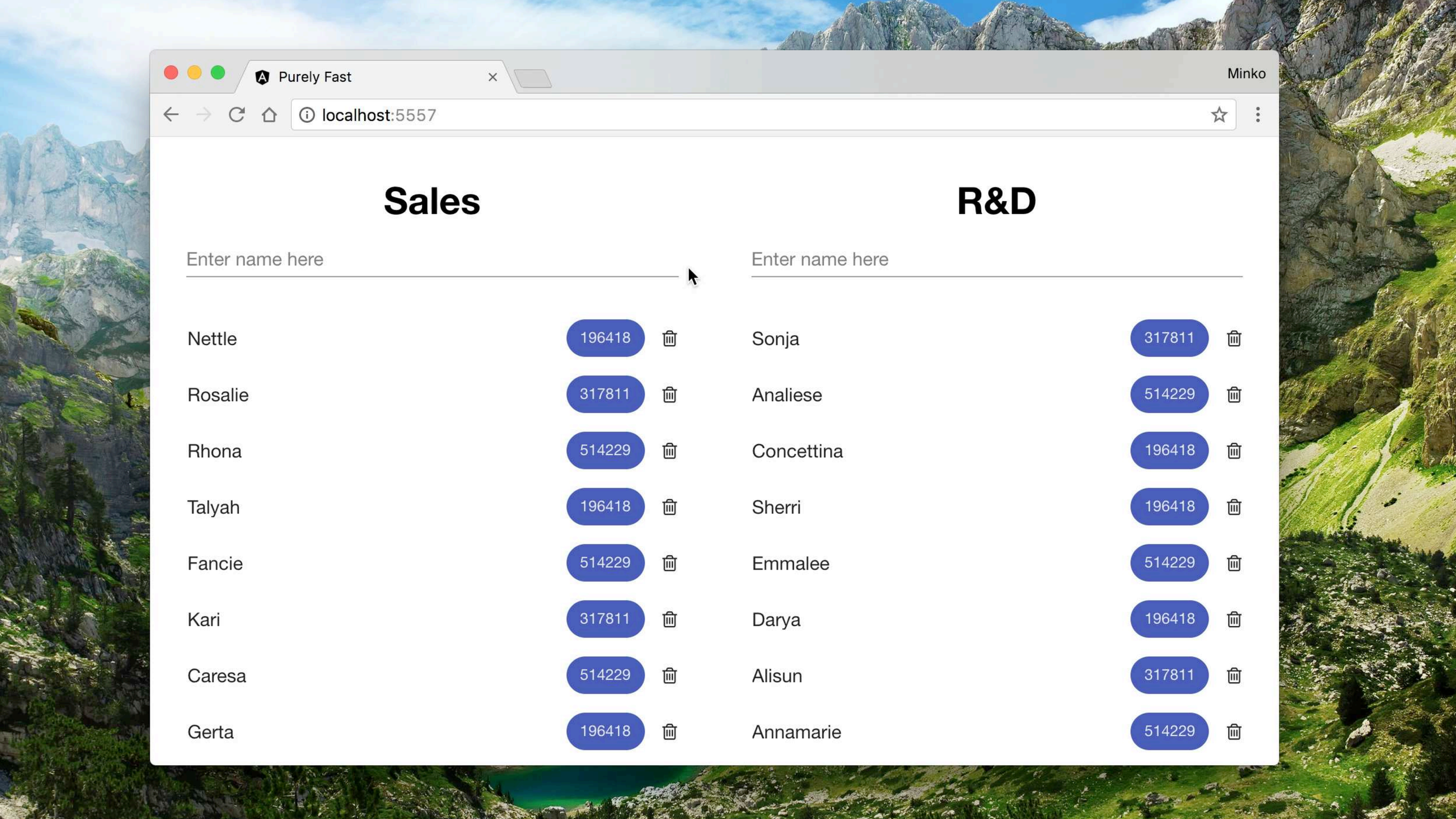

AppComponent
EmployeesListComponent
NameInputComponent
ListComponent


Purely Fast
Minko
localhost:5557
Sales
Enter name here
Nettle 196418
Rosalie 317811
Rhona 514229
Talyah 196418
Fancie 514229
Kari 317811
Caresa 514229
Gerta 196418
R&D
Enter name here
Sonja 317811
Analiese 514229
Concettina 196418
Sherri 196418
Emmalee 514229
Darya 196418
Alisun 317811
Annamarie 514229


AppComponent
EmployeesListComponent
NameInputComponent
ListComponent


Purely Fast
Minko
localhost:5557
Sales
Enter name here
Nettle 196418
Rosalie 317811
Rhona 514229
Talyah 196418
Fancie 514229
Kari 317811
Caresa 514229
Gerta 196418
R&D
Enter name here
Sonja 317811
Analiese 514229
Concettina 196418
Sherri 196418
Emmalee 514229
Darya 196418
Alisun 317811
Annamarie 514229

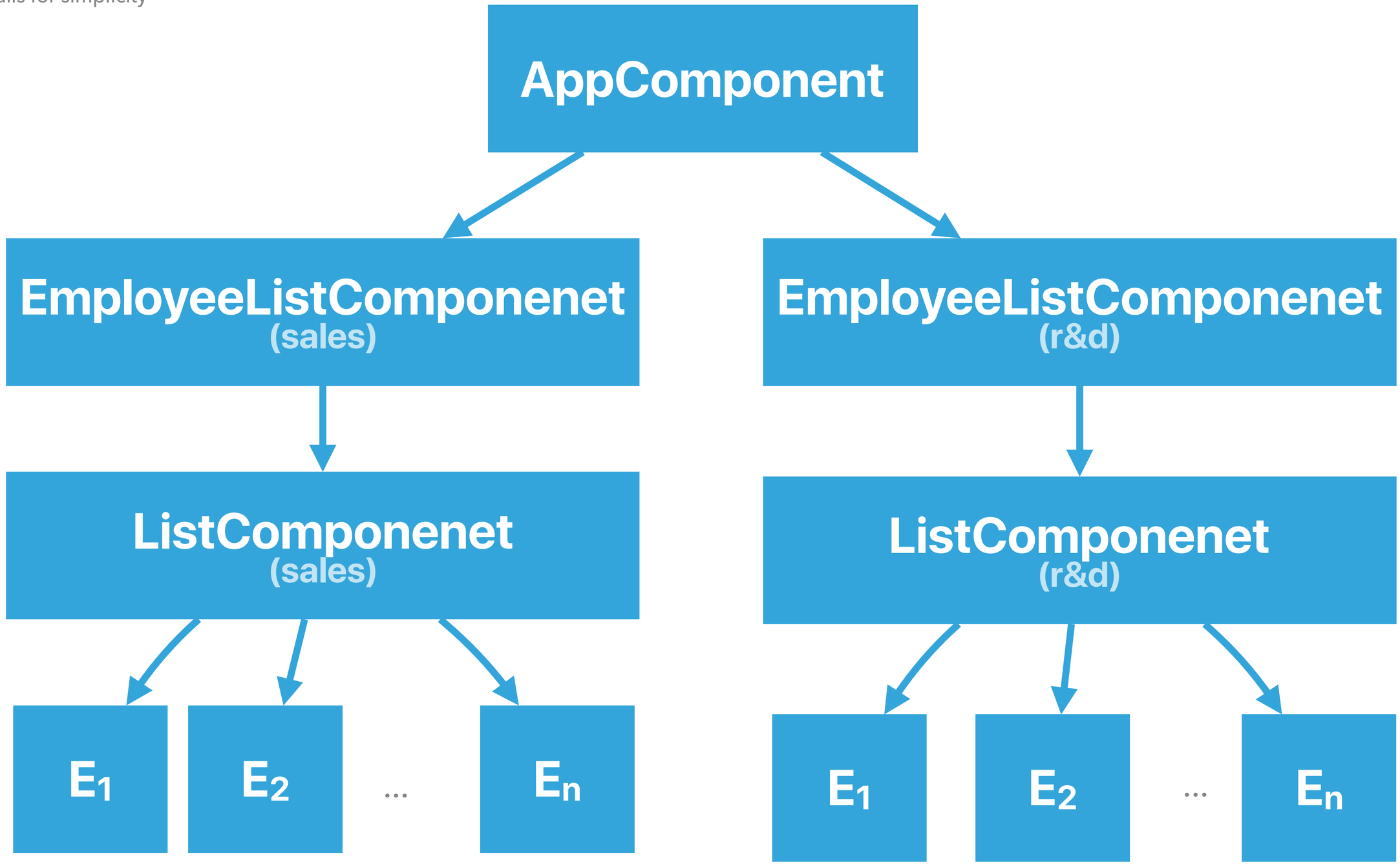

AppComponent
EmployeesListComponent
NameInputComponent
ListComponent


Purely Fast
Minko
localhost:5557
Sales
Enter name here
Nettle 196418
Rosalie 317811
Rhona 514229
Talyah 196418
Fancie 514229
Kari 317811
Caresa 514229
Gerta 196418
R&D
Enter name here
Sonja 317811
Analiese 514229
Concettina 196418
Sherri 196418
Emmalee 514229
Darya 196418
Alisun 317811
Annamarie 514229

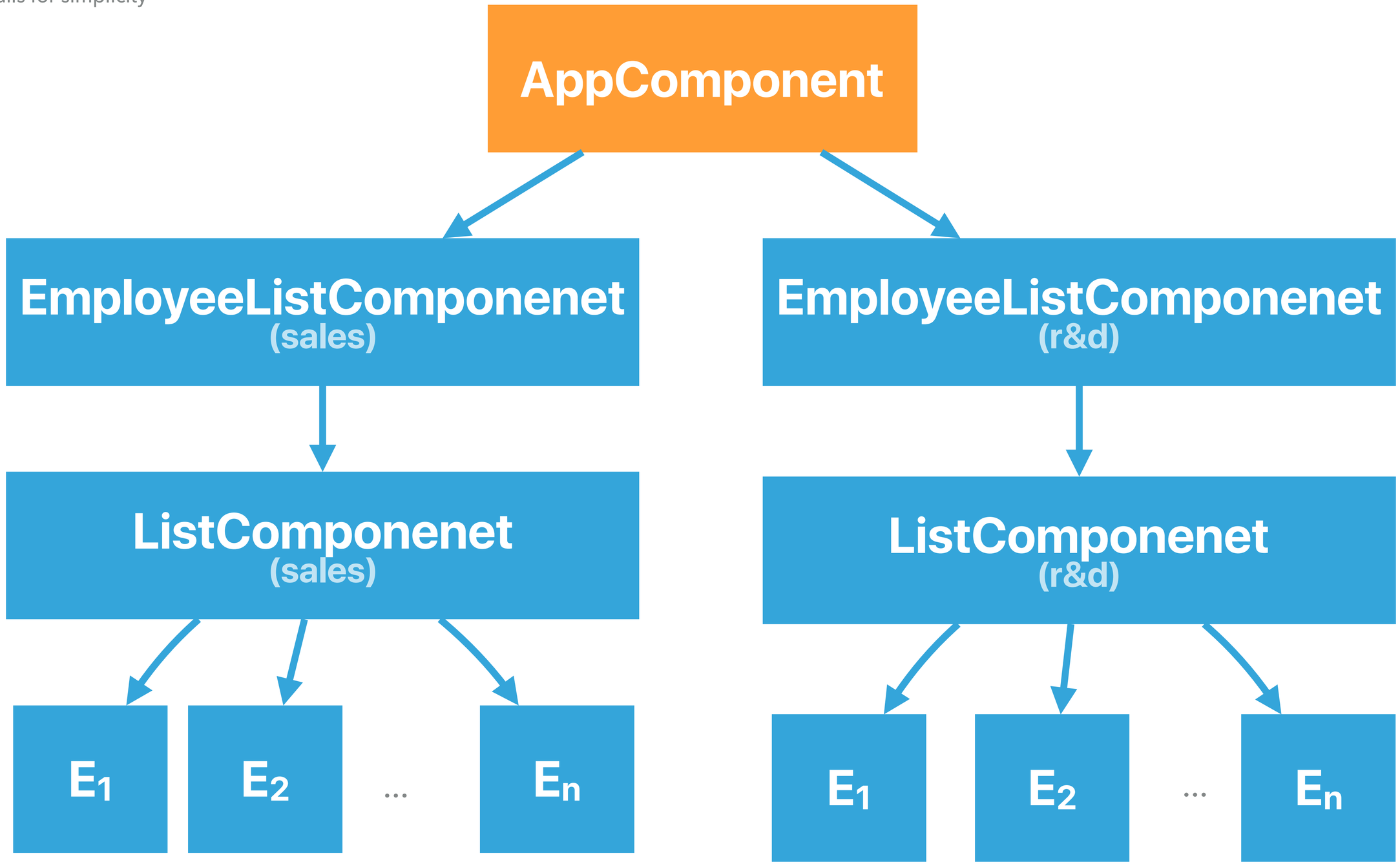
Sooo much faster!

twitter.com/mgechev

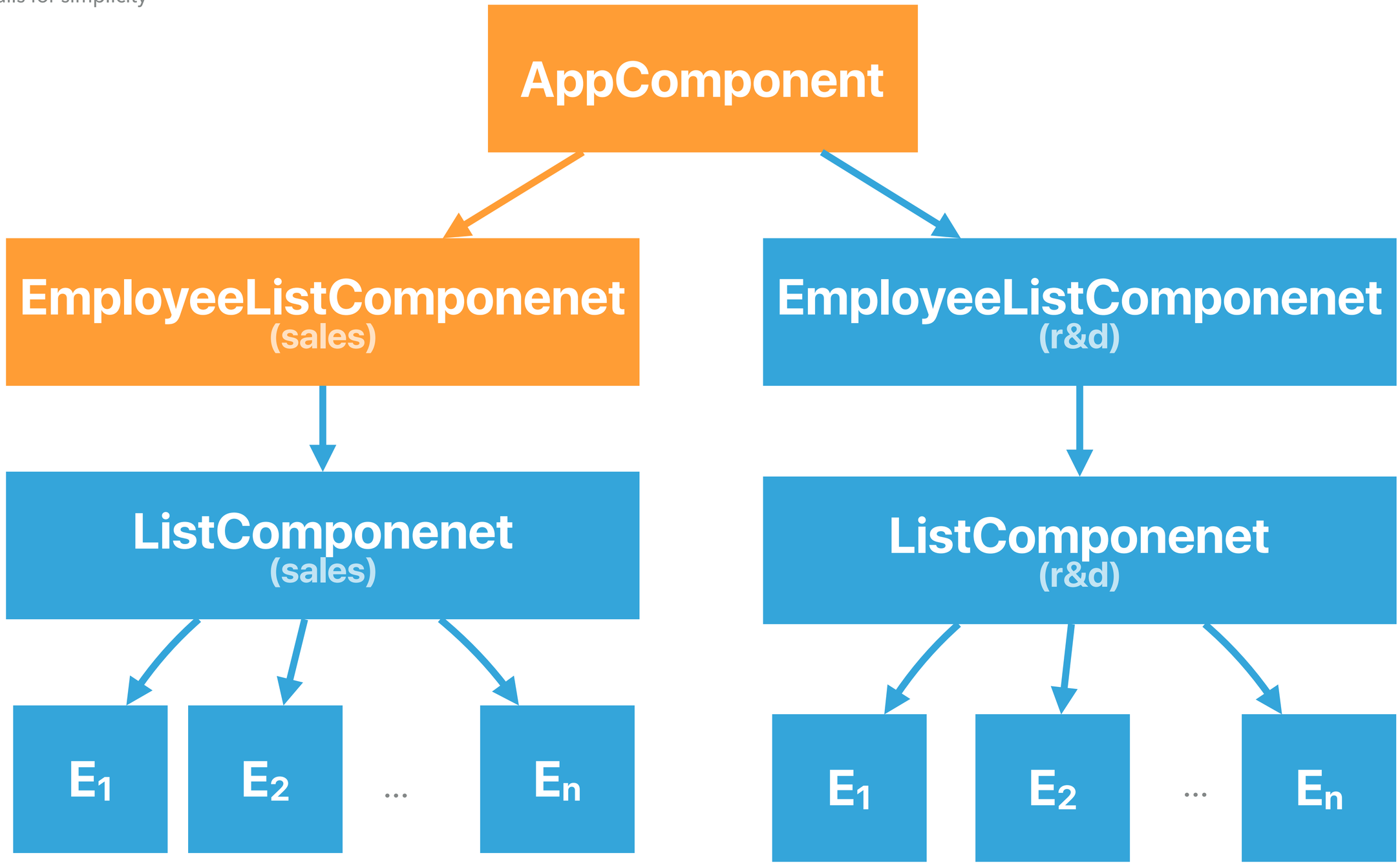
Ignored details for simplicity



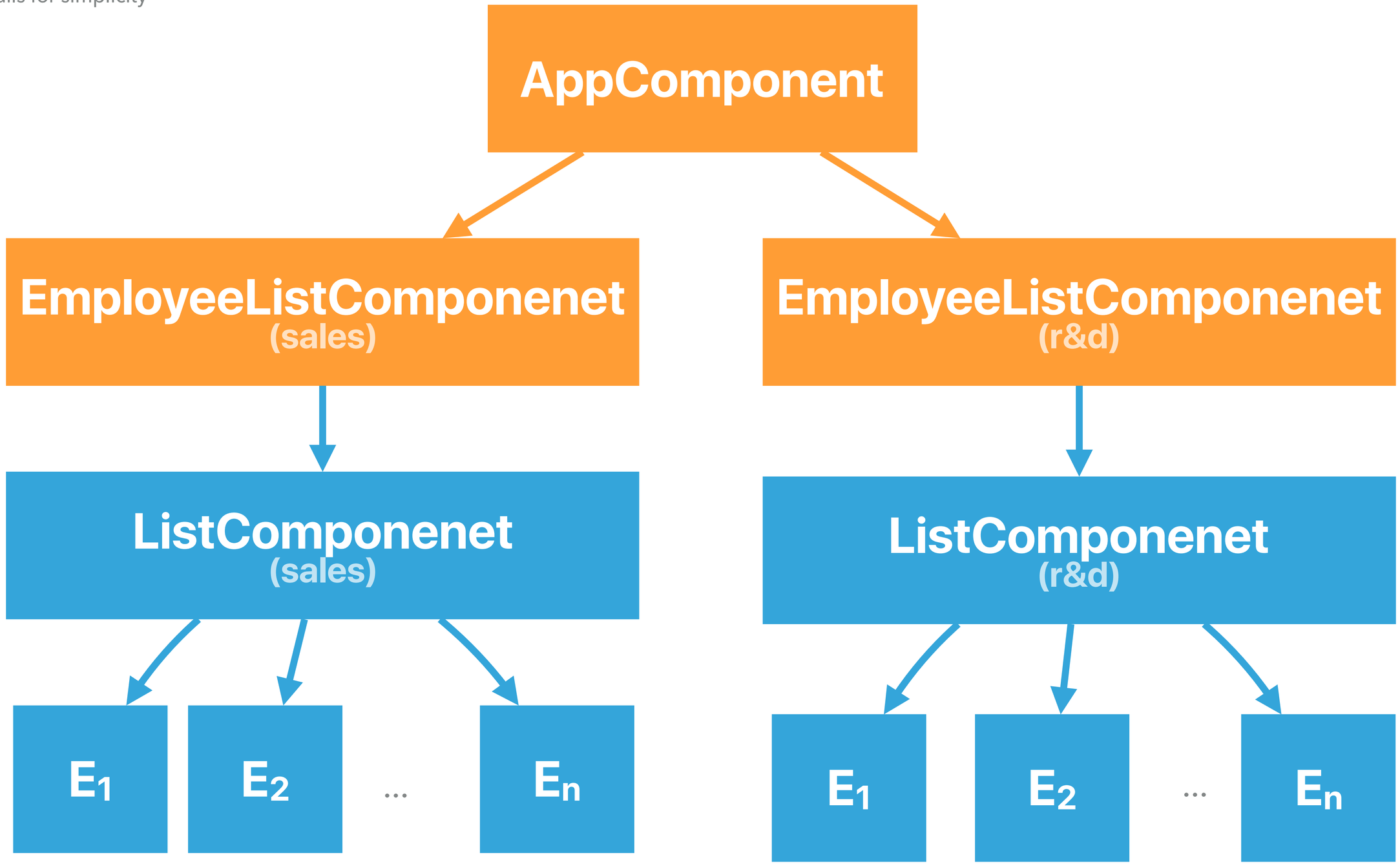
Ignored details for simplicity



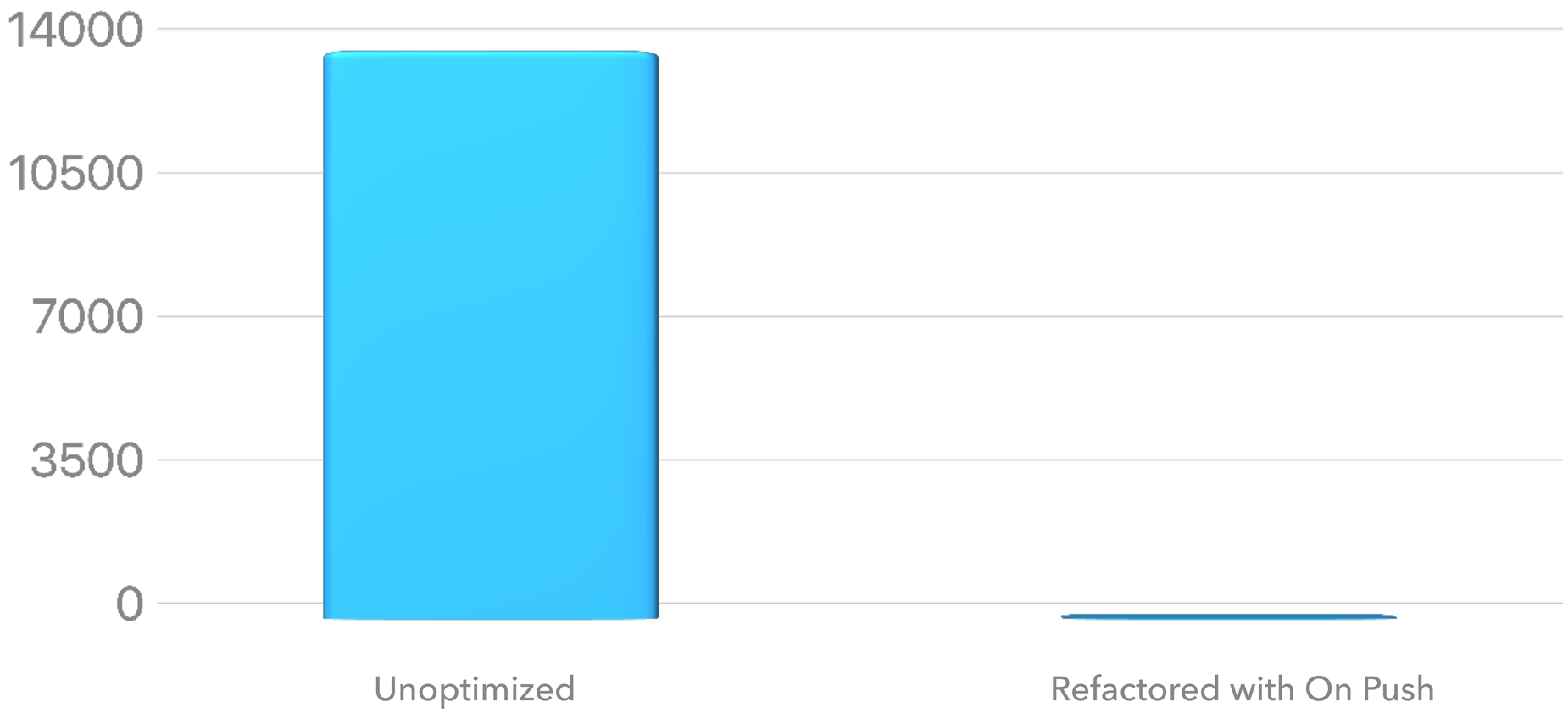
Ignored details for simplicity

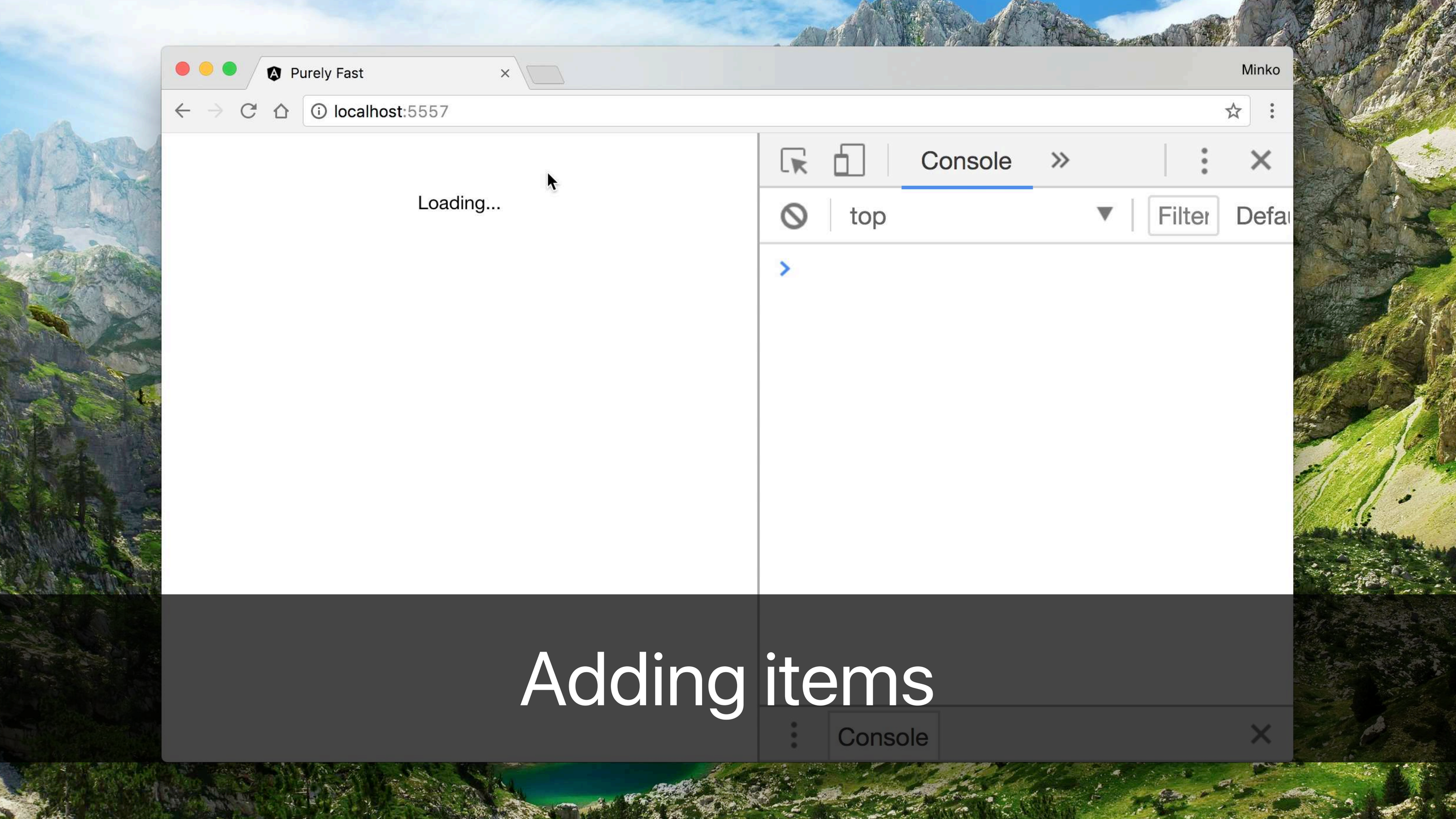


Ignored details for simplicity

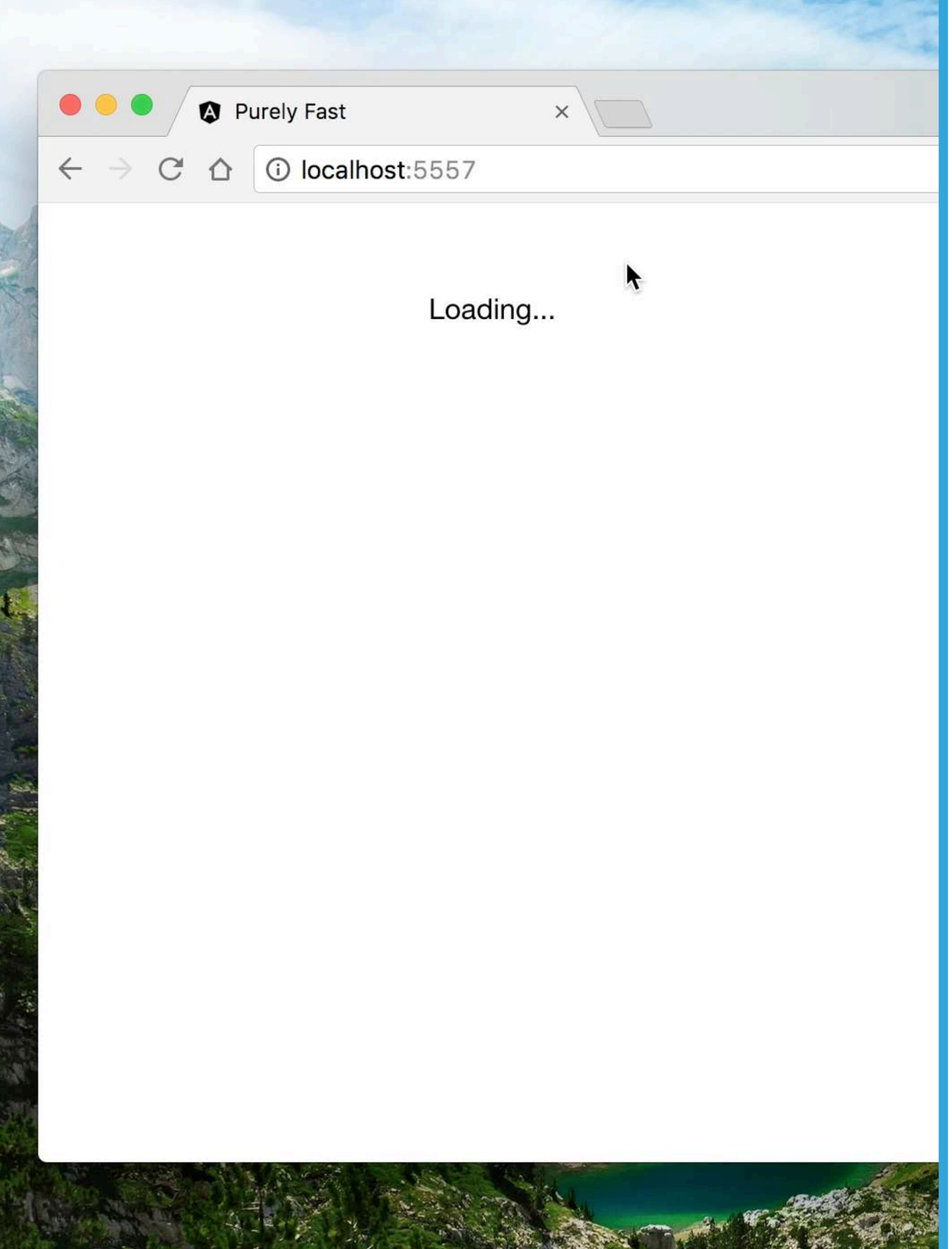


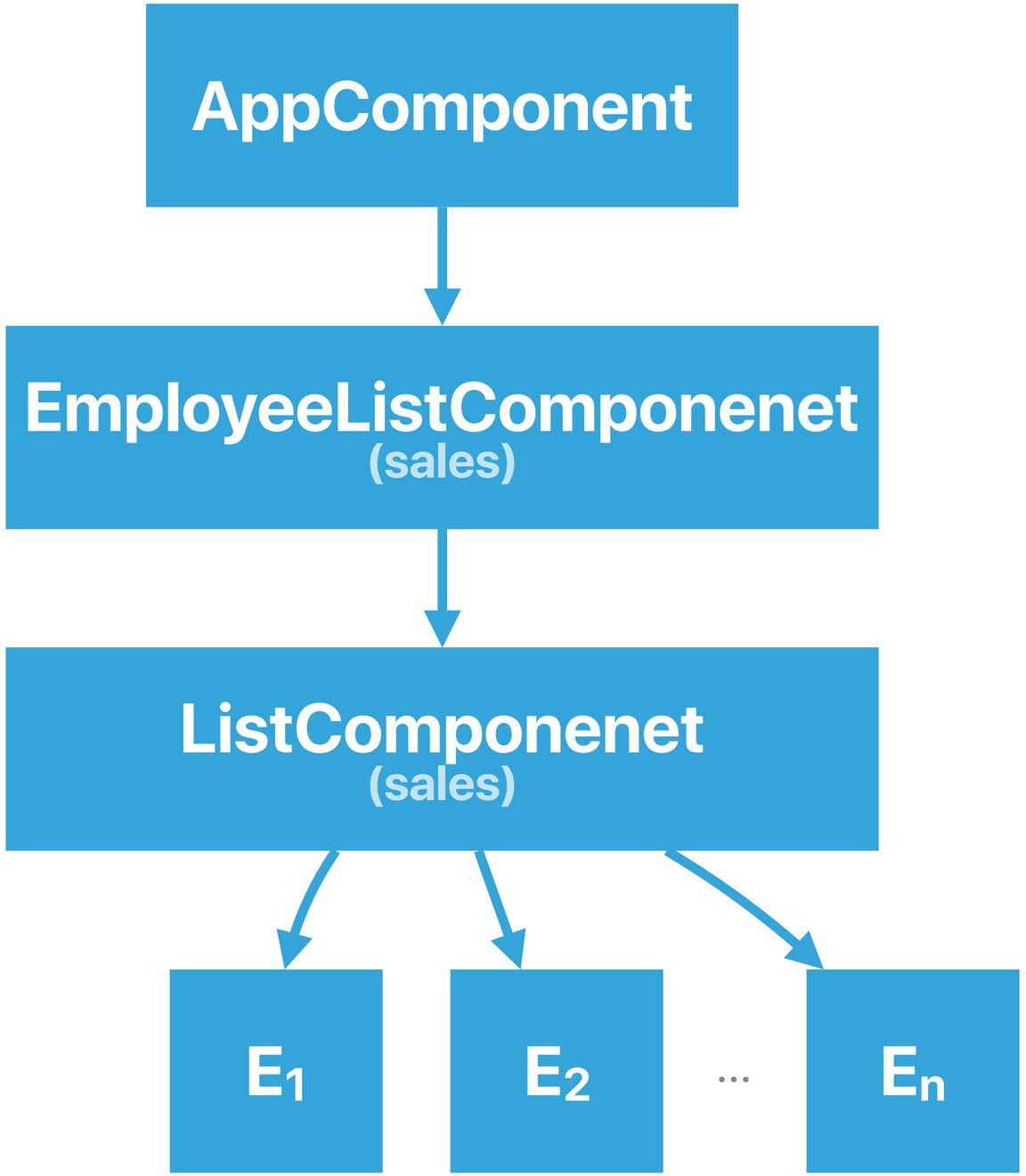
Typing Speed



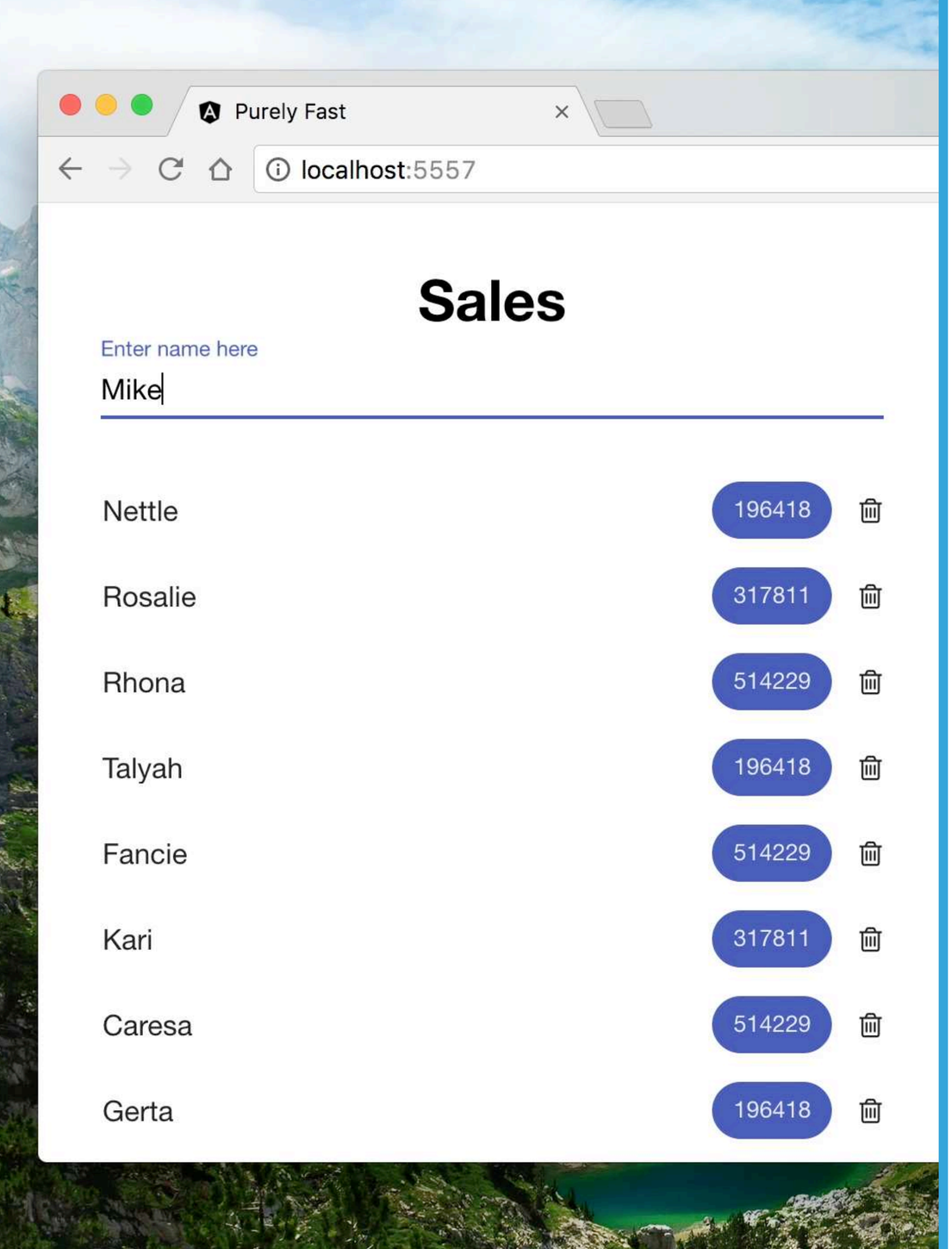


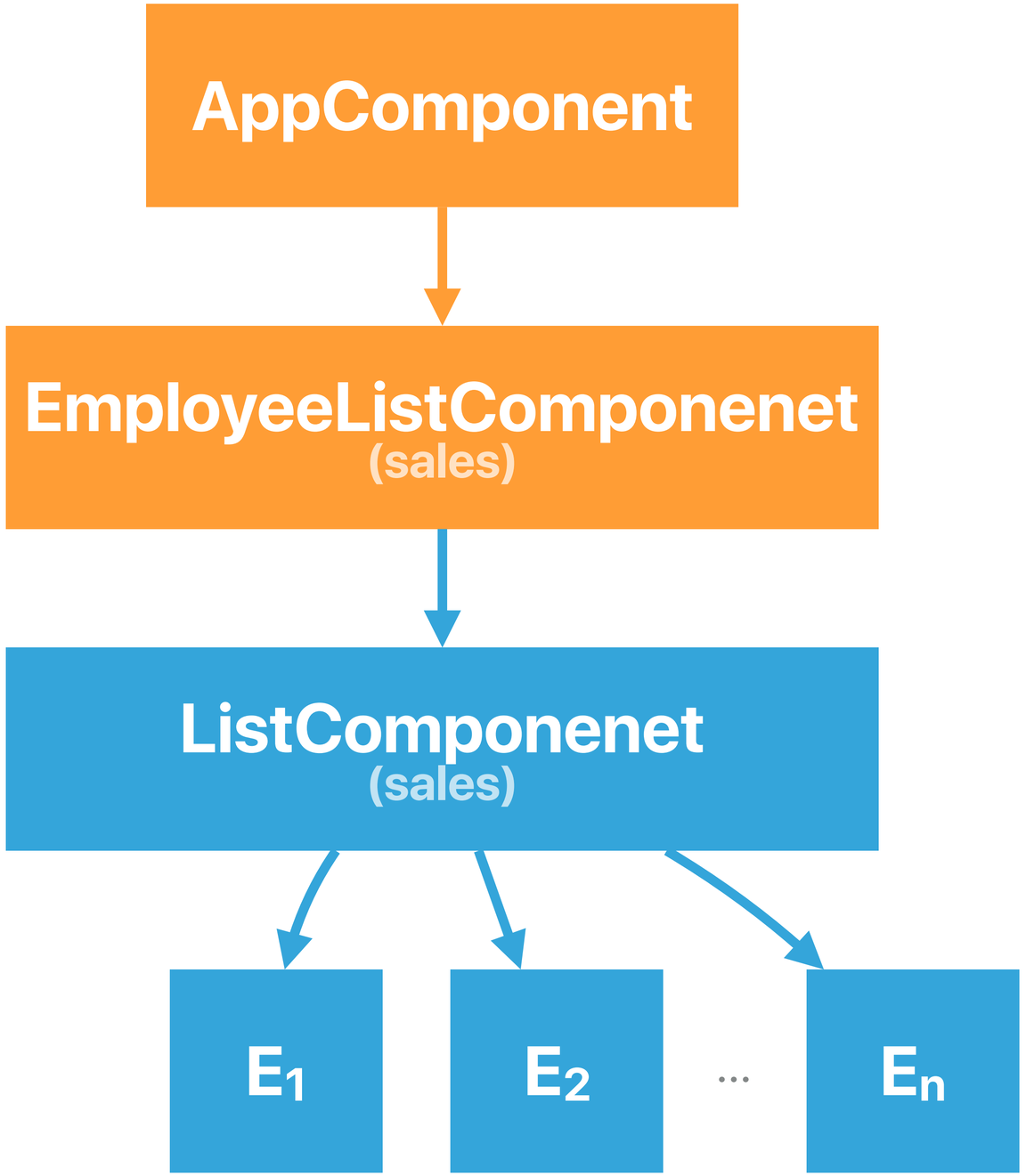
Adding items



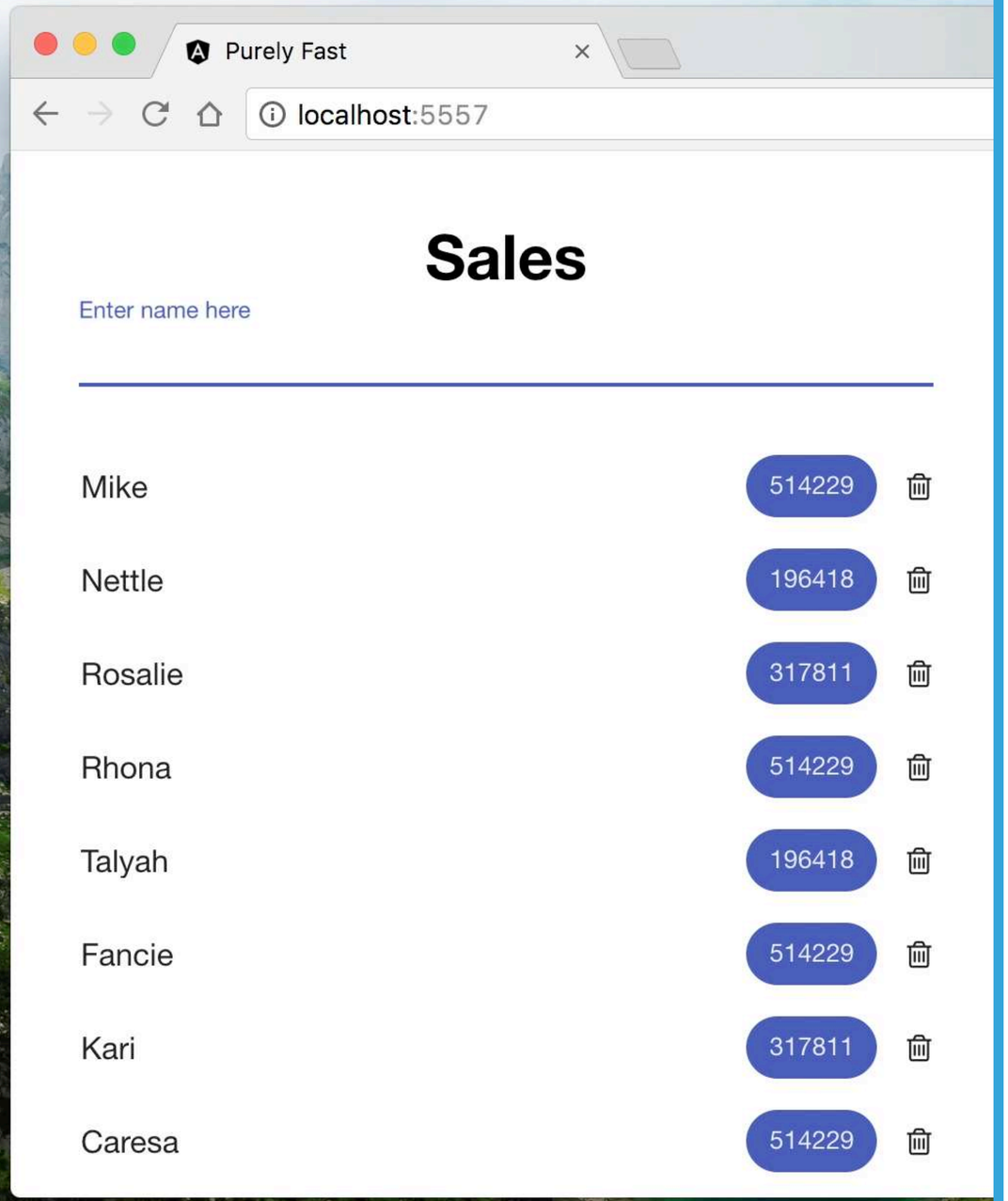


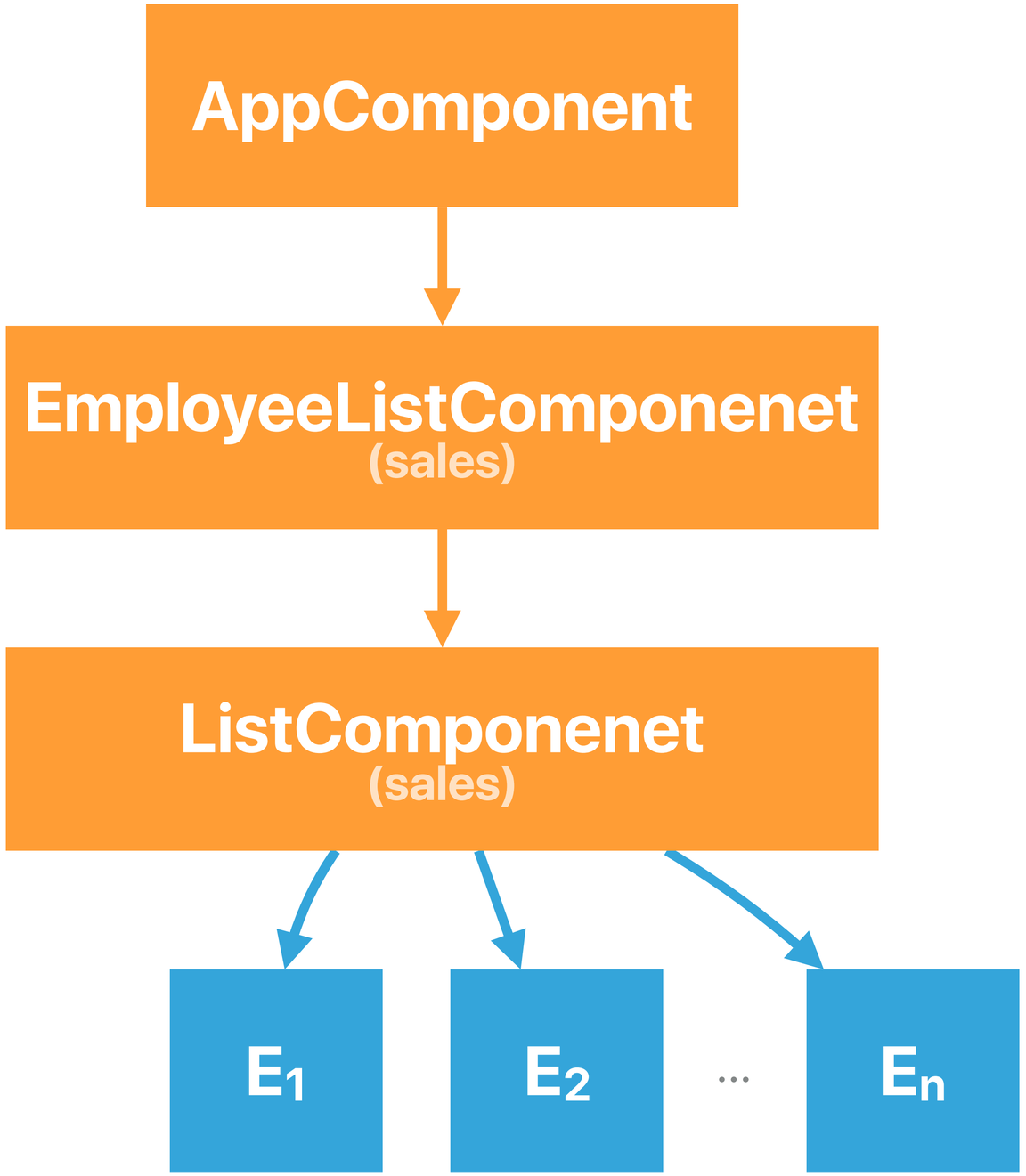
Ignored details for simplicity



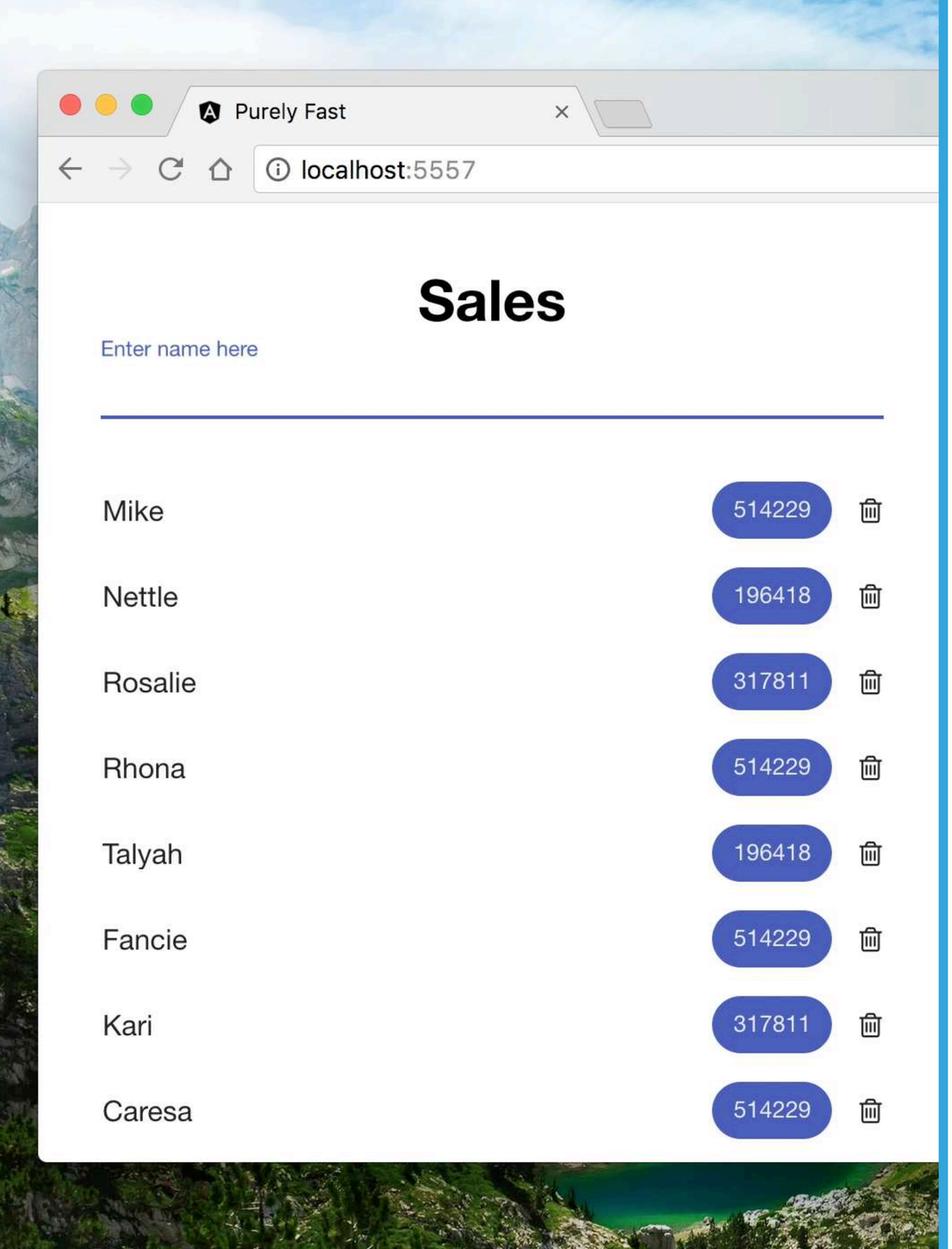


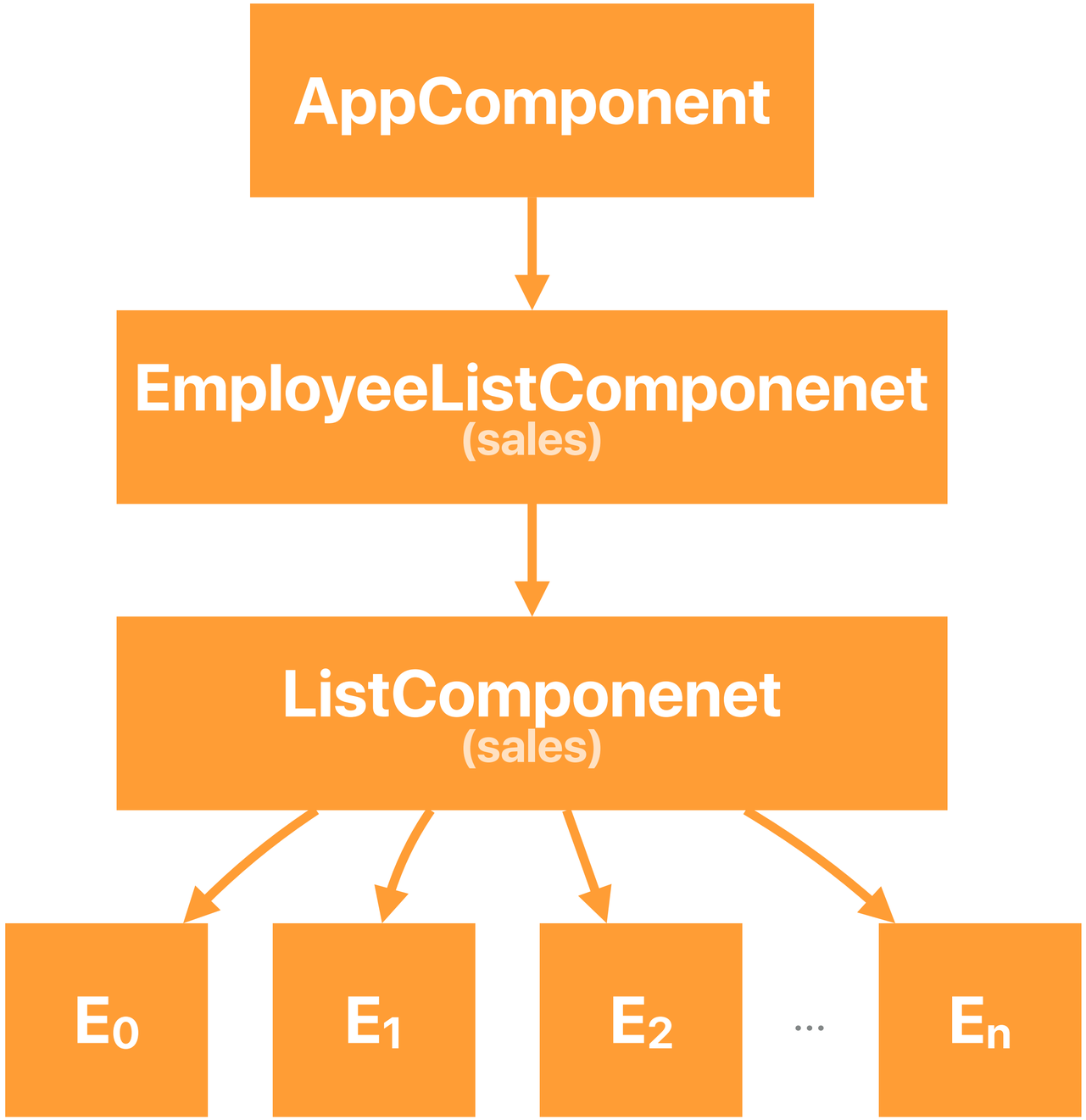
Ignored details for simplicity





Ignored details for simplicity





Ignored details for simplicity

Recomputing everything

every time we add a new entry

```
const fibonacci = n ⇒ {
  if (n === 1 || n === 2) return 1;
  return fibonacci(n - 1) + fibonacci(n - 2);
};
```

```
const fibonacci = n ⇒ {
  if (n === 1 || n === 2) return 1;
  return fibonacci(n - 1) + fibonacci(n - 2);
};


  // Two properties
  // - No side effects
  // - Same result for same arguments
```

Pure Function

Pipes in Angular

- Pure
- Impure

Angular executes a pure pipe only when it detects a change to the input value. A pure change is either a change to a primitive input value (String, Number, Boolean, Symbol) or a changed object reference (Date, Array, Function, Object).

Angular treats expressions with pure pipes as **referentially transparent**

```
{{ birthday | date }}
{{ birthday | impureDate }}
```

```
{{ birthday | date }}
{{ birthday | impureDate }}
```

```
i1.ɵunv(_v, 1, 0, _ck(_v, 2, 0,
  i1.ɵnov(_v, 0), _co.birthday));

i1.ɵunv(_v, 1, 1,
  i1.ɵnov(_v, 3).transform(_co.birthday));
```

```
{{ birthday | date }}
{{ birthday | impureDate }}
```

```
i1.ɵunv(_v, 1, 0, _ck(_v, 2, 0,
  i1.ɵnov(_v, 0), _co.birthday));

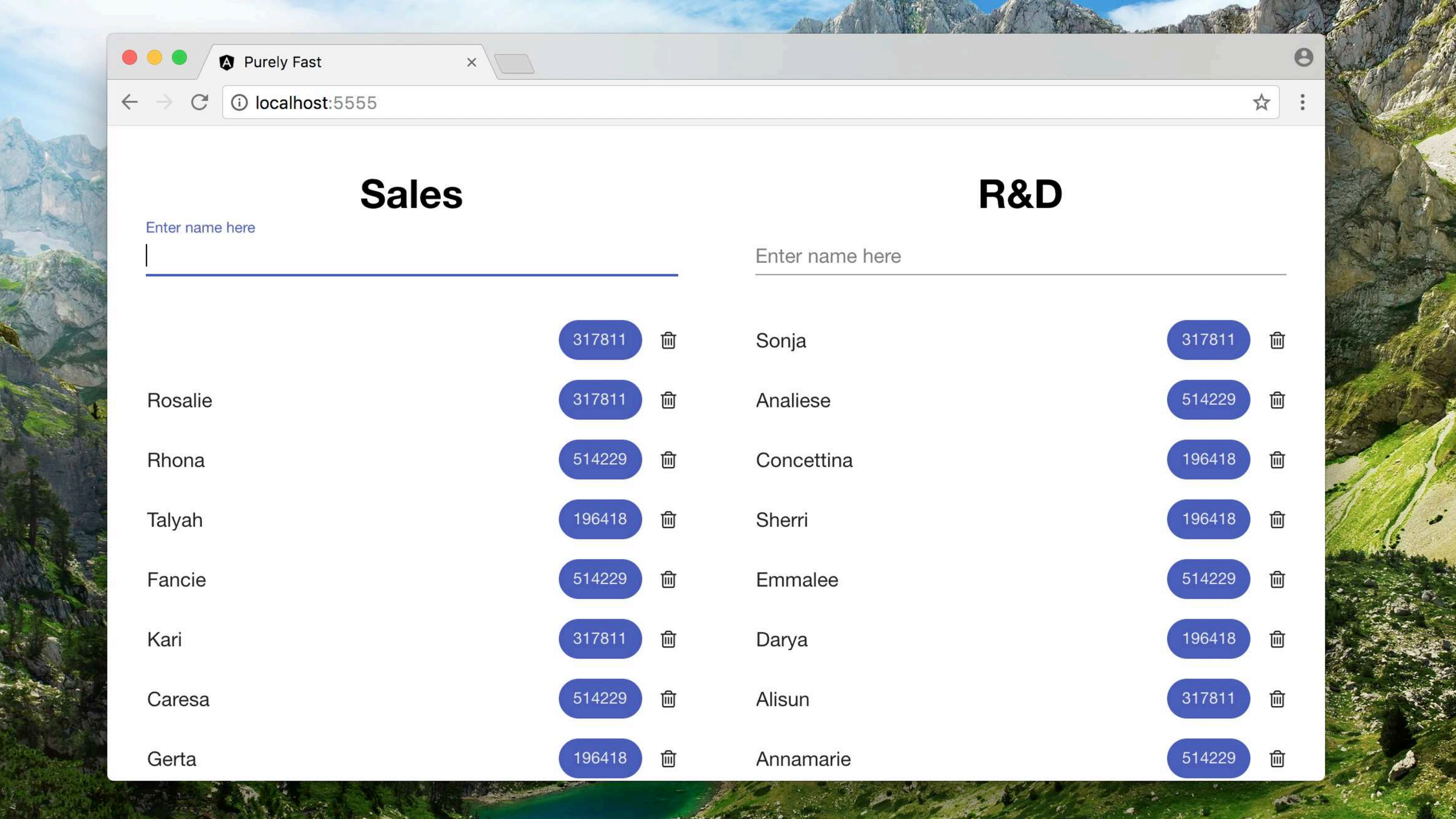
i1.ɵunv(_v, 1, 1,
  i1.ɵnov(_v, 3).transform(_co.birthday));
```

```
@Pipe({
  name: 'calculate',
  pure: true
})
export class CalculatePipe {
  transform(num: number) {
    return fibonacci(num);
  }
}
```

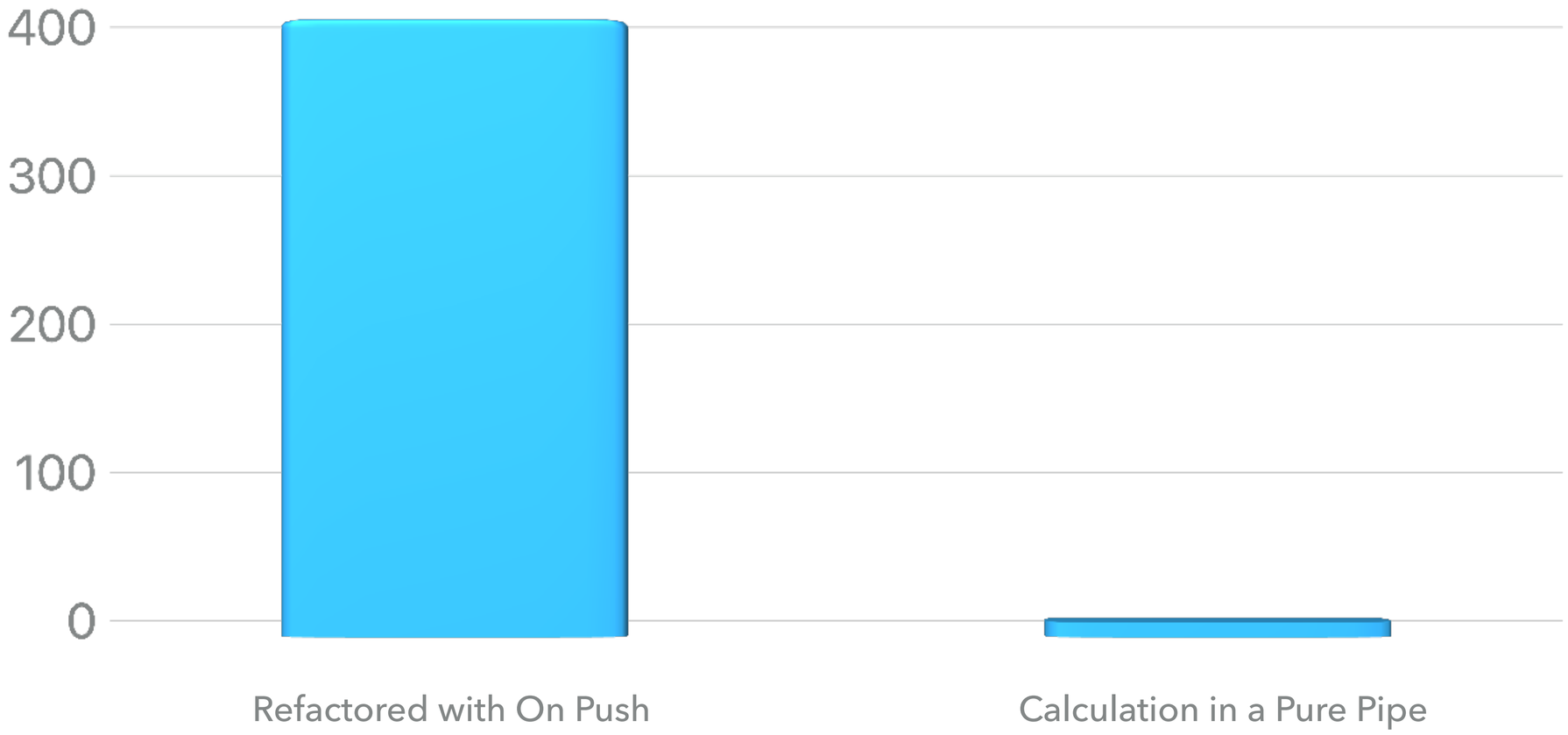
```
@Component({
  changeDetection:
    ChangeDetectionStrategy.OnPush,
  template: `
    ...
     {{ item.num | calculate }}
    ...
  `
})
export class ListComponent {  ...  }
```

Lets **benchpress** it!

twitter.com/mgechev

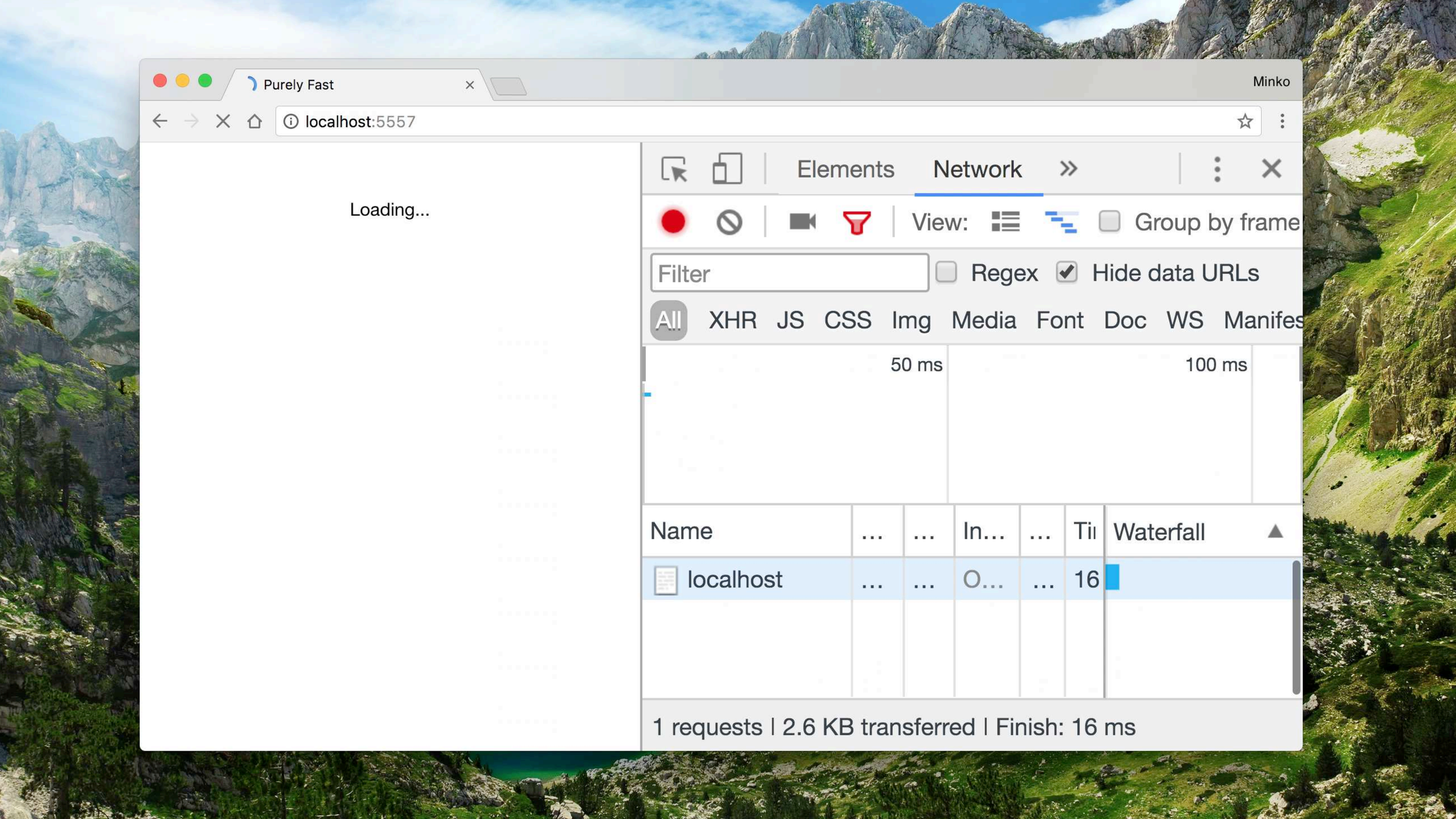

Purely Fast
localhost:5555
Sales
Enter name here
317811
Rosalie
317811
Rhona
514229
Talyah
196418
Fancie
514229
Kari
317811
Caresa
514229
Gerta
196418
R&D
Enter name here
Sonja
317811
Analiese
514229
Concettina
196418
Sherri
196418
Emmalee
514229
Darya
196418
Alisun
317811
Annamarie
514229

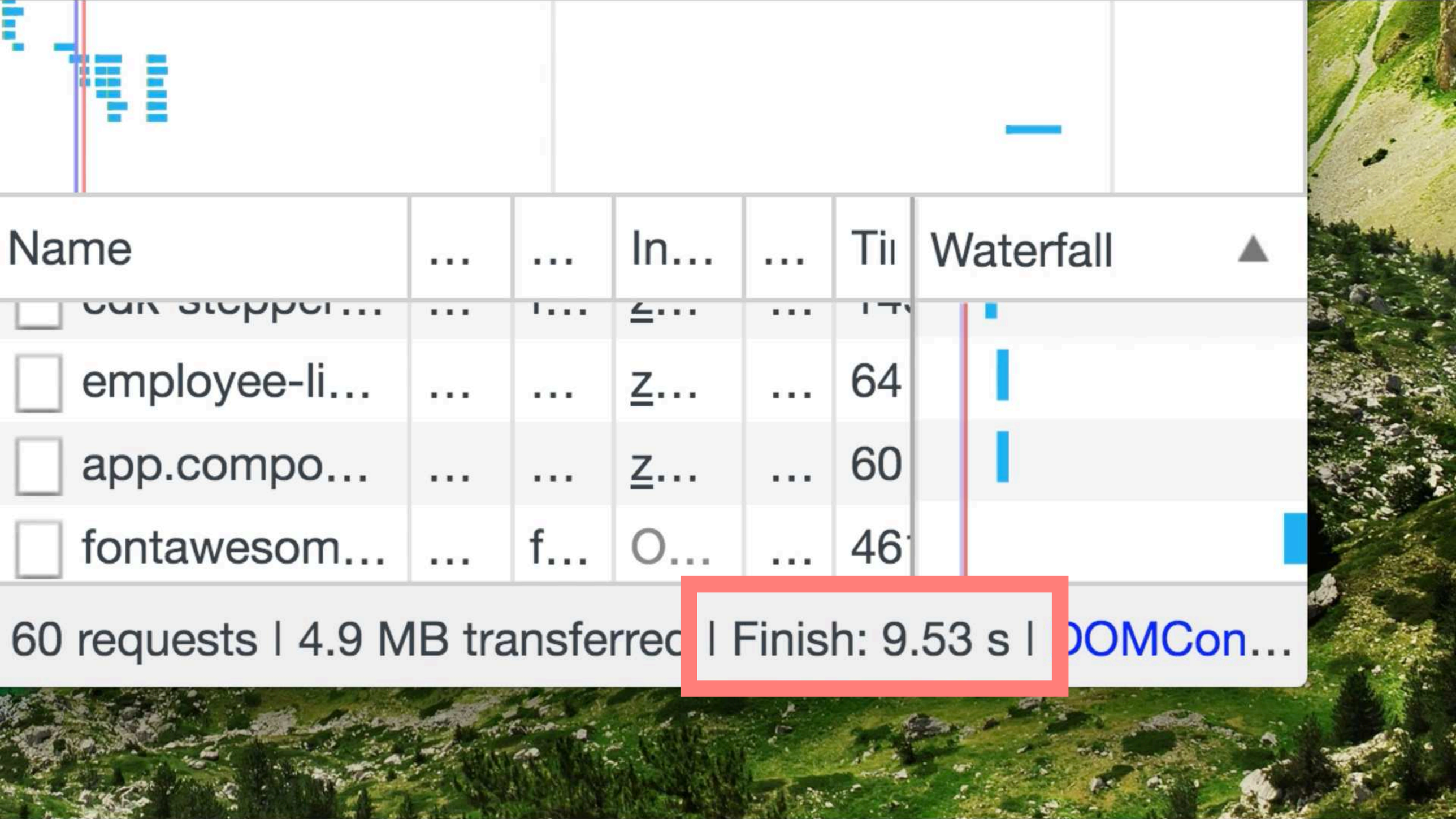
Adding / Removing Entries



Initial rendering...

with 1000 items


Purely Fast
Minko
localhost:5557
Loading...
Elements
Network
View:
Group by frame
Filter
Regex
Hide data URLs
All
XHR
JS
CSS
Img
Media
Font
Doc
WS
Manifes
50 ms
100 ms
Name
Waterfall
localhost
16
1 requests | 2.6 KB transferred | Finish: 16 ms


Name
...
...
In...
...
Ti
Waterfall
employee-li...
z...
64
app.compo...
z...
60
fontawesom...
f...
46
60 requests | 4.9 MB transferred
| Finish: 9.53 s |
DOMCon...

Lets take a look at our data

Sales

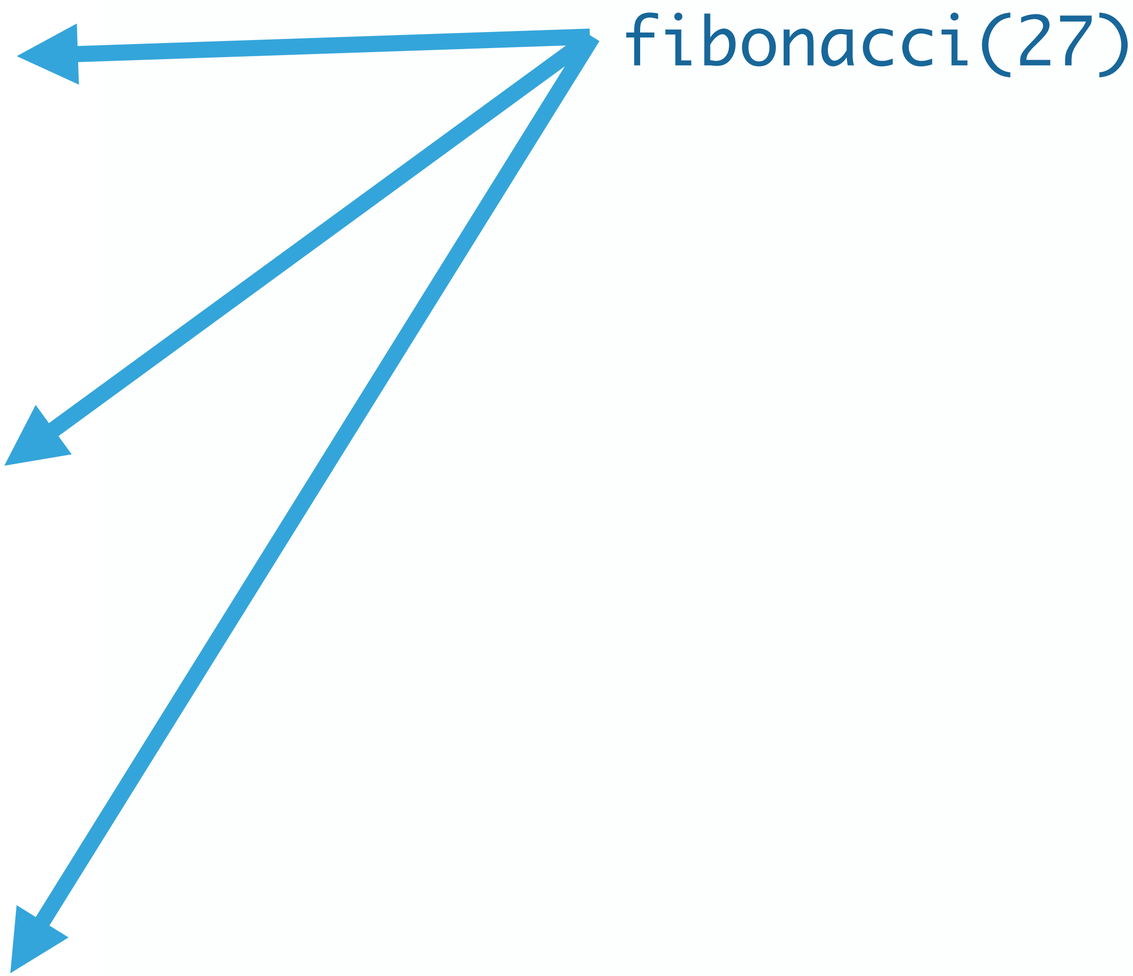
Enter name here

Nettle	196418
Rosalie	317811
Rhona	514229
Talyah	196418
Fancie	514229
Kari	317811
Caresa	514229
Gerta	196418

Sales

Enter name here

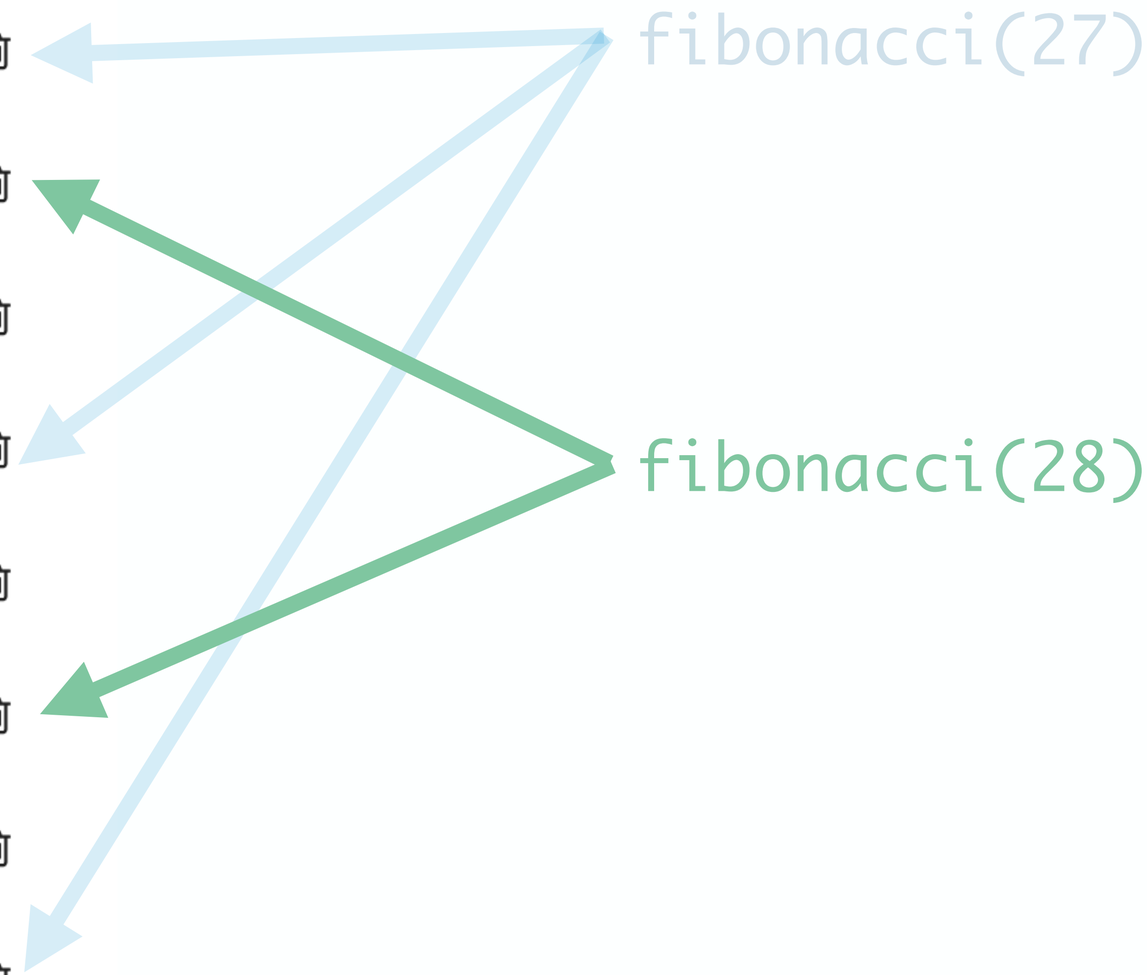
Nettle	196418
Rosalie	317811
Rhona	514229
Talyah	196418
Fancie	514229
Kari	317811
Caresa	514229
Gerta	196418



Sales

Enter name here

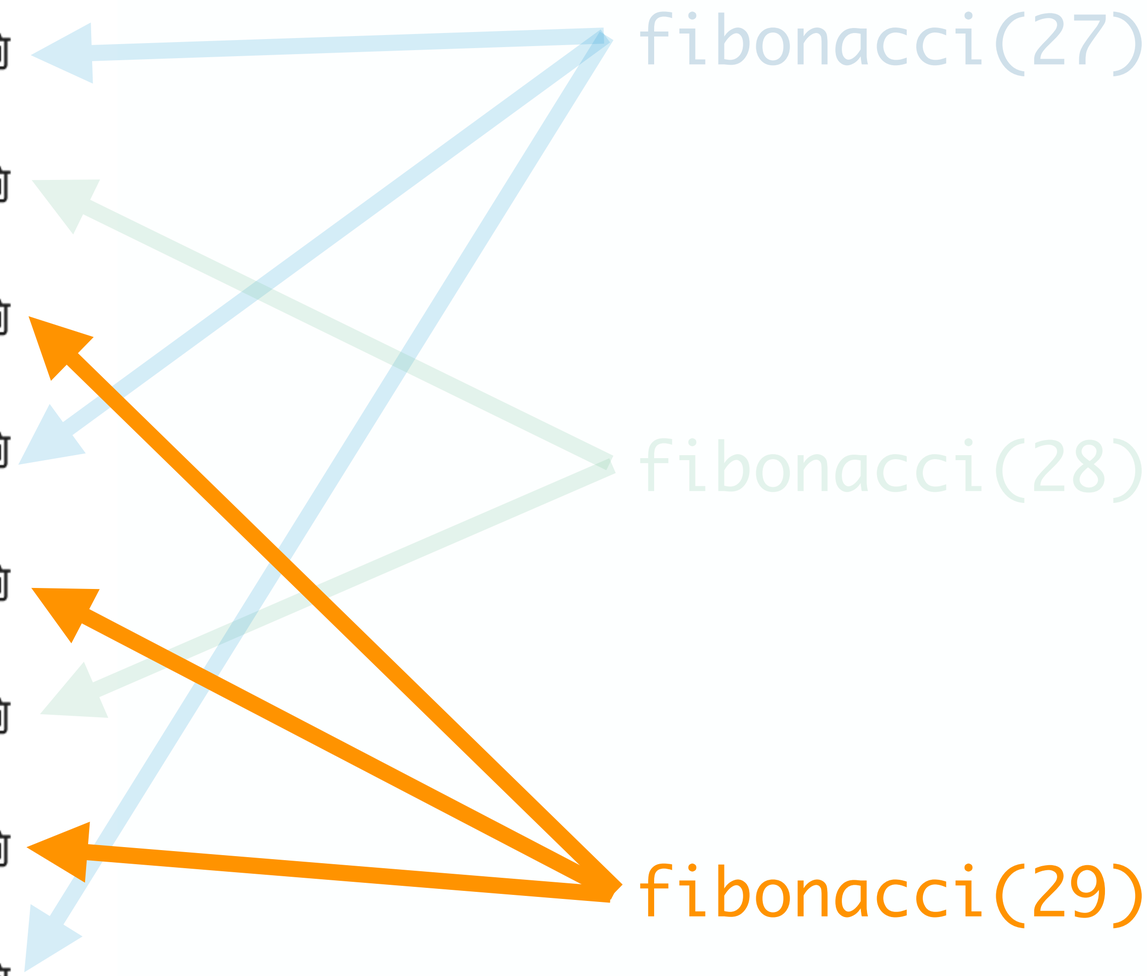
Nettle	196418
Rosalie	317811
Rhona	514229
Talyah	196418
Fancie	514229
Kari	317811
Caresa	514229
Gerta	196418



Sales

Enter name here

Nettle	196418
Rosalie	317811
Rhona	514229
Talyah	196418
Fancie	514229
Kari	317811
Caresa	514229
Gerta	196418



Samples from a small range

During initial rendering we **recompute same value multiple times**

Solution

Caching the value once computed

Memoization

Memoization

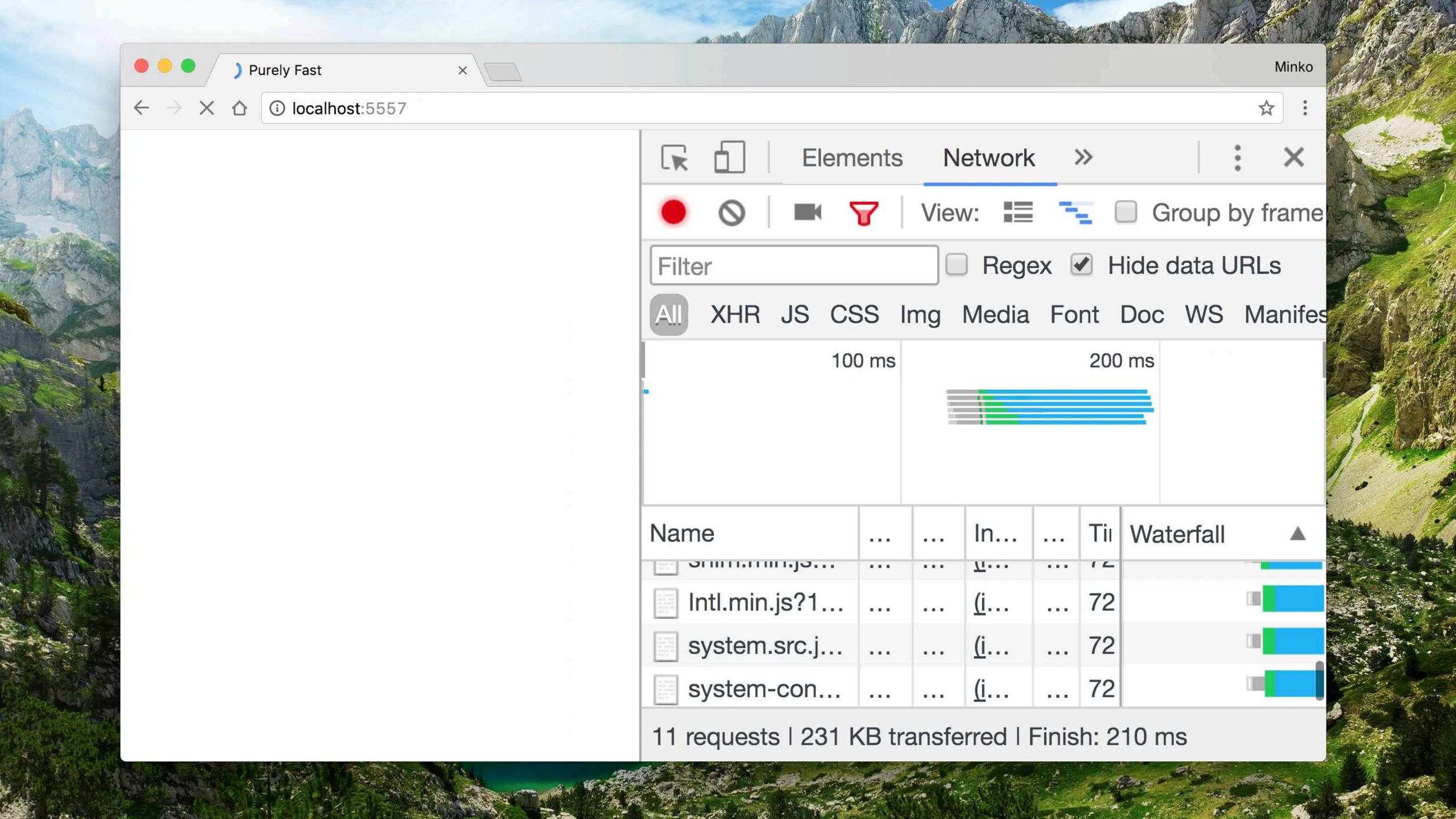
possible for pure functions

```
const memoize = require('lodash.memoize');

const fibonacci = memoize((num: number): number ⇒ {
  if (num === 1 || num === 2) return 1;
  return fibonacci(num - 1) + fibonacci(num - 2);
});
```

```
const memoize = require('lodash.memoize');

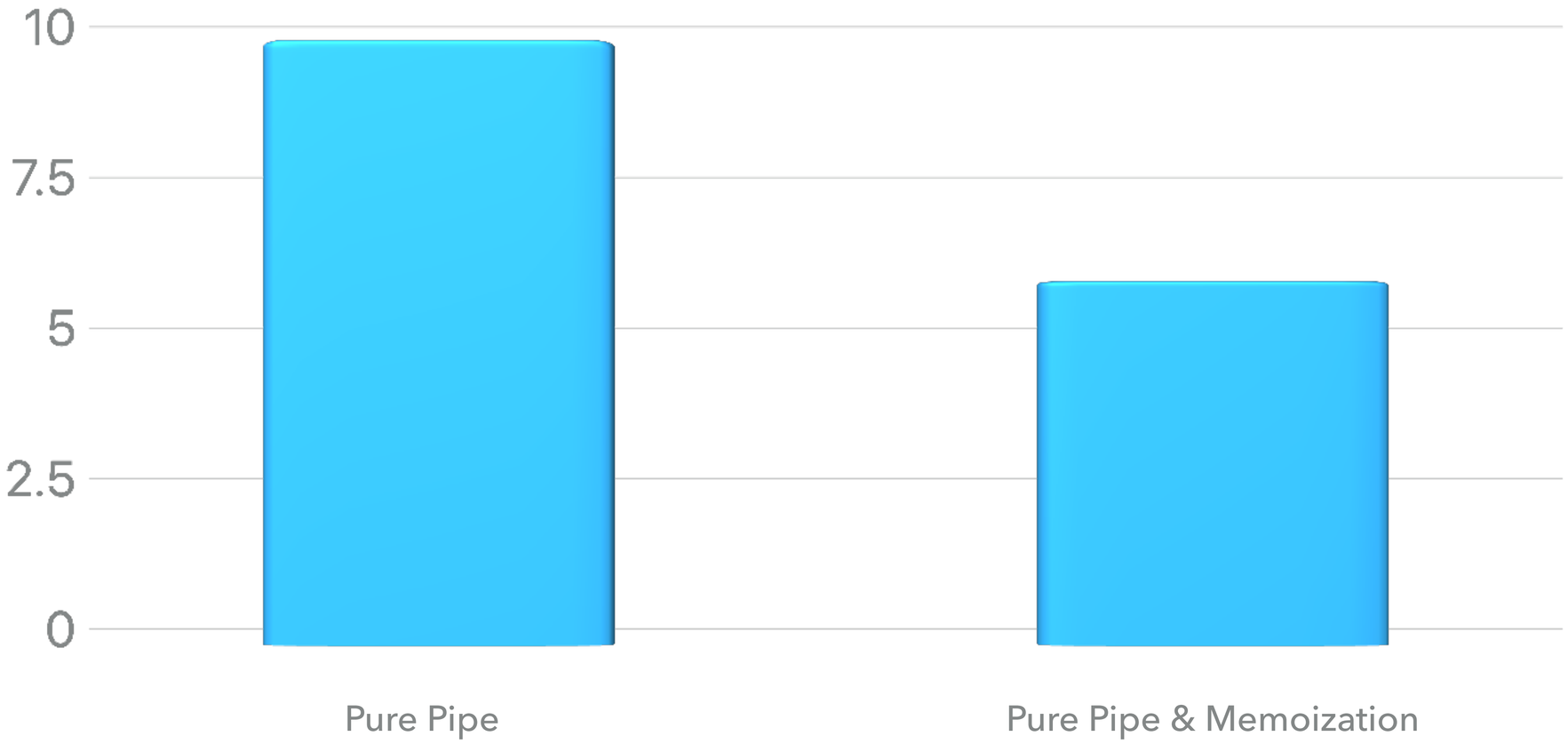
const fibonacci = memoize((num: number): number => {
  if (num === 1 || num === 2) return 1;
  return fibonacci(num - 1) + fibonacci(num - 2);
});
```


Purely Fast
Minko
localhost:5557
Elements
Network
View:
Group by frame
Filter
Regex
Hide data URLs
All
XHR
JS
CSS
Img
Media
Font
Doc
WS
Manifes
100 ms
200 ms
Name
Waterfall
Intl.min.js?1…
system.src.j…
system-con…
72
11 requests | 231 KB transferred | Finish: 210 ms

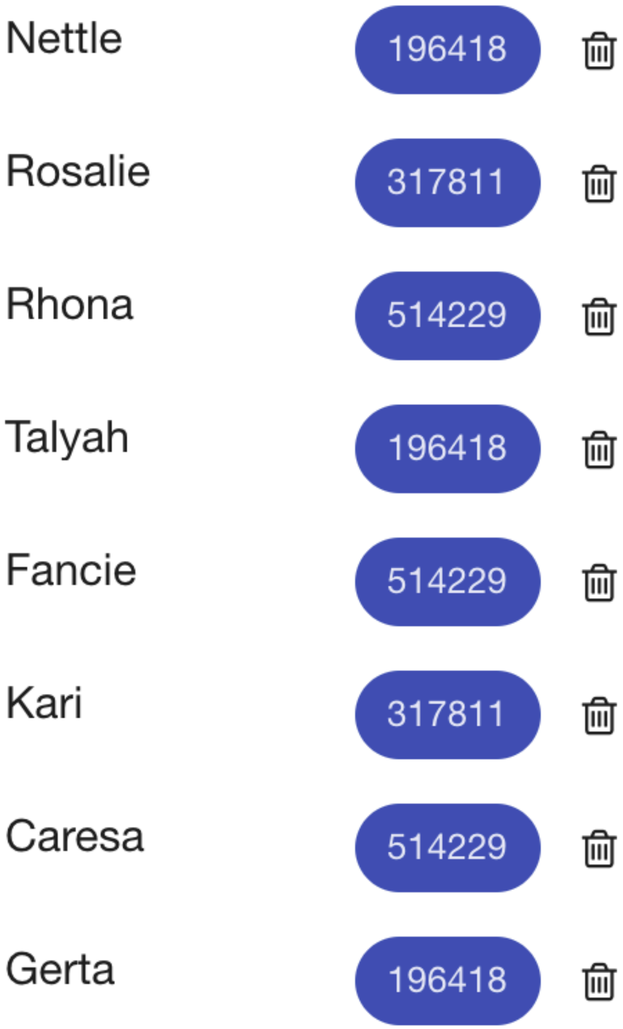
Name	...	...	In...	...	Ti	Waterfall
cdk-stepper...	...	f...	z...	...	10	
employee-li...	...	...	z...	...	73	
app.compo...	...	...	z...	...	69	
fontawesom...	...	f...	O...	...	479	

61 requests | 4.9 MB transferred | Finish: 6.73 s | DOMCon...

Initial Rendering



Pure Pipes

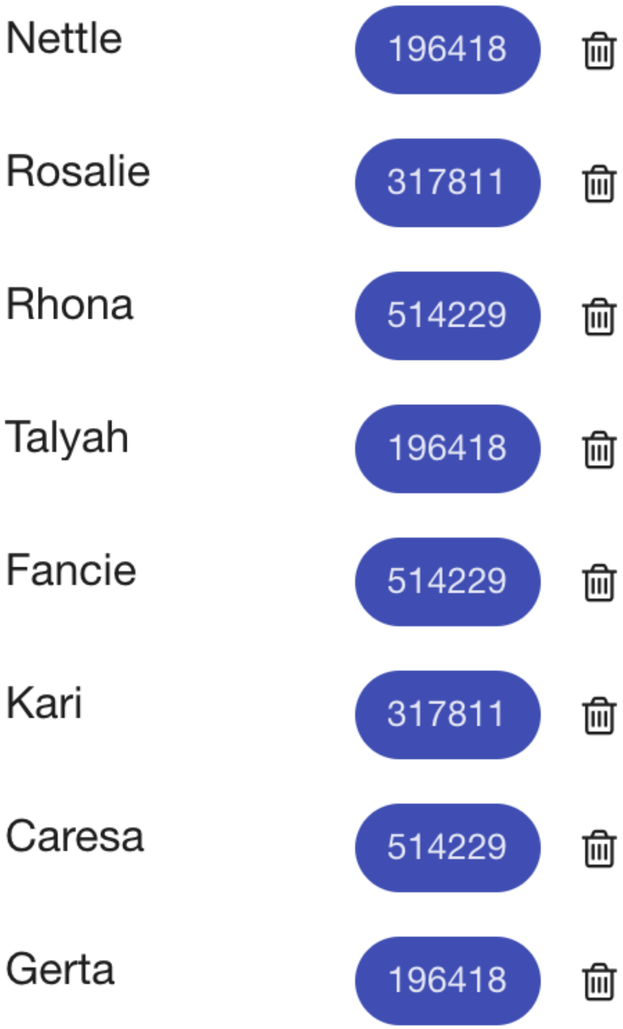



```
27 | calculate
```

```
27 | calculate
```

```
27 | calculate
```

Pure Pipes

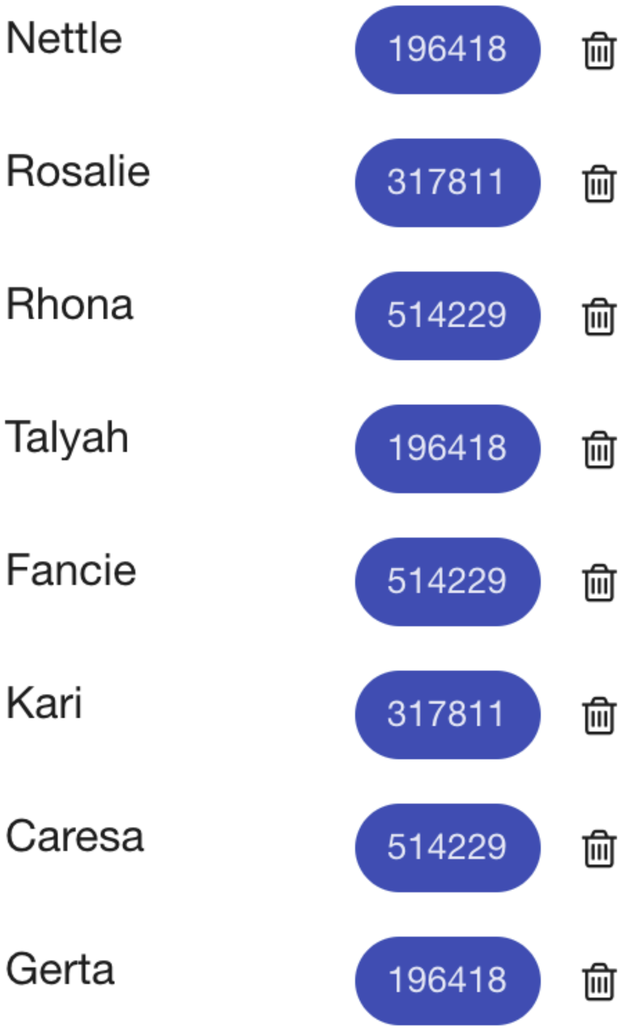



```
27 | calculate → fib(27) → 196418
```

```
27 | calculate
```

```
27 | calculate
```

Pure Pipes

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27 | calculate → fib(27) → 196418
```

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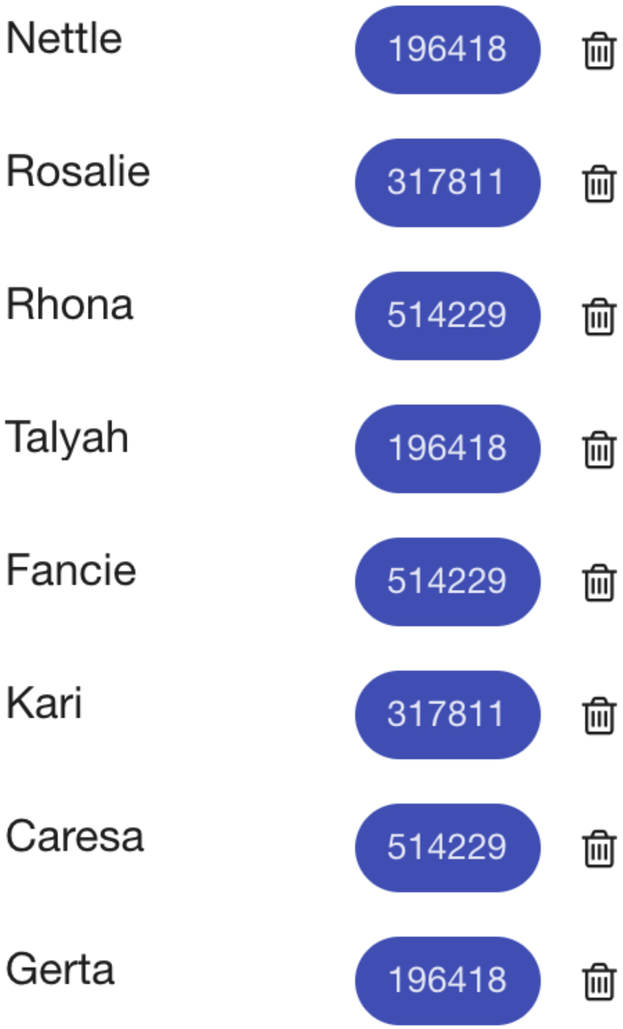


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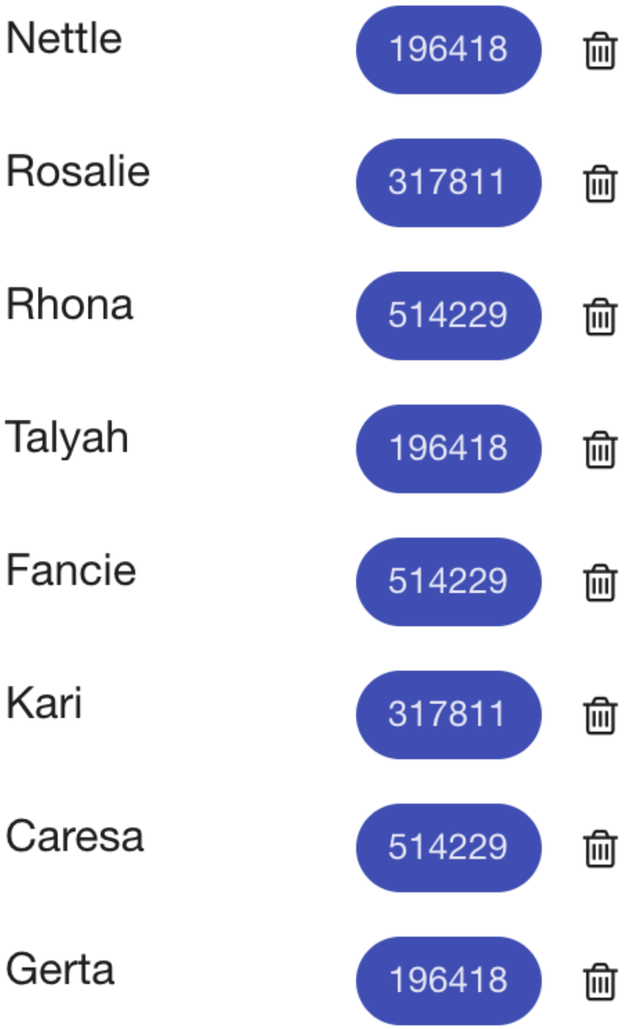
Memoization

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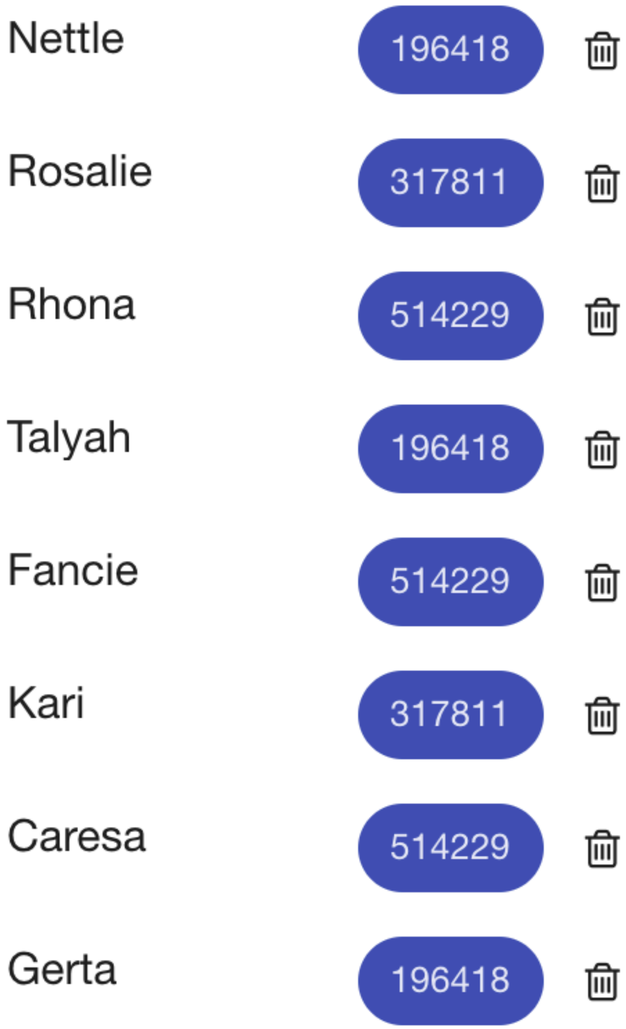


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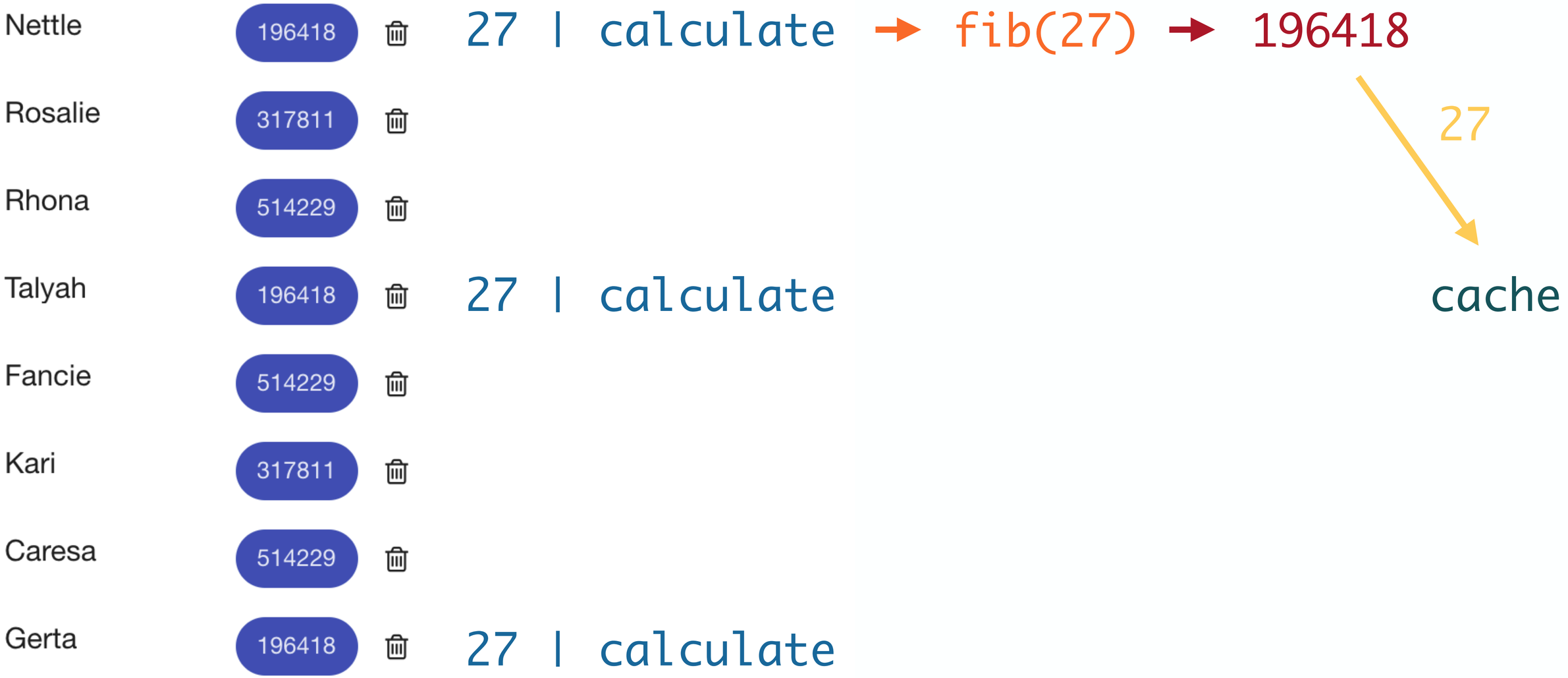

Memoization

Nettle	196418
Rosalie	317811
Rhona	514229
Talyah	196418
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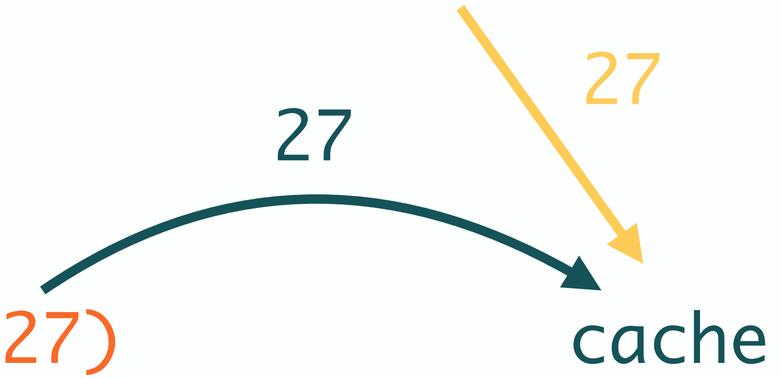


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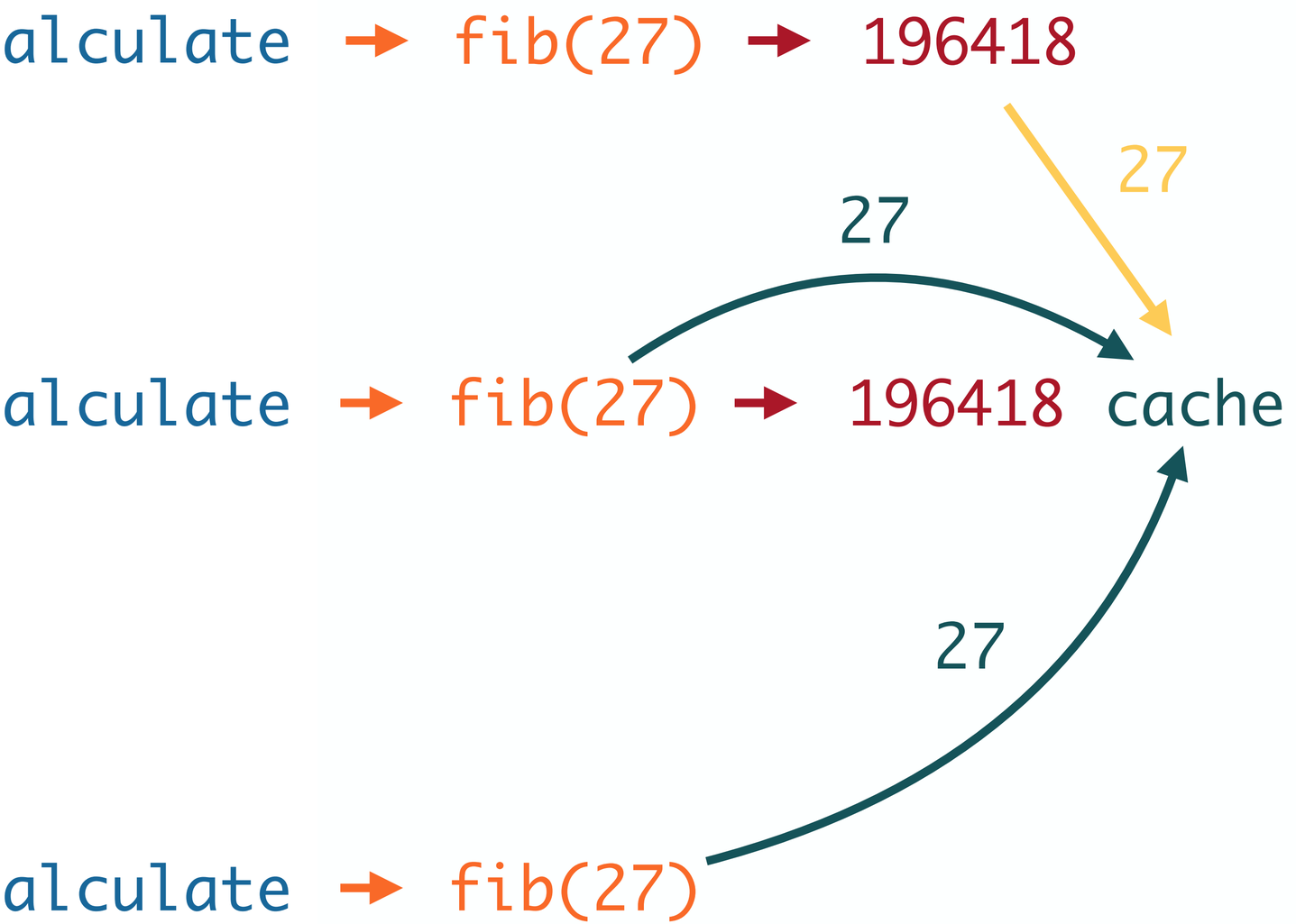

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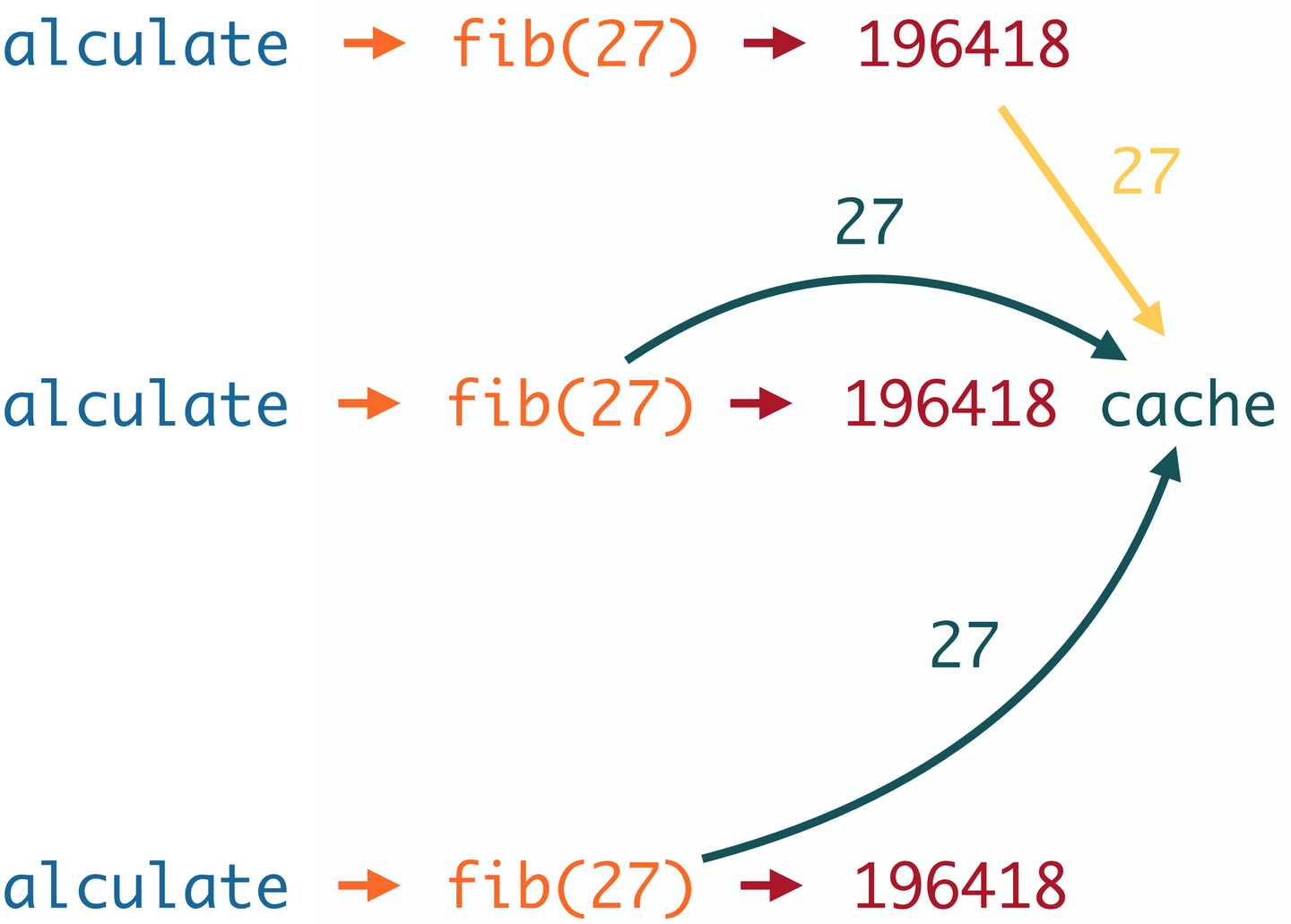

Pattern...

- On push performs “memoization”
- Pure pipes are “memoized”

Pattern...

- On push performs “memoization”
- Pure pipes are “memoized”

for their last input

Lets try to do better!

twitter.com/mgechev

Sam Saccone

@samccone

99.7% of software development in one requirement

A user should be able to view a list of items.

8:36 PM - 1 Dec 2017

637 Retweets **1,911** Likes

27 637 1.9K

How NgForOf works

```
@Directive({selector: '[ngFor][ngForOf]'})
class NgForOf<T> implements DoCheck, OnChanges {
   ...

  constructor(private _differs: IterableDiffers) {}

  ngDoCheck(): void {
    const changes = this._differ.diff(this.ngForOf);
    if (changes) this._applyChanges(changes);
  }
   ...
}
```

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  ...
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```

```
class IterableDiffers {
  constructor(factories: IterableDifferFactory[]) {}

  find(iterable: any): IterableDifferFactory {
    const factory =
      this.factories.find(f ⇒ f.supports(iterable));
    if (factory ≠= null) {
      return factory;
    } else {
      throw new Error(
        `Cannot find a differ supporting object`
      );
    }
  }
  //  ...
}
```

```
interface IterableDifferFactory {
  supports(objects: any): boolean;
  create<V>(trackByFn?: TrackByFunction<V>):
    IterableDiffer<V>;
}

interface IterableDiffer<V> {
  diff(object: NgIterable<V>):
    IterableChanges<V>|null;
}

interface TrackByFunction<T> {
  (index: number, item: T): any;
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```

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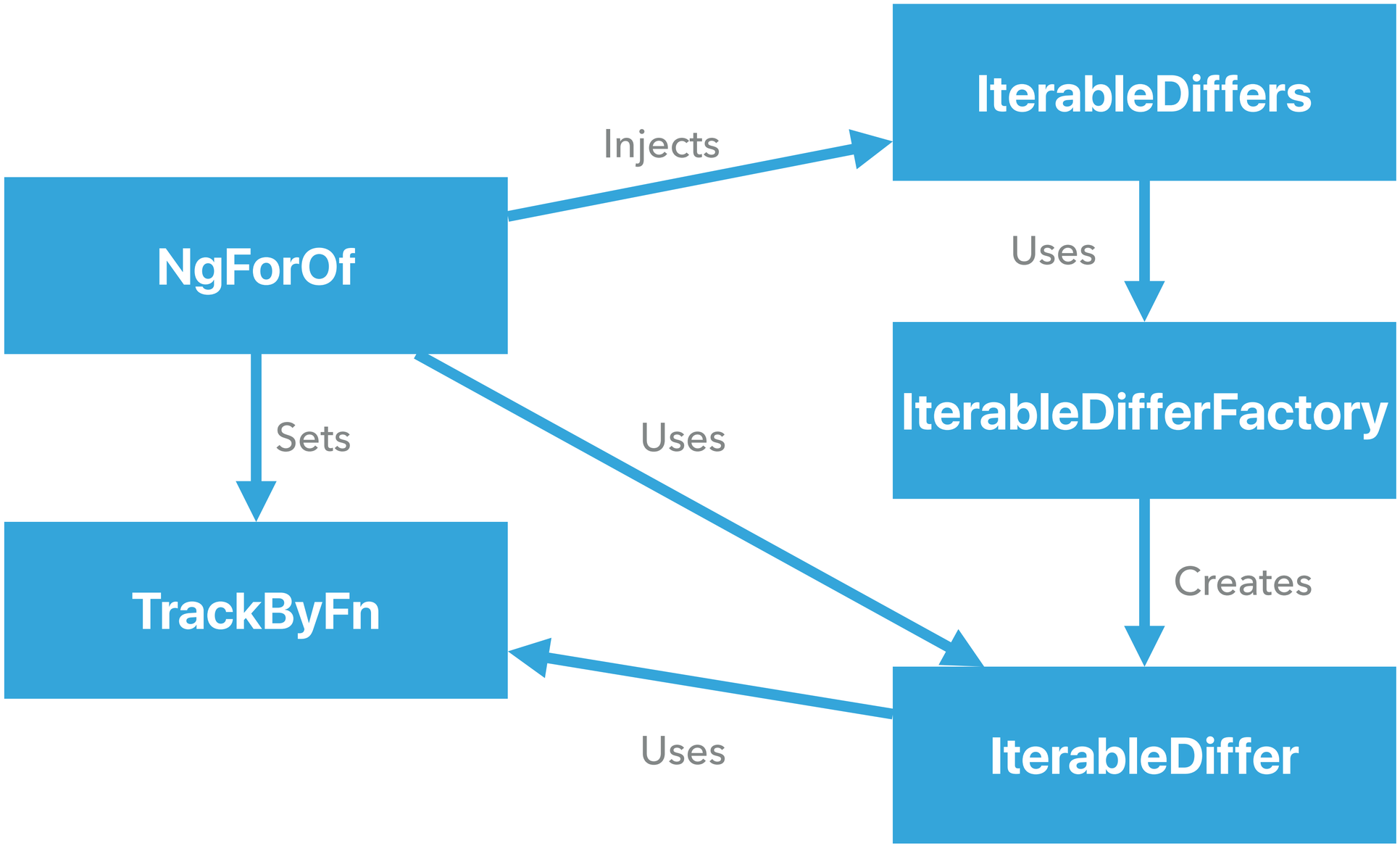
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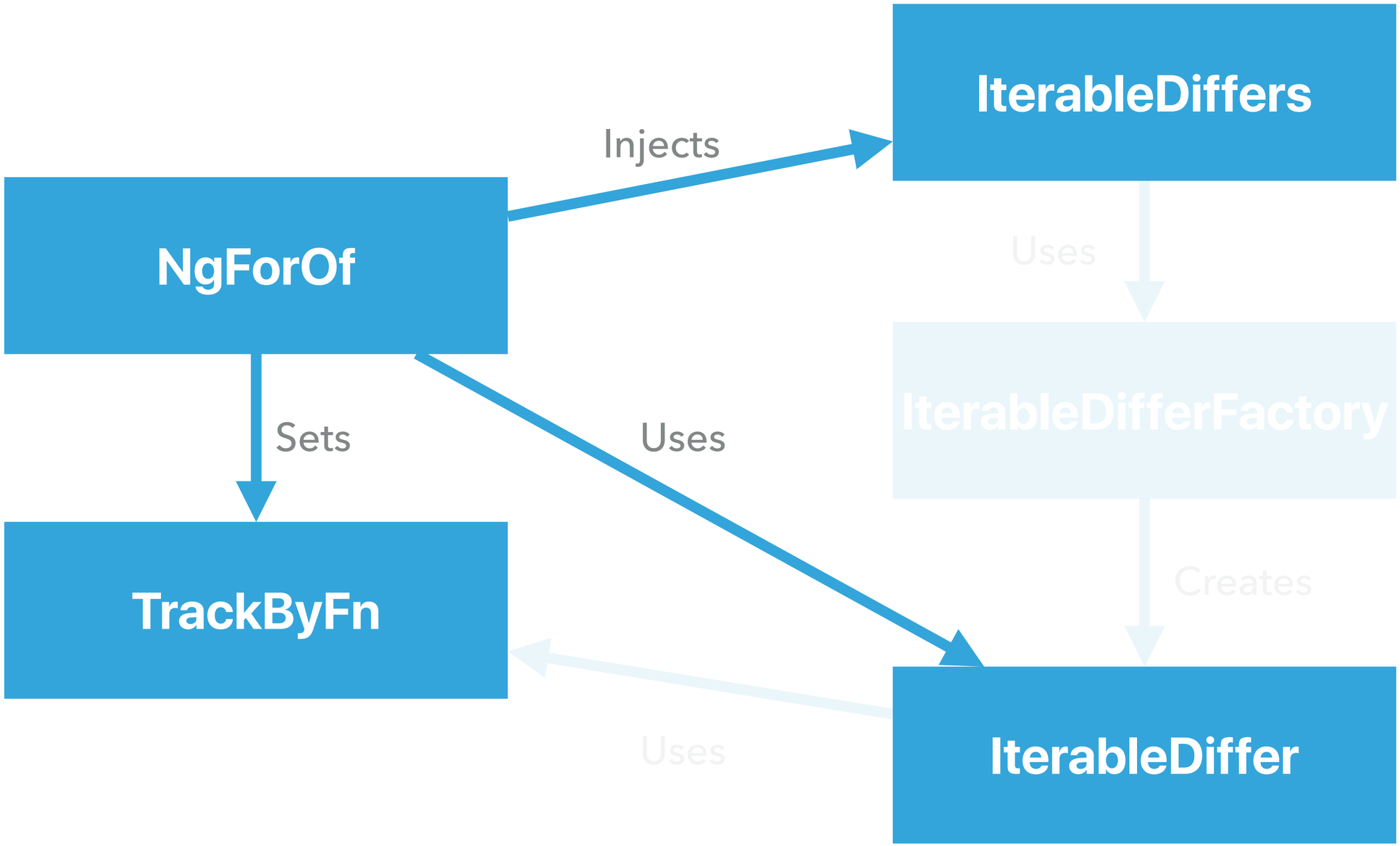
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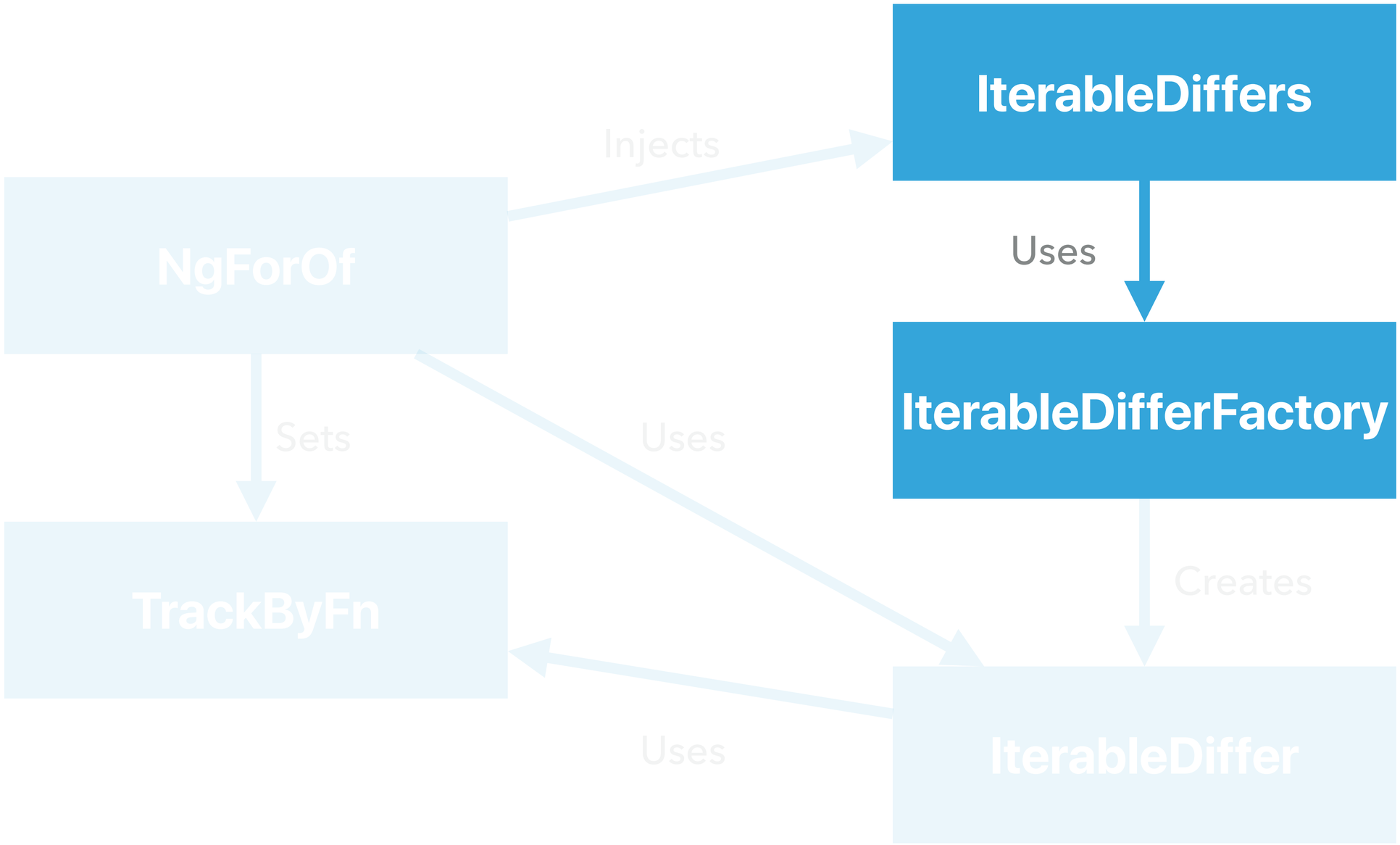
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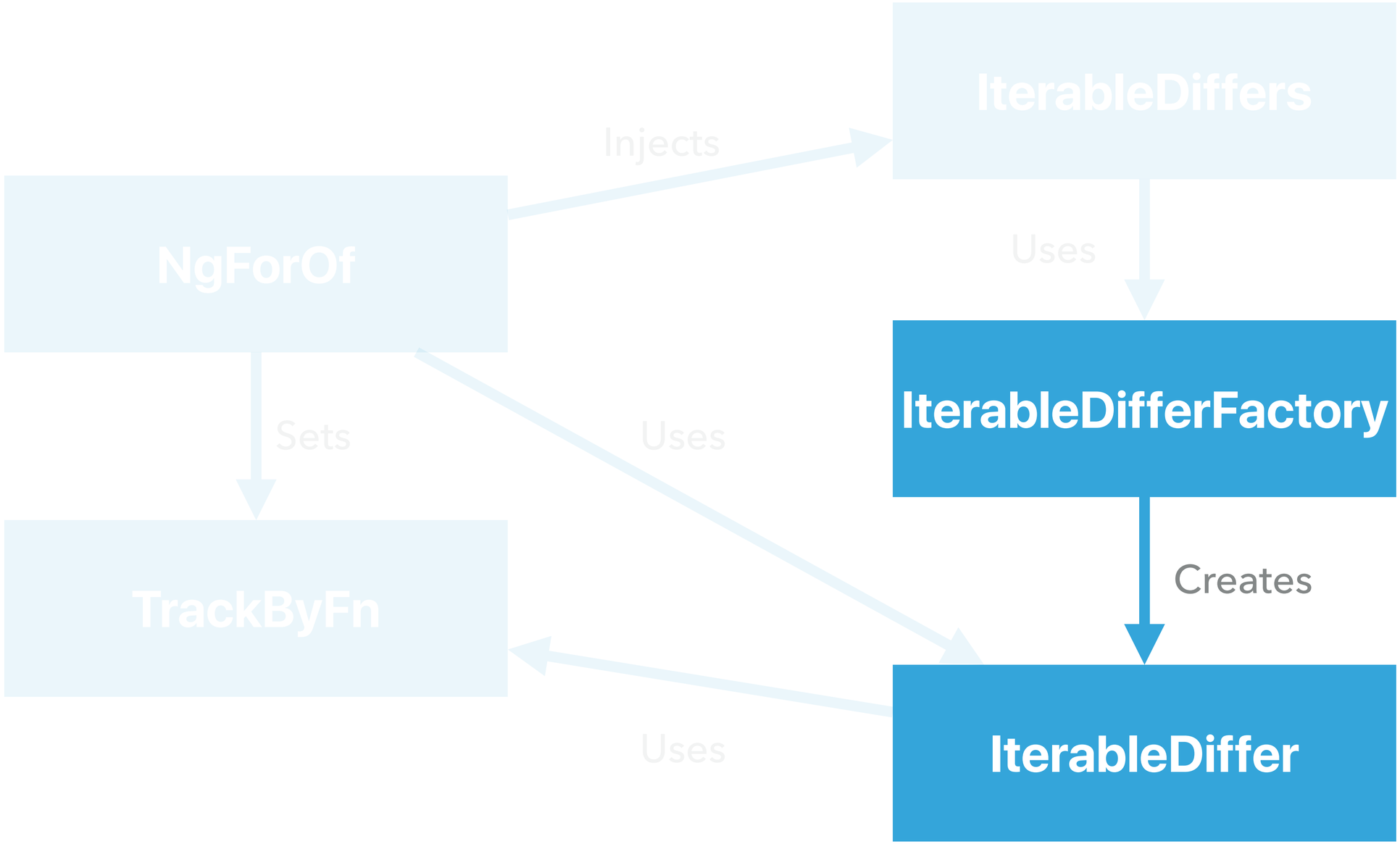
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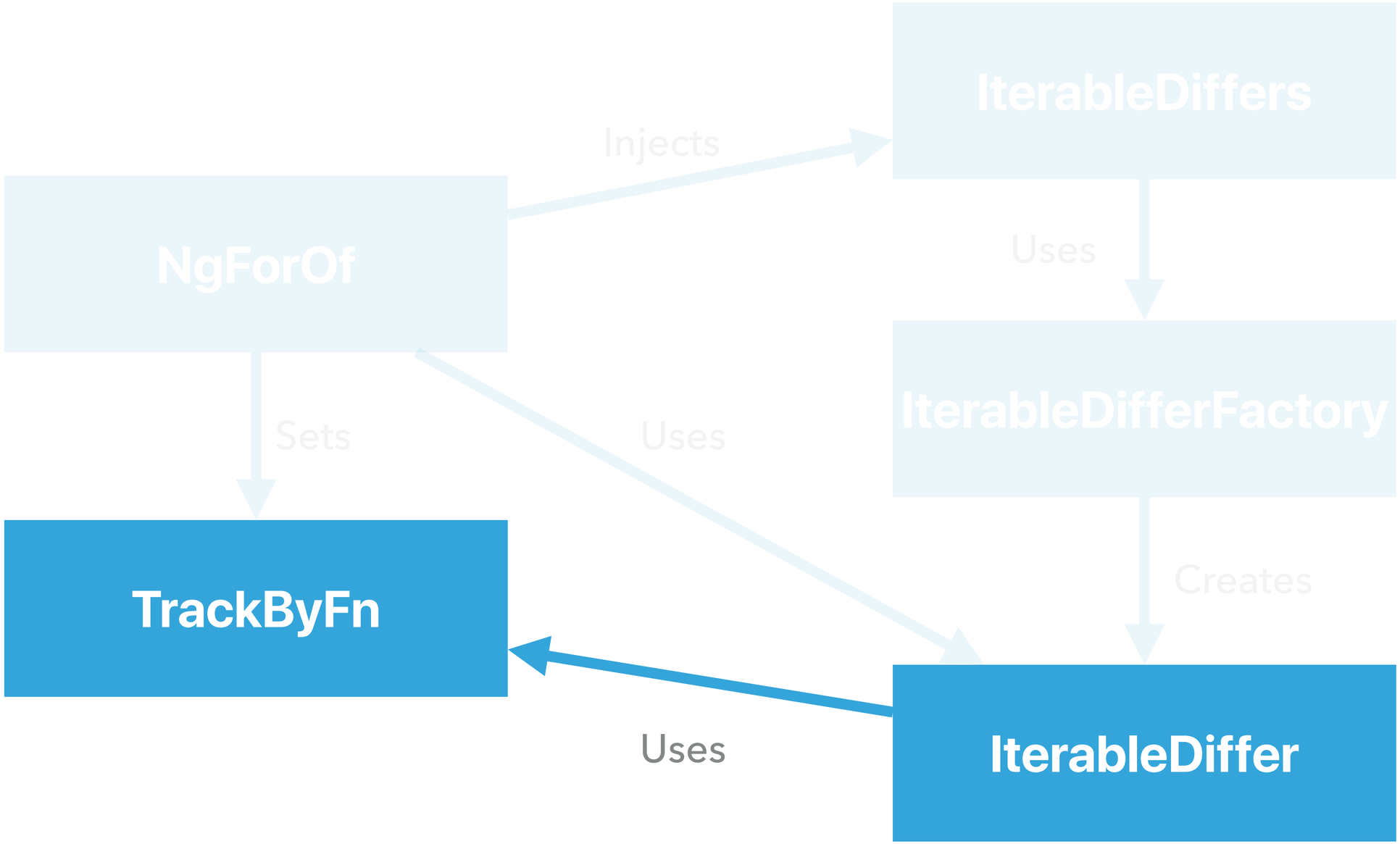
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  ...
}
```

Ignored details for simplicity

```
const trackBy = (_, item) ⇒ item.id;
```

```
const a = [
  { id: 1, name: 'Dan' },
  { id: 2, name: 'Joe' },
  { id: 3, name: 'Josh' }
];
```

```
const b = [
  { id: 1, name: 'Dan' },
  { id: 2, name: 'Adam' },
  { id: 4, name: 'Josh' }
];
```

Identical

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```
trackBy(0, a[0]) === trackBy(0, b[0])
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✅

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```

```
trackBy(0, a[0]) === trackBy(0, b[0])

trackBy(1, a[1]) === trackBy(1, b[1])
```

Identical

✅

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const trackBy = (_, item) ⇒ item.id;
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```

```
trackBy(0, a[0]) === trackBy(0, b[0])

trackBy(1, a[1]) === trackBy(1, b[1])

trackBy(2, a[2]) === trackBy(2, b[2])
```

Identical

✅

✅

❌

IterableDiffer checks from the outside whether the data structure has changed

But the data structure knows that best!

```
export class DifferableList<T> {
  changes = new LinkedList<IterableChangeRecord<T>>();

  constructor(private data = List<T>([])) {}

  unshift(data: T) {
    const result = new DifferableList<T>(this.data.unshift(data));
    result.changes.add({ ... });
    return result;
  }

  ...

  [Symbol.iterator]() {
    return new DifferableListIterator<T>(this);
  }
}
```

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```

Data structure optimized for Angular

twitter.com/mgechev

```
export class DifferableListDiffer<V>
  implements IterableDiffer<V>, IterableChanges<V> {
   ...

  diff(collection: NgIterable<V>): DifferableListDiffer<V> | null {
    const changes = this._data.changes;
    this._changes = changes;
    if (changes.size() > 0) {
      this._data.changes = new LinkedList<IterableChangeRecord<V>>();
      return this;
    } else {
      return null;
    }
  }
}
```

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    }
  }
}
```

Required refactoring

```
@Component({
  selector: 'sd-employee-list',
  providers: [
    IterableDiffers.extend([
      new DifferableListDifferFactory()
    ])
  ],
  template: `...`,
})
export class EmployeeListComponent {  ...  }
```

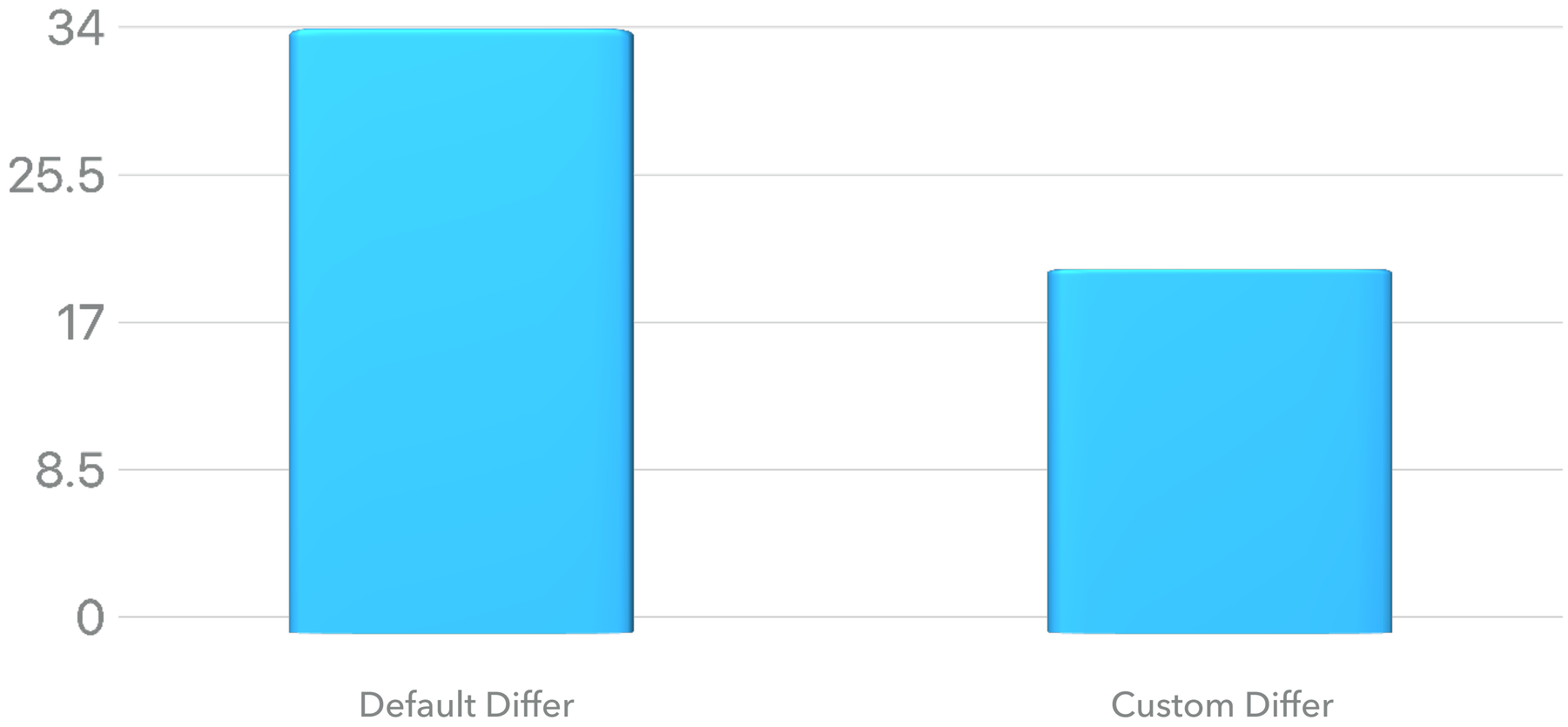
Inspired by

Persistent

data structures

twitter.com/mgechev

Adding / Removing Entries



Recap

- OnPush change detection
  - When it gets triggered
- Pure pipes vs Memoization
  - Purity and Referential Transparency
- Differs and Track by function

Lessons learned

- No silver bullet
- Understand your component structure
- Understand your data
- Application specific benchmarks

Get inspiration from **computer science**

twitter.com/mgechev

Links

mgv.io/ng-cd – Angular's OnPush Change Detection Strategy

mgv.io/ng-pure – Pure Pipes and Referential Transparency

mgv.io/ng-diff – Understanding Angular Differs

mgv.io/ng-perf-checklist – Angular Performance Checklist

mgv.io/ng-checklist-video – Angular Performance Checklist (video)

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Thank you!

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