DRepl

Optimizing Access to Application Data for Analysis and Visualization

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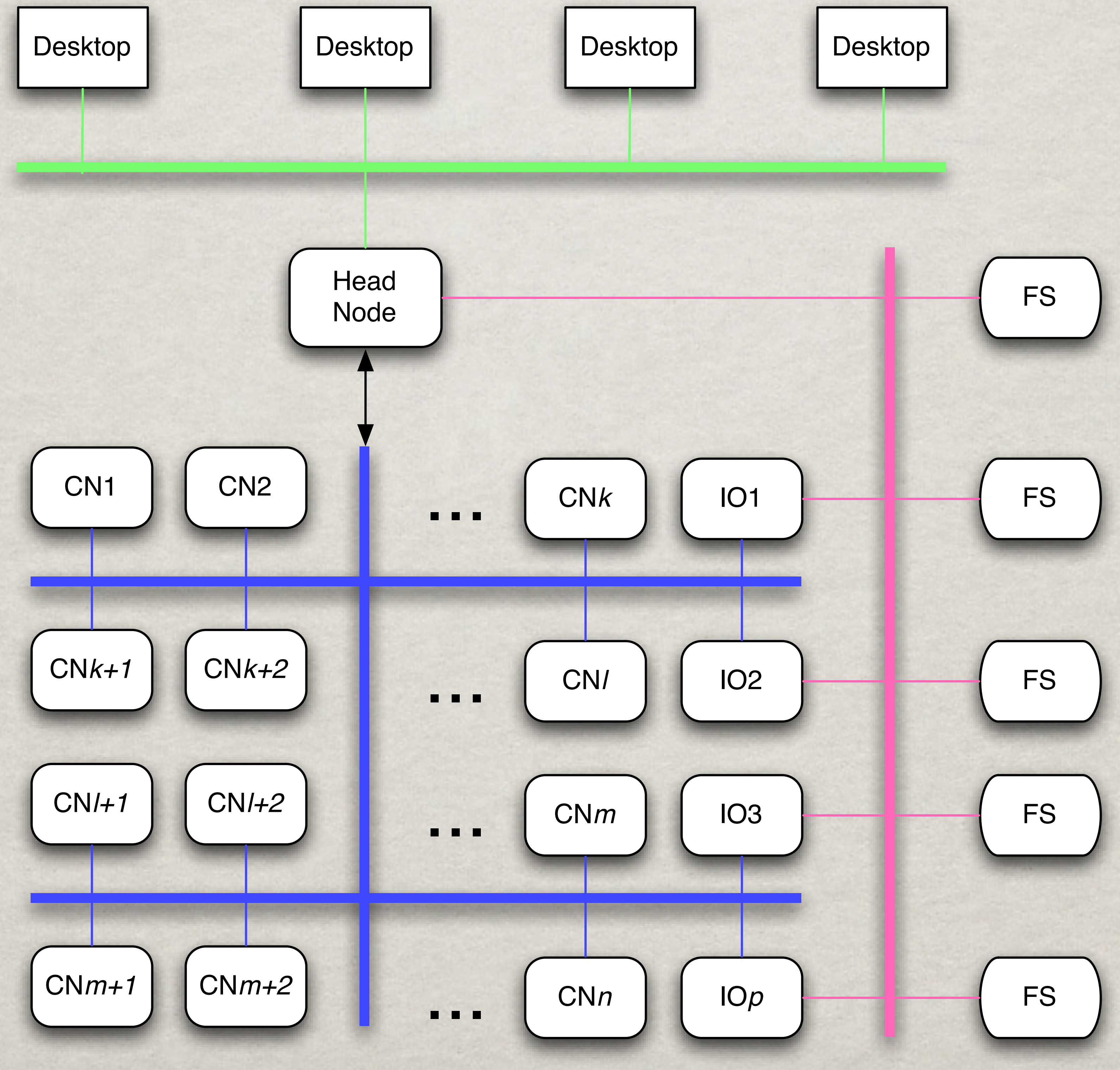

Desktop
Desktop
Desktop
Desktop
Head Node
FS
CN1
CN2
...
CN*k*
IO1
FS
CN*k+1*
CN*k+2*
...
CN*l*
IO2
FS
CN*l+1*
CN*l+2*
...
CN*m*
IO3
FS
CN*m+1*
CN*m+2*
...
CN*n*
IO*p*
FS

Data Storage

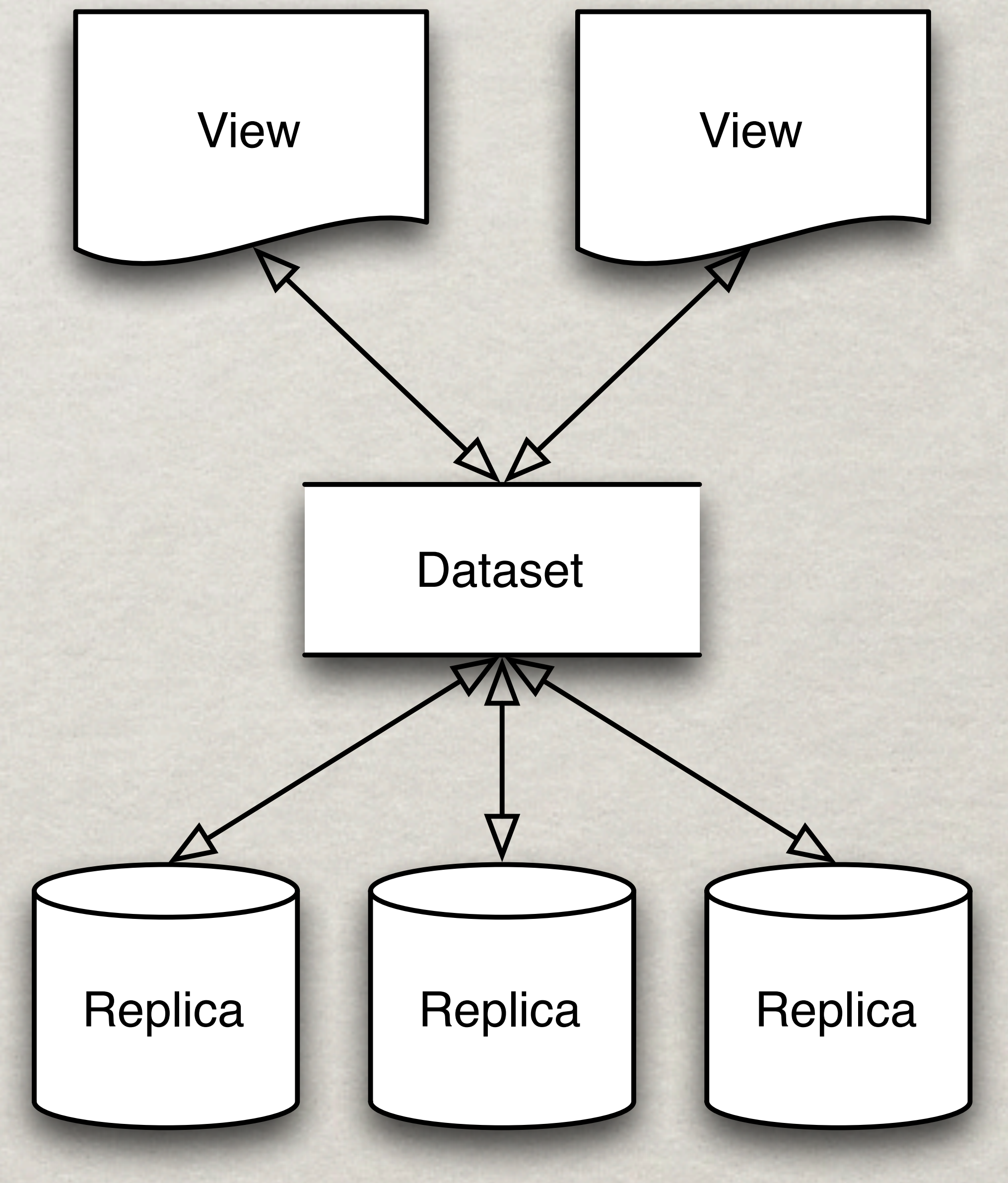
- Data stored in files
- Many applications use legacy formats
- Data is stored in format, convenient for the producer
- In-situ and in-transit data analysis slow

Objective

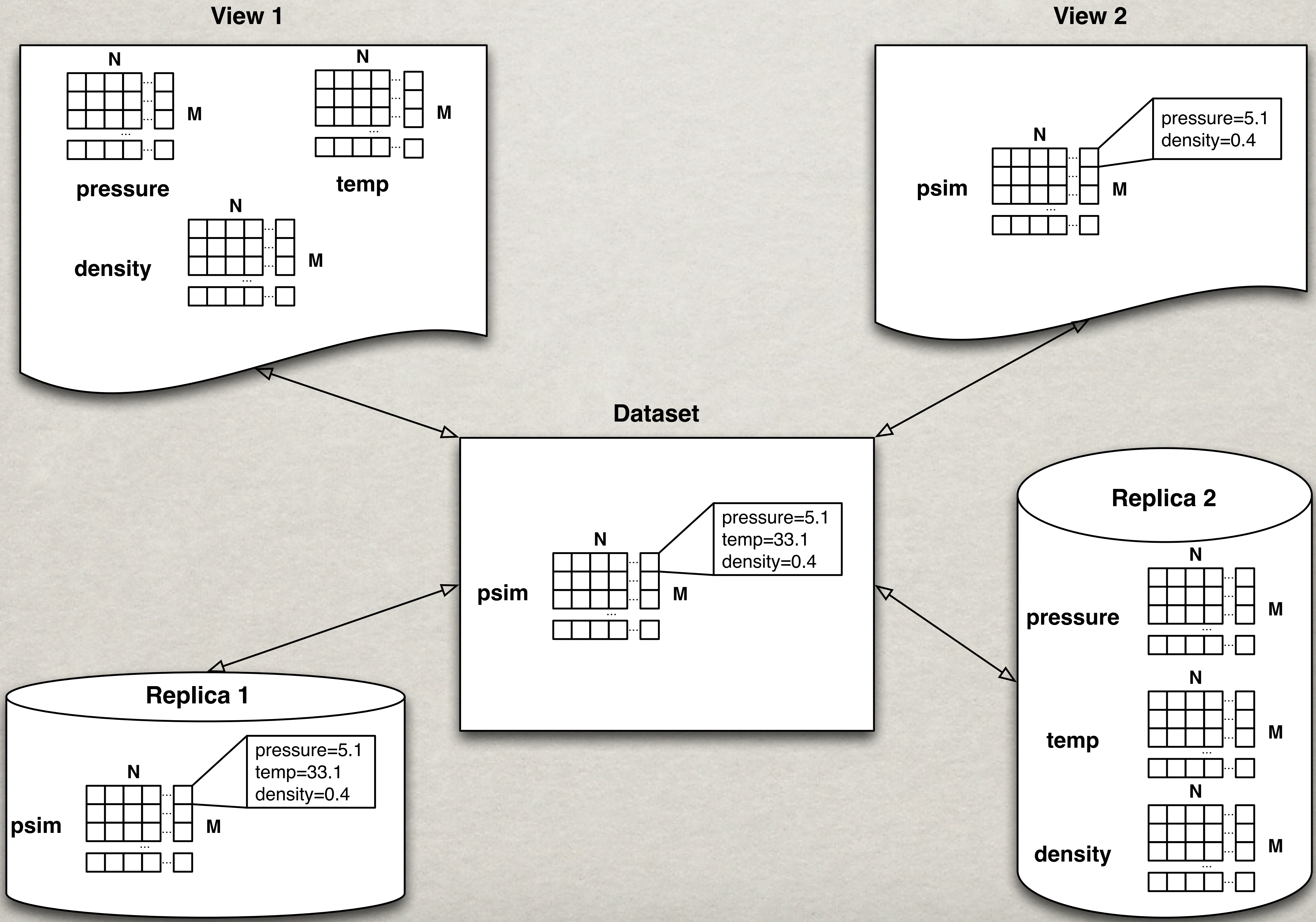
- Decouple storage data layout from application data layout(s)
- Make replicas with different data layouts
- Each application working with the data can use a layout that is optimized for it
- Allow both materialized (on-storage) and on-the-fly data layouts

Design

- Definitions
  - **Dataset** -- abstract data model
  - **Views** -- how applications see the data
  - **Replicas** -- how the data is stored
- Provision of an easy way to express how data is used by the applications

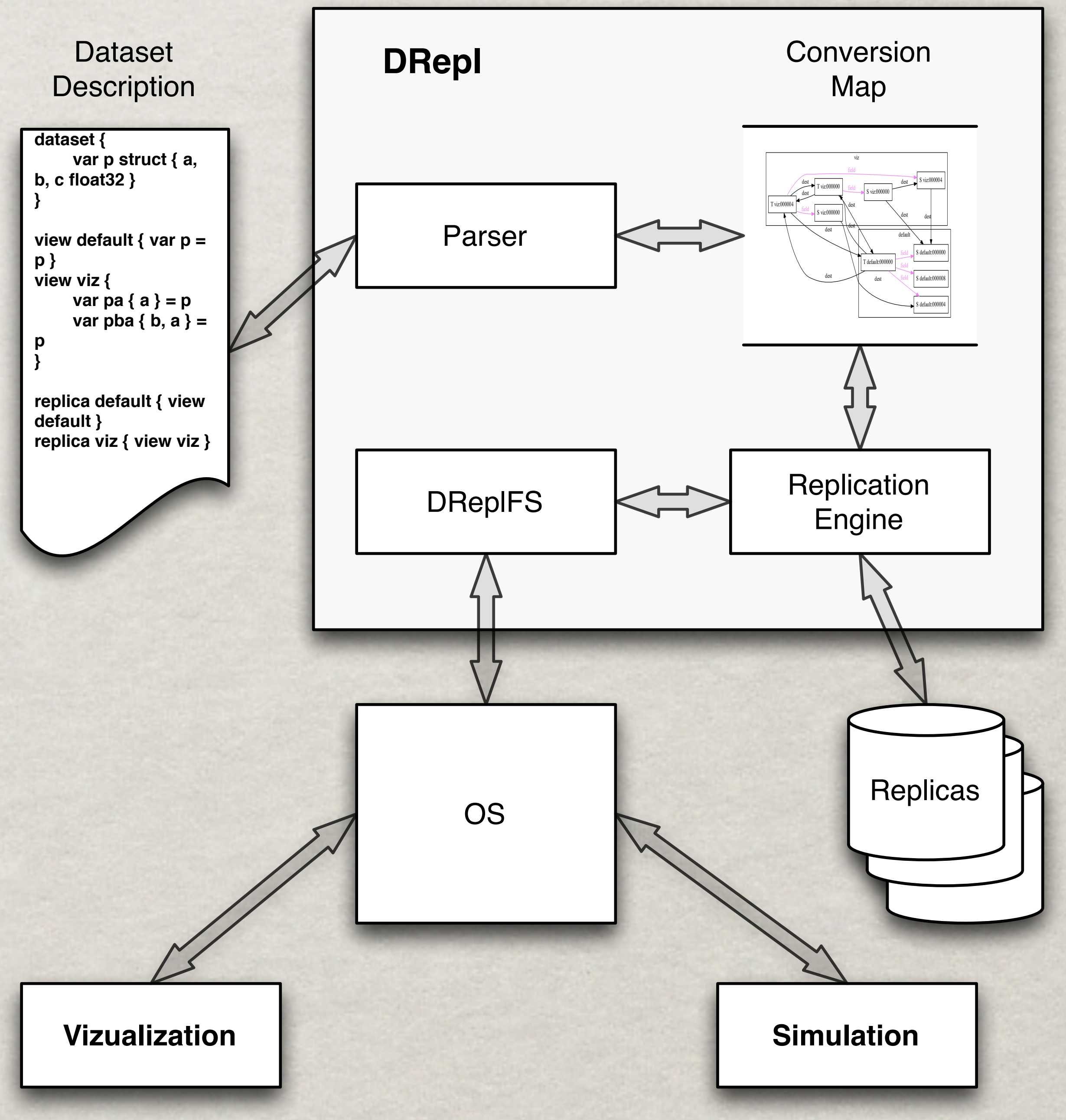


Example


View 1
N
M
pressure
N
M
temp
N
M
density
View 2
N
psim
M
pressure=5.1
density=0.4
Dataset
psim
N
M
pressure=5.1
temp=33.1
density=0.4
Replica 1
psim
N
M
pressure=5.1
temp=33.1
density=0.4
Replica 2
N
pressure
M
N
temp
M
N
density
M

DRepl

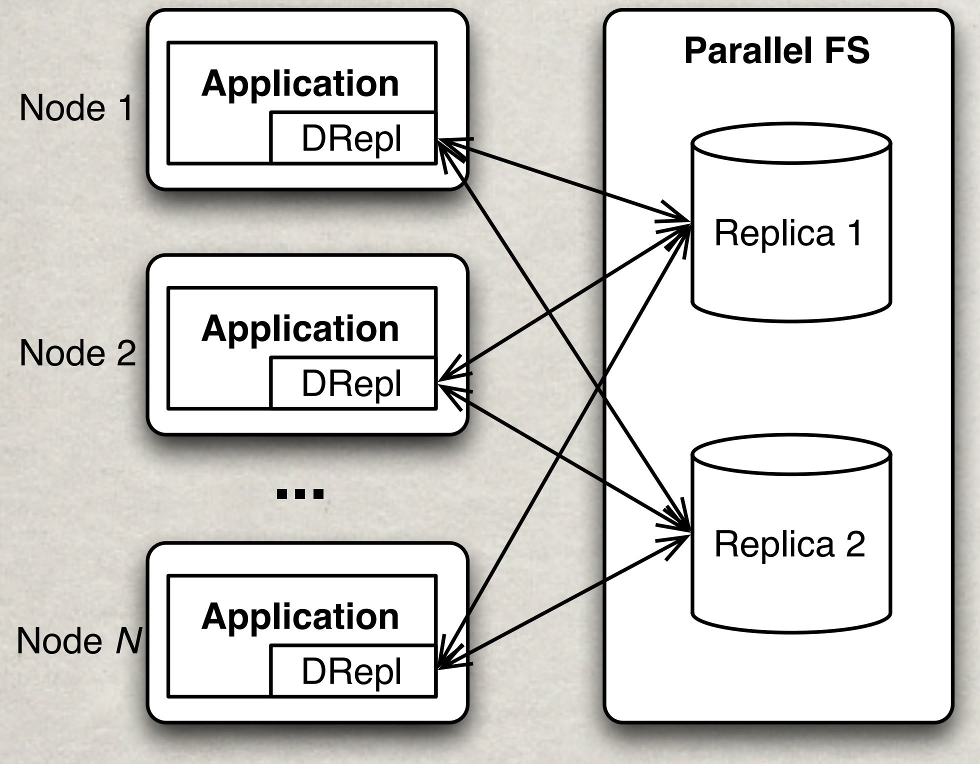
- Dataset Language
- Parser
- Replication Engine
- File Server



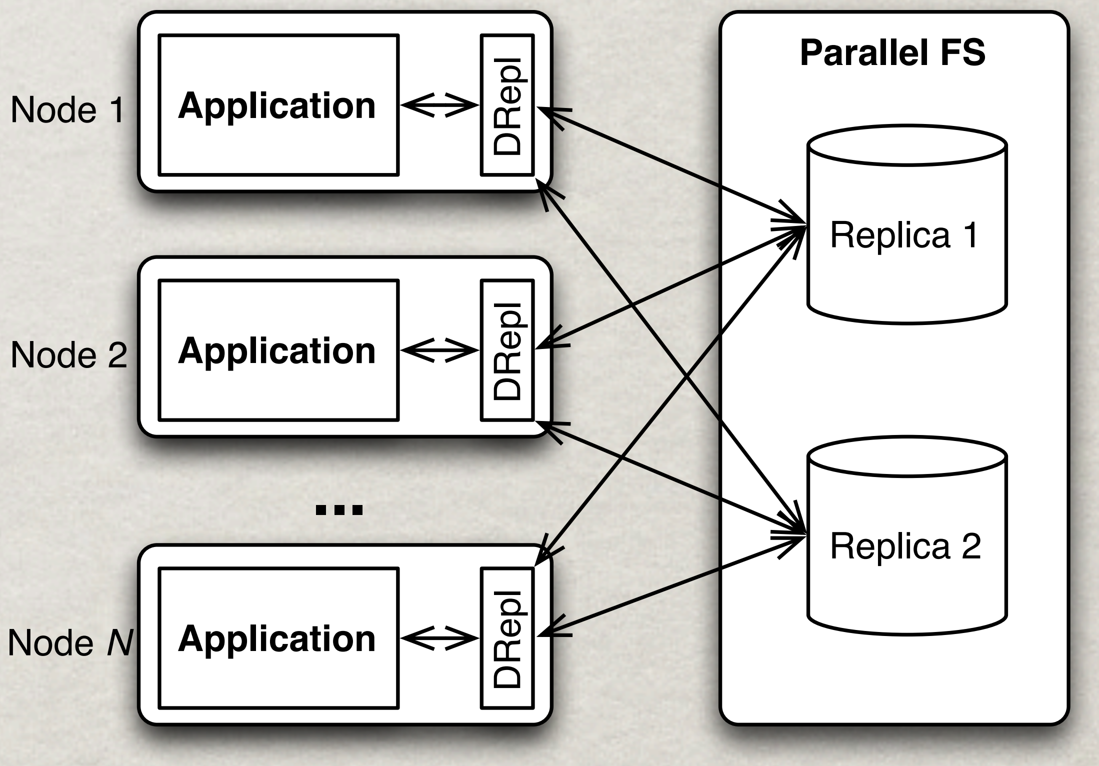
```
dataset {
        var p struct { a,
b, c float32 }
}

view default { var p =
p }
view viz {
        var pa { a } = p
        var pba { b, a } =
p
}

replica default { view
default }
replica viz { view viz }
```

Configurations

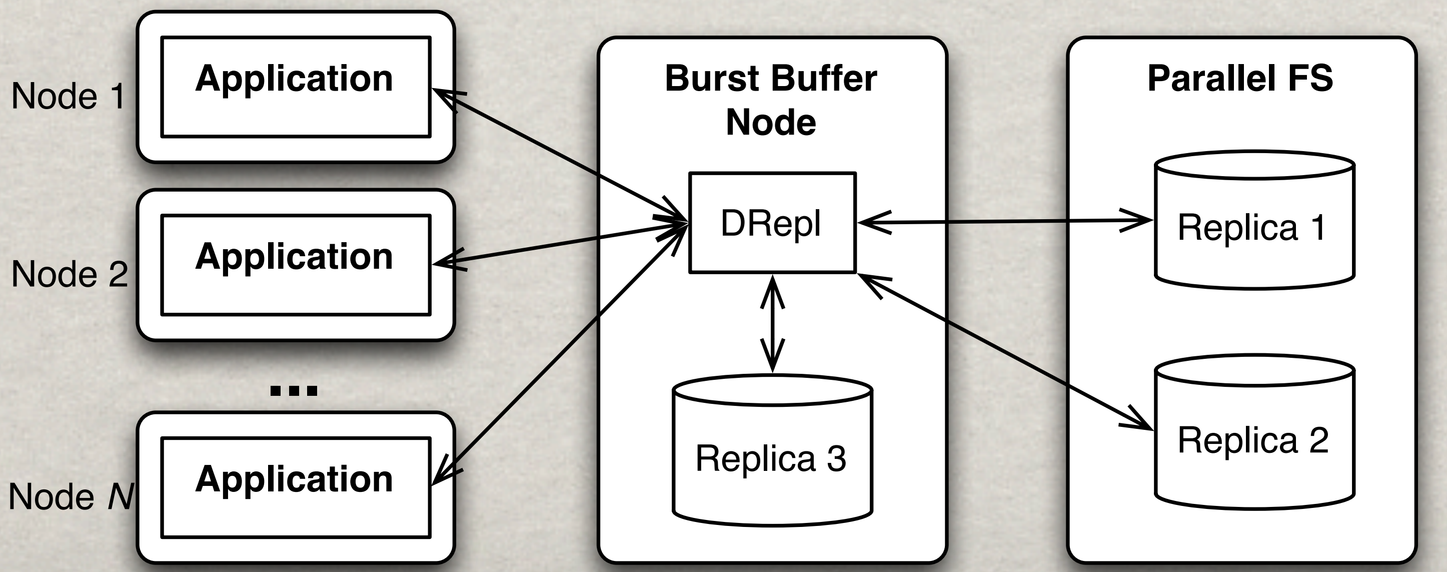
Embedded



Separate



Burst Buffer



Dataset Language

- Syntax Similar to C, C++, Java
- Dataset
  - define data types (structs, arrays)
  - define named data of the types
- View(s)
  - define substructs and subarrays
  - define named data based on the dataset data
- Replica(s)

Dataset Language

- Primary types - **`int8, int16, int32, int64, float32, float64, stringN`**

- Structs

```
struct {
    a, b, c  float64
}
```

- Multidimensional arrays

```
[50,40,21] Point
```

- Custom types

```
type int64 Point
```

- Arithmetic expressions in the subarray definitions

a[i*3, j + 2] = aa[j, i - 1]

- Support for different array orders -- row-major, row-minor, in future Hilbert and z-order

Language Example

```
dataset {
  const N = 500

  type Data struct {
    a, b, c float32
  }

  var data [N]Data
}

view array-of-structs {
  var ds = data
}

view struct-of-arrays {
  var a[i]{a} = data[i]
  var b[i]{b} = data[i]
  var c[i]{c} = data[i]
}
```

```
view ab rowmajor {
  var ab[i]{a,b} = data[i]
}

replica array-of-structs {
  view array-of-structs
}

replica struct-of-arrays {
  view struct-of-arrays
}

replica other {
  view array-of-structs
  view ab
}
```

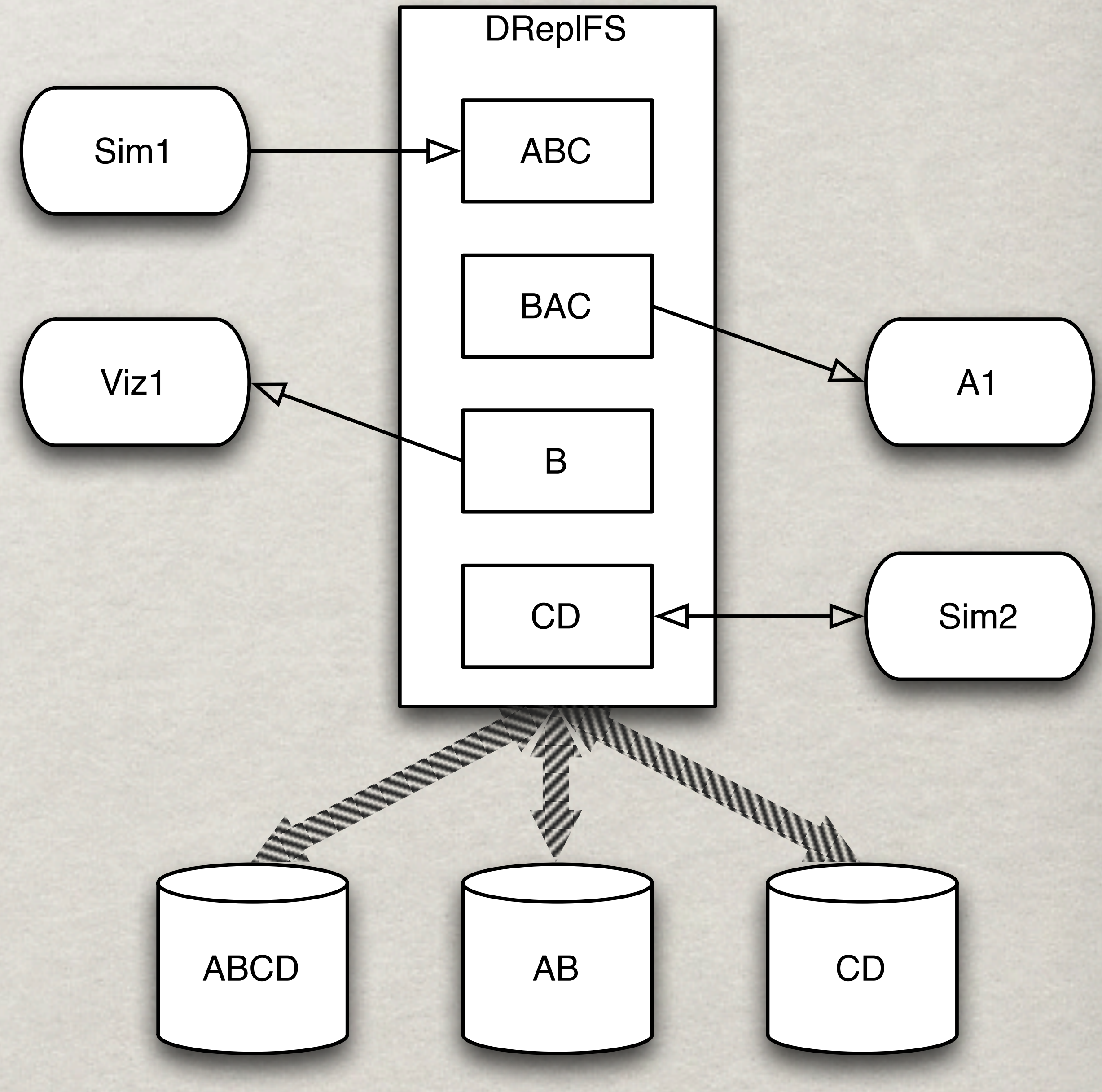
Subarray Examples

```
dataset {
  const N = 500
  const M = 200

  var data [N, M]float32
}

view v {
  // flip dimensions
  var flip[i,j] = data[j,i]

  // middle row
  var mr[i] = data[N/2, i]

  // each third element
  var te[i, j] = data[i*3, j*3]
}
```

DReplFS

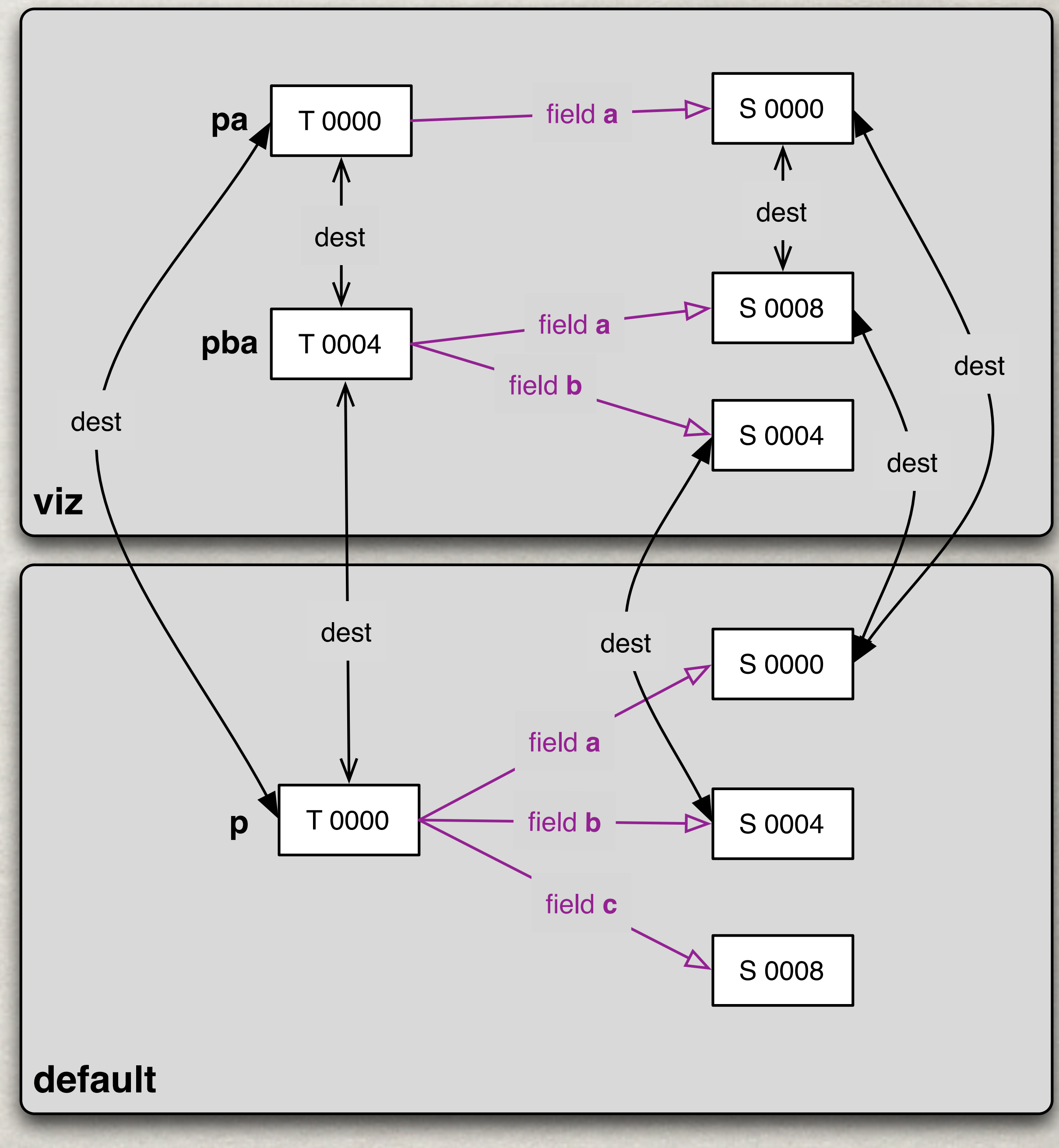
- Represent the application data formats (**views**) as virtual files

- Stored data formats (**replicas**) -- collection of replicas



Transformation Rules

```
dataset {
    var p struct {
        a, b, c float32
    }
 }

 view default {
    var p = p
 }

 view viz {
    var pa { a } = p
    var pba { b, a } = p
 }
```



Implementation

- DReplFS -- Parser, Replication Engine, File Server in Go
- KDreplFS -- Parser in Go, Replication Engine and File Server in the Linux kernel

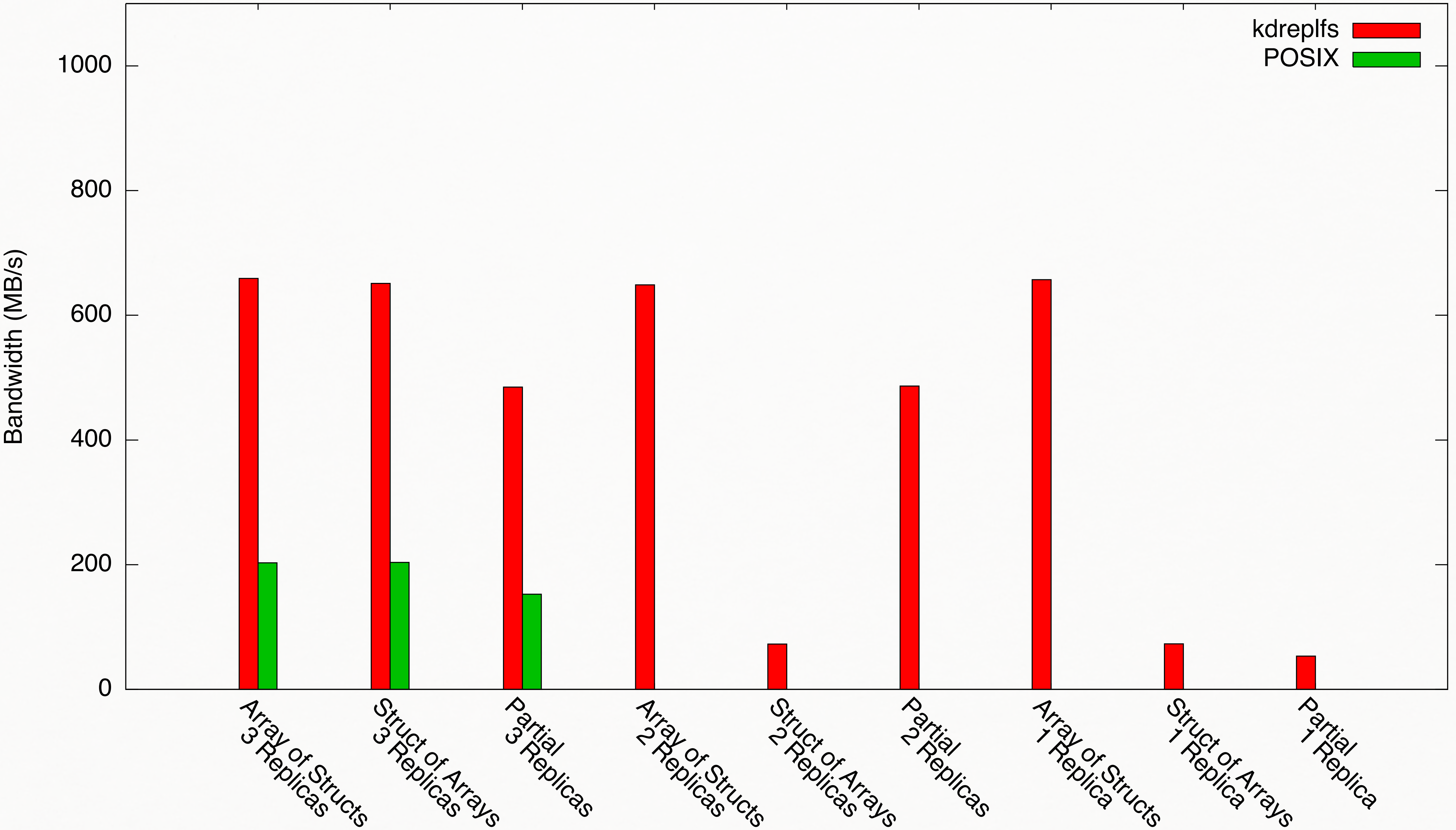
Experiments

- Dataset

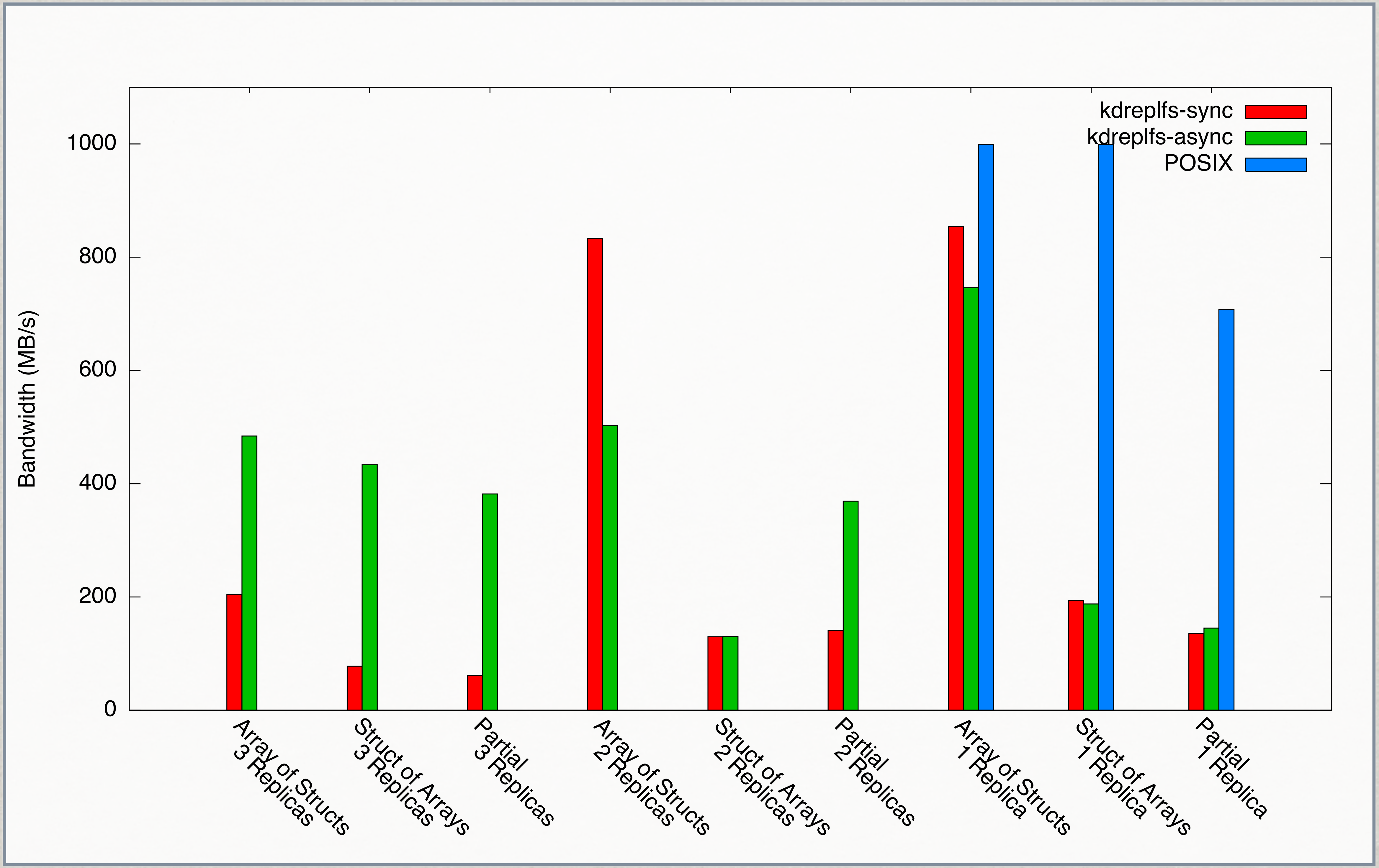
```
const N = 176160768
type Data struct {
  a, b, c float32
}
var data [N]Data
```

- Views
  - array of structs (AOS)
  - struct of arrays (SOA)
  - partial (only b)
- Replicas
  - three replicas (AOS, SOA, b)
  - two replicas (AOS, b)
  - one replica (AOS)
- Each replica on separate SSD
- File Servers
  - pass-through (POSIX)
  - kdreplfs

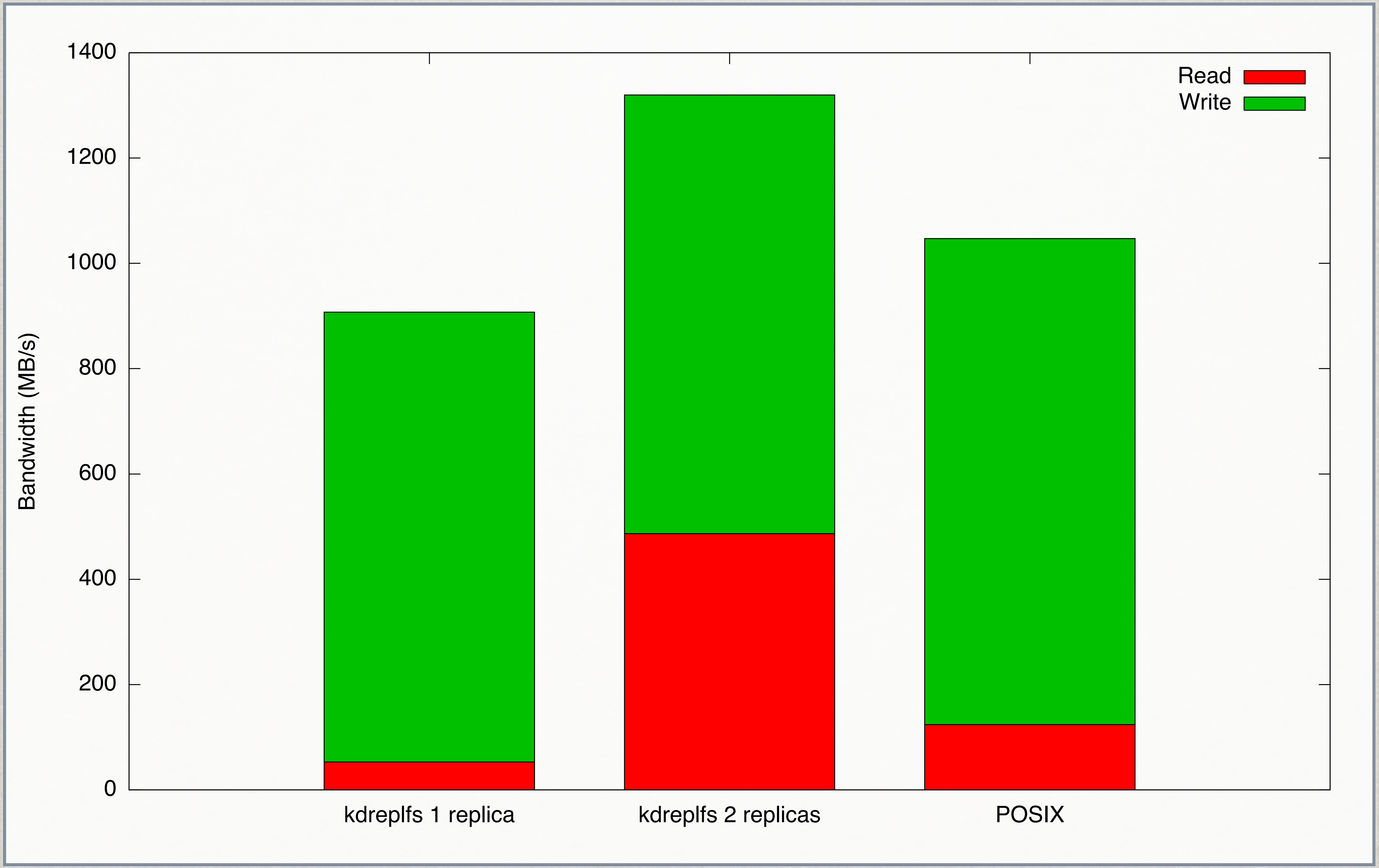
Results: Read



Results: Write



Results: Combined



Future Work

- Variable-sized arrays
- More array element orders (z-order, Hilbert)
- Optimizations
- Endianness for primary types
- Support for HDF5 replicas
- Implementation that doesn't use file servers
- Automatic generation of dataset definition from standard data formats (HDF5, NetCDF)