An API For Distributed Computing

(Building a TB-Scale Math Platform)

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H2O is...

- Pure Java, Open Source: 0xdata.com
    - https://github.com/0xdata/h2o/
- A Platform for doing Math
    - Parallel Distributed Math
    - In-memory analytics: GLM, GBM, RF, Logistic Reg
- Accessible via REST & JSON
- A K/V Store: ~150ns per get or put
- Distributed Fork/Join + Map/Reduce + K/V

A Collection of Distributed Vectors

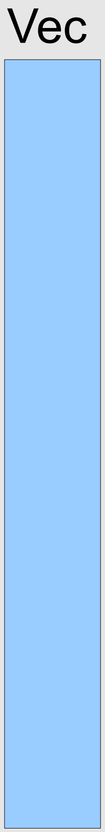
```
// A Distributed Vector
//   much more than 2billion elements
class Vec {
  long length(); // more than an int's worth

  // fast random access
  double at(long idx); // Get the idx'th elem
  boolean isNA(long idx);

  void set(long idx, double d); // writable
  void append(double d); // variable sized
}
```

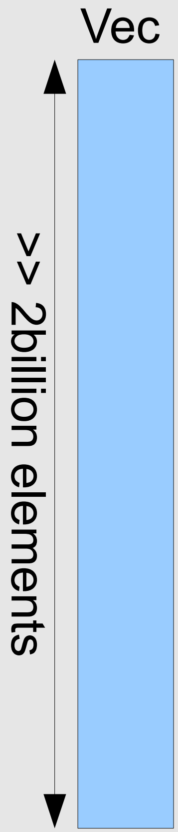
Distributed Data Taxonomy

A Single Vector



Distributed Data Taxonomy

A Very Large Single Vec



- Java primitive
- Usually **`double`**

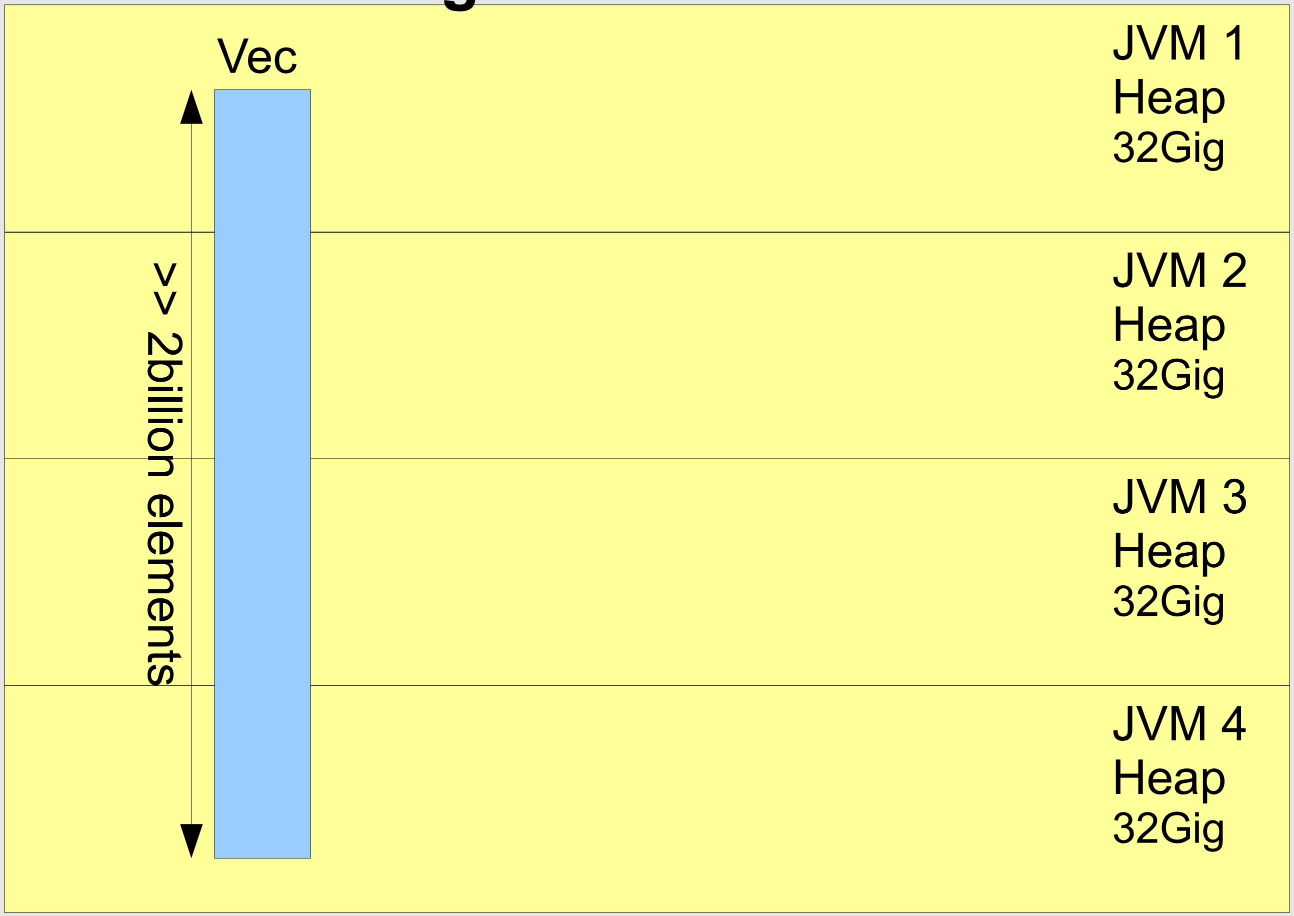
- Length is a **`long`**
- >> 2^31 elements

- Compressed
  - Often 2x to 4x
- Random access

- Linear access is FORTRAN speed

Distributed Data Taxonomy

A Single Distributed Vec



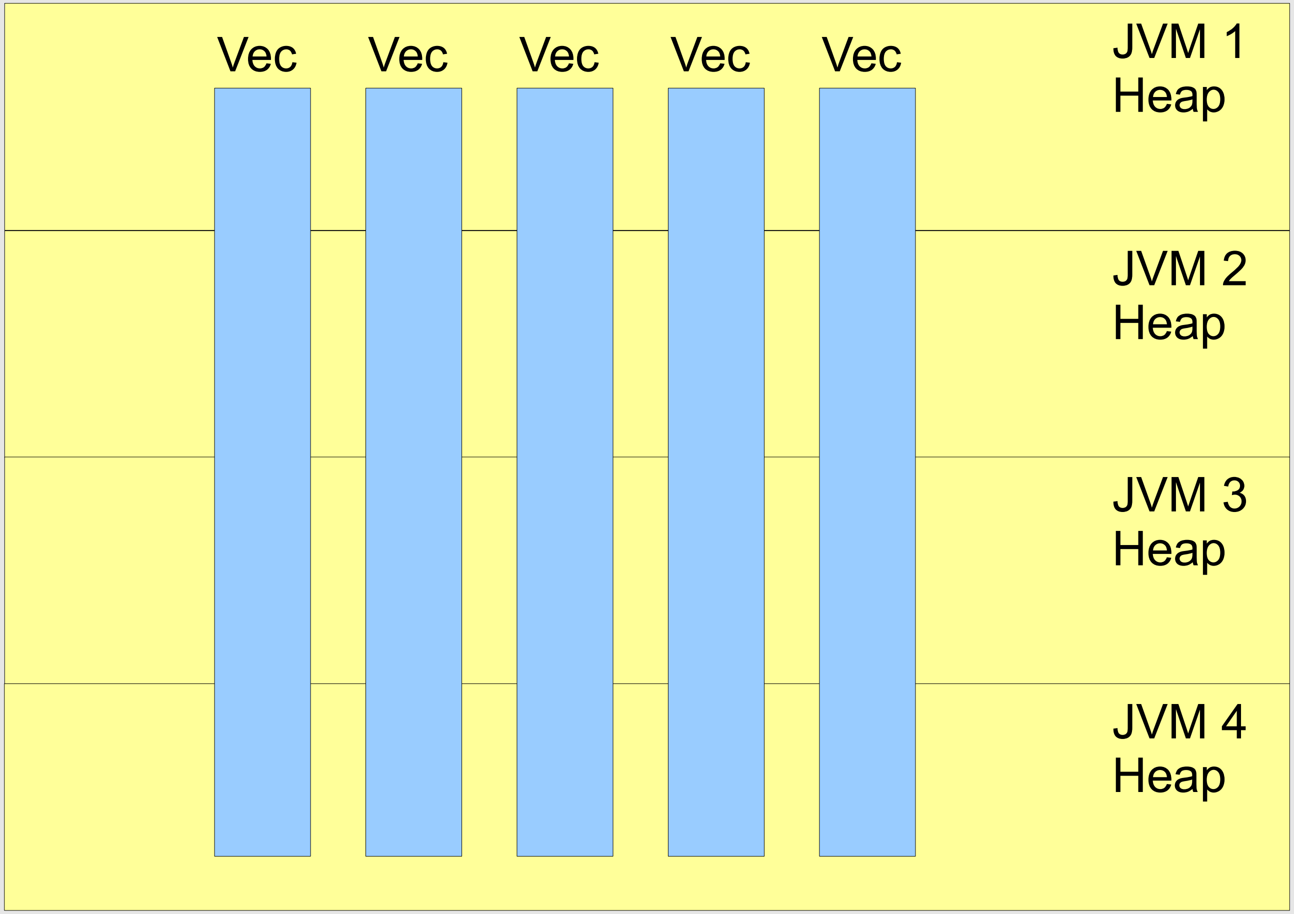
- Java Heap
  - Data In-Heap
  - Not off heap
- Split Across Heaps

- GC management
  - Watch FullGC
  - Spill-to-disk
  - GC very cheap
  - Default GC

- Fortran-speed
- Java ease

Distributed Data Taxonomy

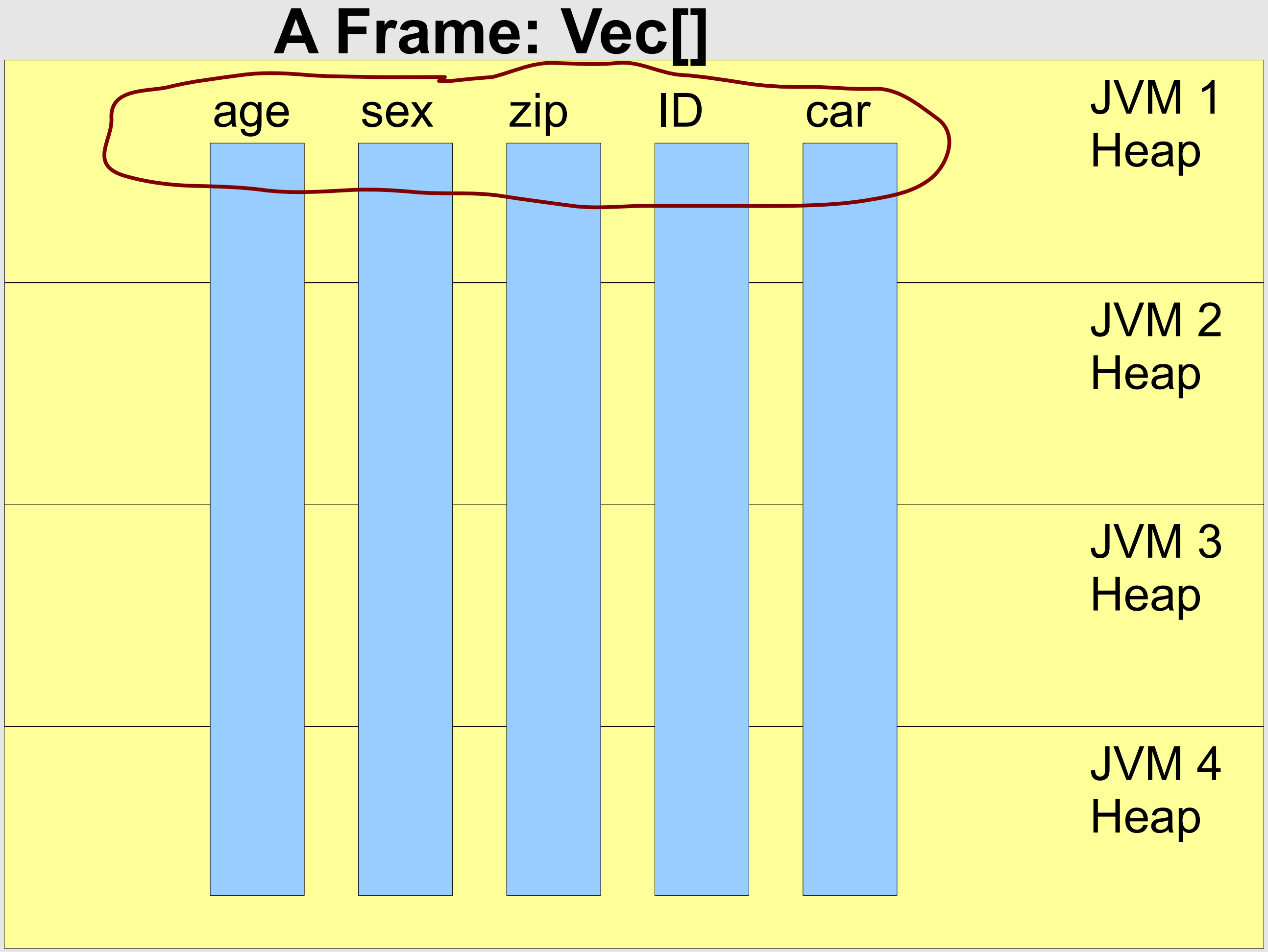
A Collection of Distributed Vecs



- Vecs aligned in heaps
- Optimized for concurrent access
- Random access any row, any JVM

- But faster if local... more on that later

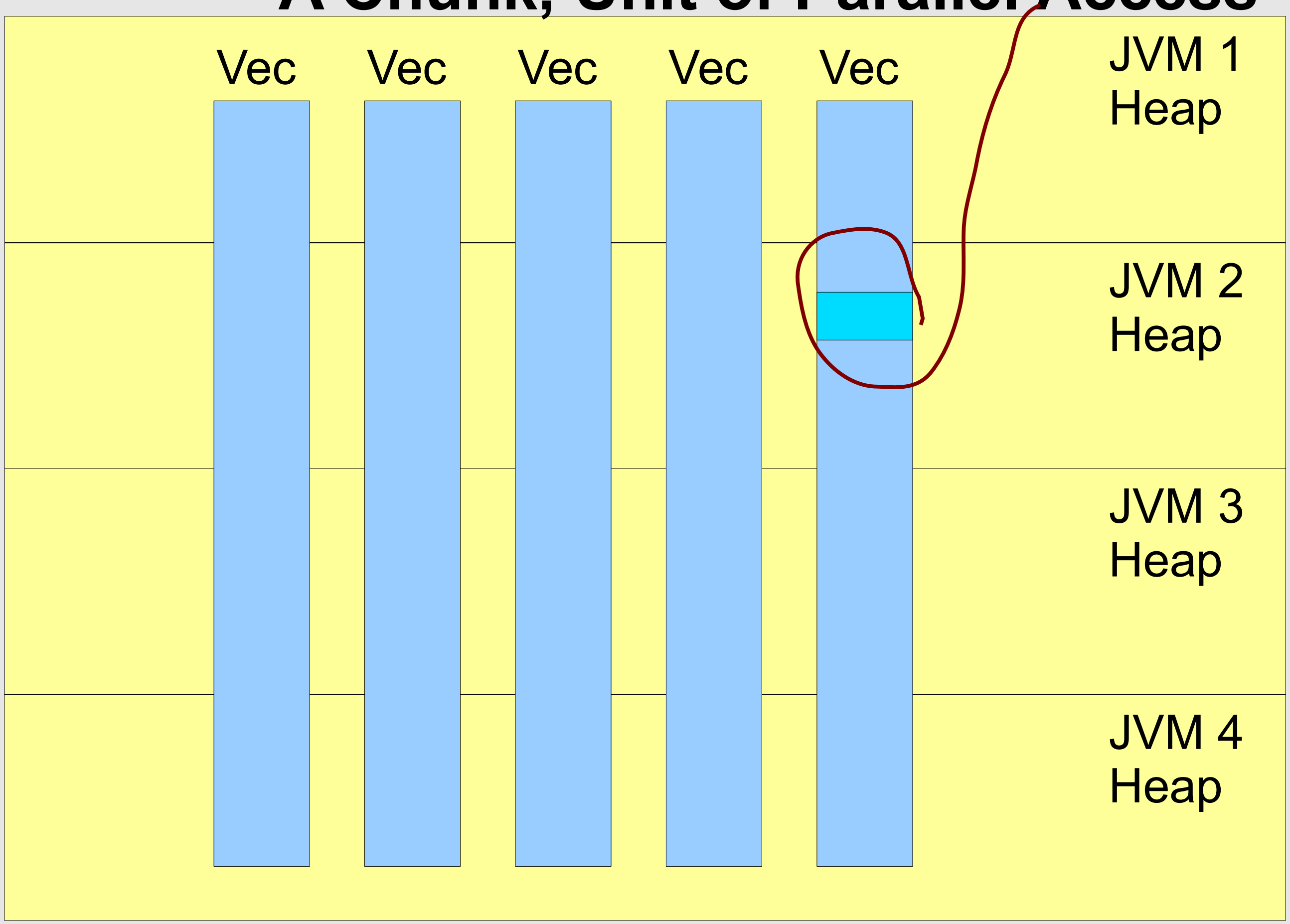
Distributed Data Taxonomy



- Similar to R frame
- Change Vecs freely
- Add, remove Vecs
- Describes a row of user data
- Struct-of-Arrays (vs ary-of-structs)

Distributed Data Taxonomy

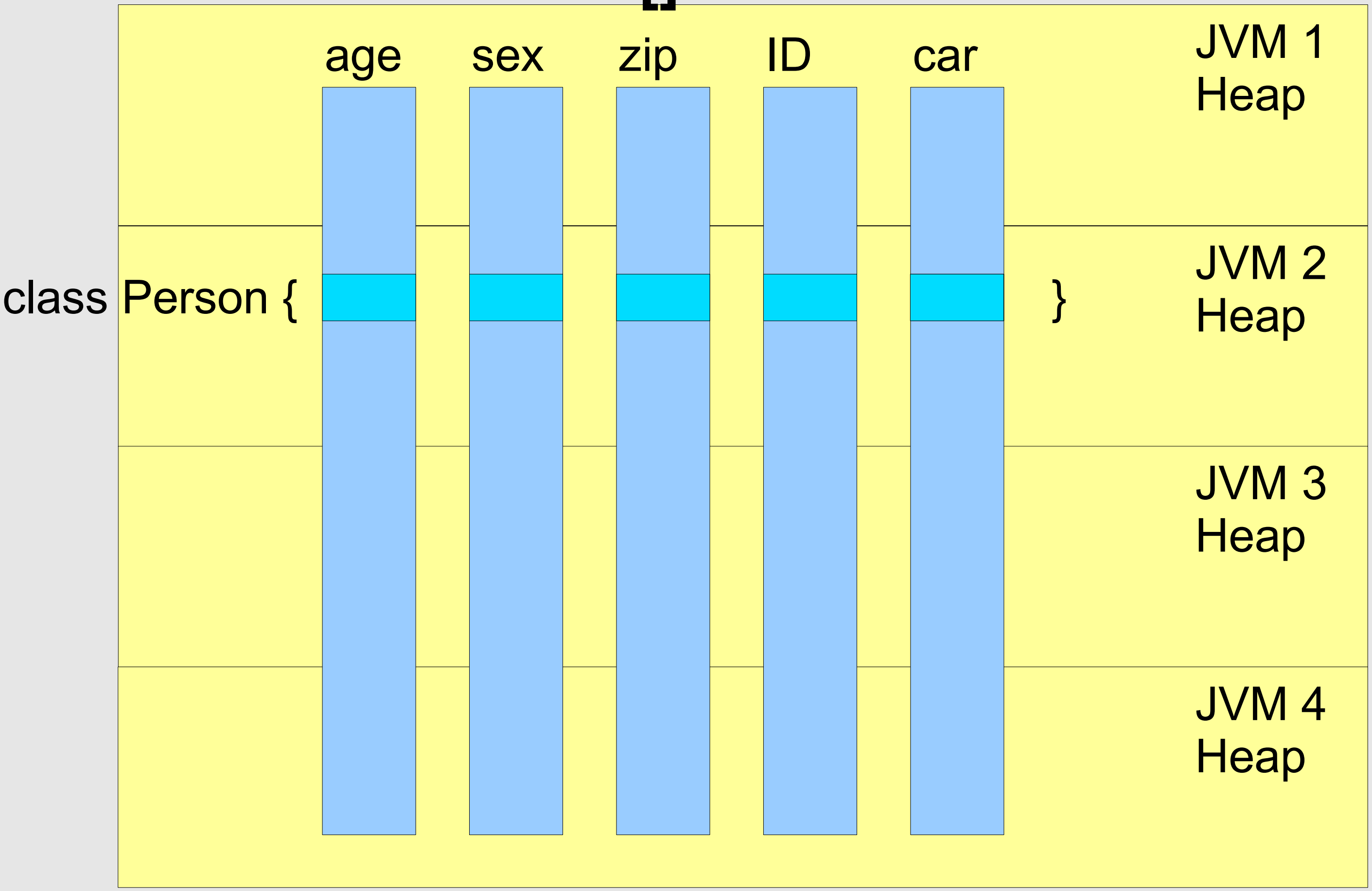
A Chunk, Unit of Parallel Access



- Typically 1e3 to 1e6 elements
- Stored compressed
- In byte arrays
- Get/put is a few clock cycles **including** compression

Distributed Data Taxonomy

A Chunk[]: Concurrent Vec Access

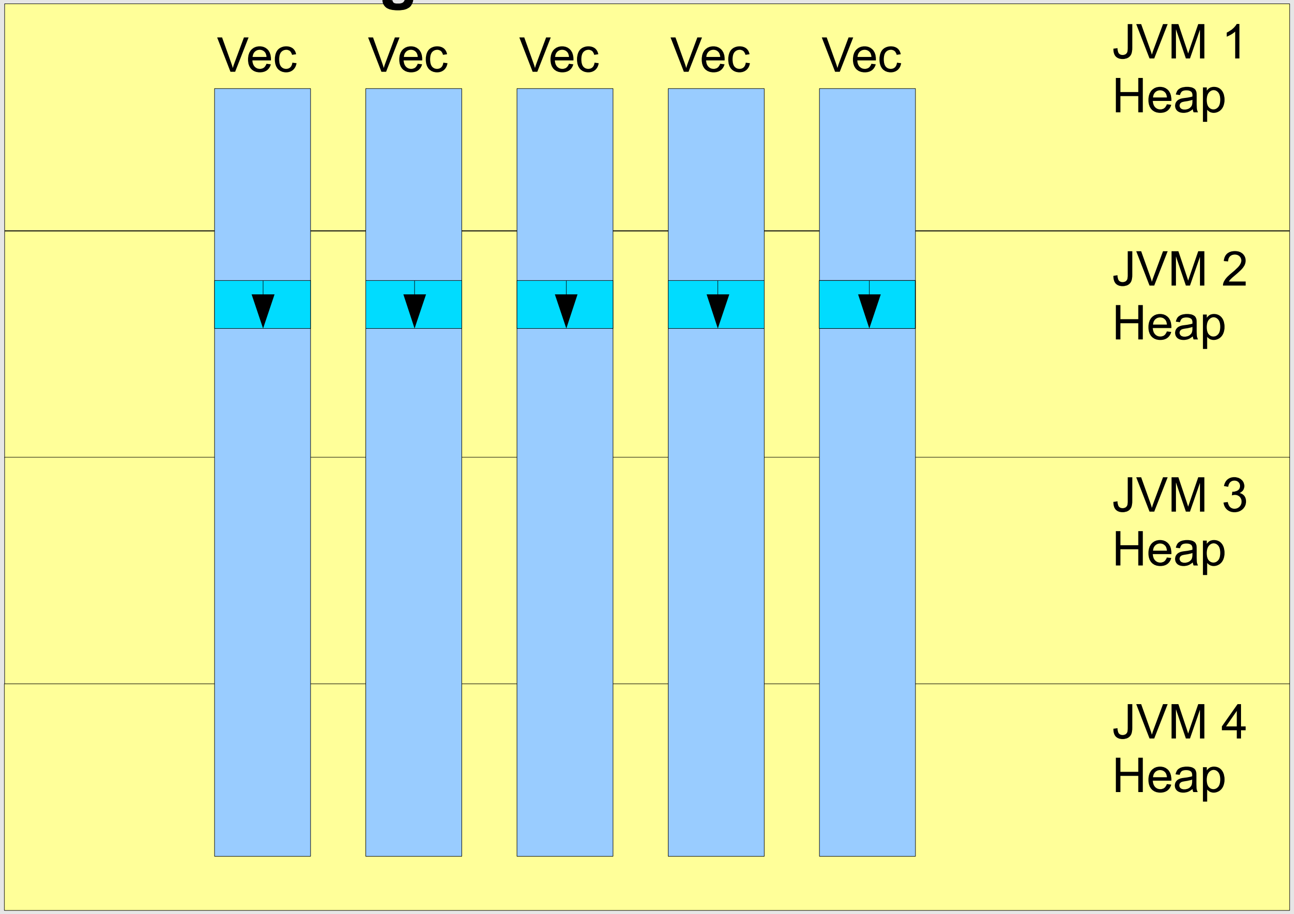


- Access Row in a single thread
- Like a Java object

- Can read & write
- Both are full Java speed
- Conflicting writes: use JMM rules

Distributed Data Taxonomy

Single Threaded Execution

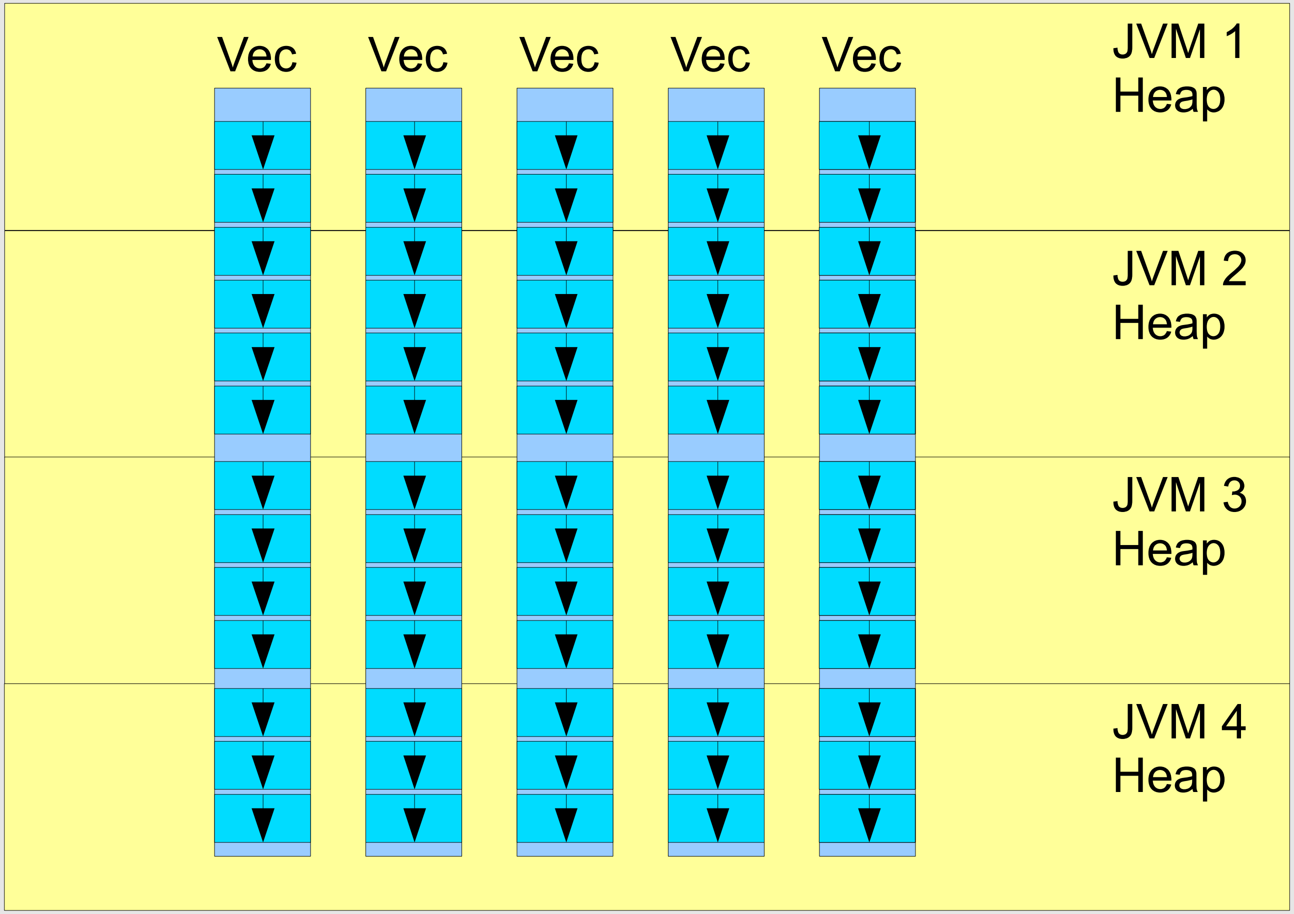


- One CPU works a Chunk of rows
- Fork/Join work unit
- Big enough to cover control overheads
- Small enough to get fine-grained par

- Map/Reduce
- Code written in a simple single-threaded style

Distributed Data Taxonomy

Distributed Parallel Execution



- All CPUs grab Chunks in parallel
- F/J load balances

- Code moves to Data
- Map/Reduce & F/J handles all sync
- H2O handles all comm, data manage

Distributed Data Taxonomy

```
Frame – a collection of Vecs
  Vec – a collection of Chunks
    Chunk – a collection of 1e3 to 1e6 elems
      elem – a java double


Row i – i'th elements of all the Vecs in a Frame
```

Distributed Coding Taxonomy

- No Distribution Coding:
  - Whole Algorithms, Whole Vector-Math
  - REST + JSON: e.g. load data, GLM, get results
- Simple Data-Parallel Coding:
  - Per-Row (or neighbor row) Math
  - Map/Reduce-style: e.g. Any dense linear algebra
- Complex Data-Parallel Coding
  - K/V Store, Graph Algo's, e.g. PageRank

Distributed Coding Taxonomy

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Read the docs!

- Simple Data-Parallel Coding:
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This talk!

- Complex Data-Parallel Coding
  - K/V Store, Graph Algo's, e.g. PageRank

Join our GIT!

Simple Data-Parallel Coding

- Map/Reduce Per-Row: **Stateless**
  - Example from Linear Regression, $\Sigma\ y^2$

```
double sumY2 = new MRTask() {
  double map( double d ) { return d*d; }
  double reduce( double d1, double d2 ) {
    return d1+d2;
  }
}.doAll( vecY );
```

- Auto-parallel, auto-distributed
- Fortran speed, Java Ease

Simple Data-Parallel Coding

- Map/Reduce Per-Row: **Statefull**
  - Linear Regression Pass1: Σx, Σy, Σy^2

```
class LRPass1 extends MRTask {
  double sumX, sumY, sumY2; // I Can Haz State?
  void map( double X, double Y ) {
    sumX += X;  sumY += Y;  sumY2 += Y*Y;
  }
  void reduce( LRPass1 that ) {
    sumX  += that.sumX ;
    sumY  += that.sumY ;
    sumY2 += that.sumY2;
  }
}
```

Simple Data-Parallel Coding

- Map/Reduce Per-Row: **Batch Statefull**

```
class LRPass1 extends MRTask {
  double sumX, sumY, sumY2;
  void map( Chunk CX, Chunk CY ) {// Whole Chunks
    for( int i=0; i<CX.len; i++ ){// Batch!
      double X = CX.at(i), Y = CY.at(i);
      sumX += X;  sumY += Y;  sumY2 += Y*Y;
    }
  }
  void reduce( LRPass1 that ) {
    sumX  += that.sumX ;
    sumY  += that.sumY ;
    sumY2 += that.sumY2;
  }
}
```

Other Simple Examples

- Filter & Count (underage males):
    - (can pass in any number of Vecs or a Frame)

```
long sumY2 = new MRTask() {
  long map( long age, long sex ) {
    return (age<=17 && sex==MALE) ? 1 : 0;
  }
  long reduce( long d1, long d2 ) {
    return d1+d2;
  }
}.doAll( vecAge, vecSex );
```

Other Simple Examples

- Filter into new set (underage males):
  - Can write or append subset of rows
    - (append order is preserved)

```
class Filter extends MRTask {
  void map(Chunk CRisk, Chunk CAge, Chunk CSex){
    for( int i=0; i<CAge.len; i++ )
      if( CAge.at(i)<=17 && CSex.at(i)==MALE )
        CRisk.append(CAge.at(i)); // build a set
  }
};
Vec risk = new AppendableVec();
new Filter().doAll( risk, vecAge, vecSex );
...risk... // all the underage males
```

Other Simple Examples

- Filter into new set (underage males):
    - Can write or append subset of rows
        - (append order is preserved)

```
class Filter extends MRTask {
  void map(Chunk CRisk, Chunk CAge, Chunk CSex){
    for( int i=0; i<CAge.len; i++ )
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        CRisk.append(CAge.at(i)); // build a set
  }
};
Vec risk = new AppendableVec();
new Filter().doAll( risk, vecAge, vecSex );
...risk... // all the underage males
```

Other Simple Examples

- Group-by: count of car-types by age

```
class AgeHisto extends MRTask {
  long carAges[][]; // count of cars by age
  void map( Chunk CAge, Chunk CCar ) {
    carAges = new long[numAges][numCars];
    for( int i=0; i<CAge.len; i++ )
      carAges[CAge.at(i)][CCar.at(i)]++;
  }
  void reduce( AgeHisto that ) {
    for( int i=0; i<carAges.length; i++ )
      for( int j=0; i<carAges[j].length; j++ )
        carAges[i][j] += that.carAges[i][j];
  }
}
```

Other Simple Examples

- Group-by: count of car-typ

Setting carAges in **map** makes it an **output** field.
Private per-map call, single-threaded write access.
Must be rolled-up in the **reduce** call.

```
class AgeHisto
  long carAges[][]
  void map( Chunk CAge, Chunk CCar ) {
    carAges = new long[numAges][numCars];
    for( int i=0; i<CAge.len; i++ )
      carAges[CAge.at(i)][CCar.at(i)]++;
  }
  void reduce( AgeHisto that ) {
    for( int i=0; i<carAges.length; i++ )
      for( int j=0; i<carAges[j].length; j++ )
        carAges[i][j] += that.carAges[i][j];
  }
}
```

Other Simple Examples

- Uniques
  - Uses distributed hash set

```
class Uniques extends MRTask {
  DNonBlockingHashSet<Long> dnbhs = new ...;
  void map( long id ) { dnbhs.add(id); }
  void reduce( Uniques that ) {
    dnbhs.putAll(that.dnbhs);
  }
};
long uniques = new Uniques().
  doAll( vecVistors ).dnbhs.size();
```

Other Simple Examples

- Uniques
  - Uses distribut

Setting dnbhs in <init> makes it an **input** field. Shared across all maps(). Often read-only. This one is written, so needs a **reduce**.

```
class Uniques extends MRTask {
  DNonBlockingHashSet<Long> dnbhs = new ...;
  void map( long id ) { dnbhs.add(id); }
  void reduce( Uniques that ) {
    dnbhs.putAll(that.dnbhs);
  }
};
long uniques = new Uniques().
  doAll( vecVistors ).dnbhs.size();
```

Summary: Write (parallel) Java

- Most simple Java “just works”
- **Fast**: parallel distributed reads, writes, appends
  - Reads same speed as plain Java array loads
  - Writes, appends: slightly slower (compression)
  - Typically memory bandwidth limited
    - (may be CPU limited in a few cases)
- **Slower**: conflicting writes (but follows strict JMM)
  - Also supports transactional updates

Summary: Writing Analytics

- We're writing Big Data Analytics
  - Generalized Linear Modeling (ADMM, GLMNET)
    - Logistic Regression, Poisson, Gamma
  - Random Forest, GBM, KMeans++, KNN
- State-of-the-art Algorithms, running Distributed
- Solidly working on 100G datasets
  - Heading for Tera Scale
- Paying customers (in production!)
- Come write your own (distributed) algorithm!!!

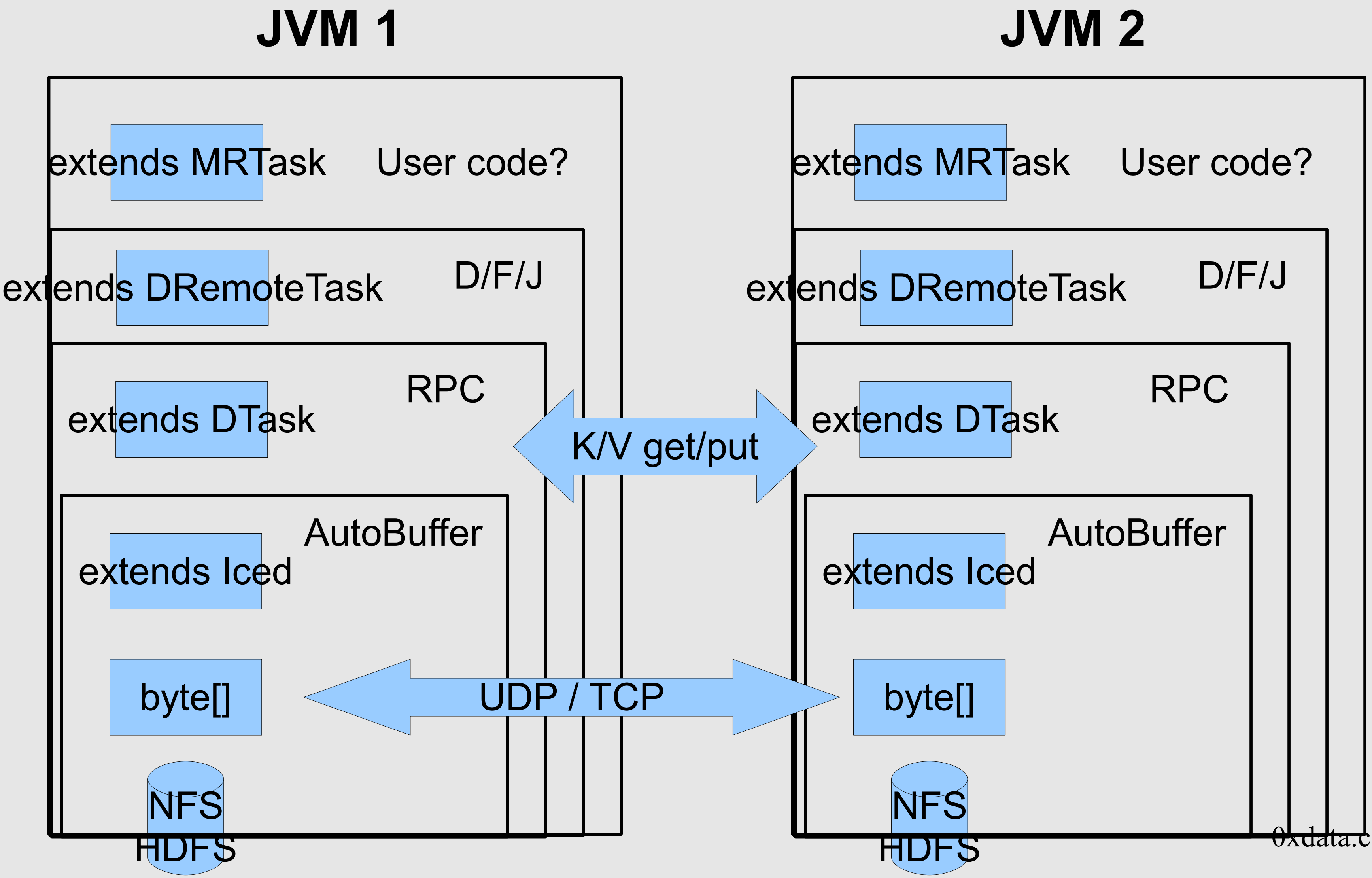
Cool Systems Stuff...

- … that I ran out of space for
- Reliable UDP, integrated w/RPC
- TCP is reliably UNReliable
  - Already have a reliable UDP framework, so no prob
- Fork/Join Goodies:
  - Priority Queues
  - Distributed F/J
  - Surviving fork bombs & lost threads
- K/V does JMM via hardware-like MESI protocol

H2O is...

- Pure Java, Open Source: 0xdata.com
  - https://github.com/0xdata/h2o/
- A Platform for doing Math
  - Parallel Distributed Math
  - In-memory analytics: GLM, GBM, RF, Logistic Reg
- Accessible via REST & JSON
- A K/V Store: ~150ns per get or put
- Distributed Fork/Join + Map/Reduce + K/V

The Platform



JVM 1

extends MRTask

User code?

extends DRemoteTask

D/F/J

extends DTask

RPC

extends Iced

AutoBuffer

byte[]

NFS
HDFS

K/V get/put

UDP / TCP

JVM 2

extends MRTask

User code?

extends DRemoteTask

D/F/J

extends DTask

RPC

extends Iced

AutoBuffer

byte[]

NFS
HDFS

TCP Fails

- In <5mins, I can force a TCP fail on Linux
- "Fail": means Server opens+writes+closes
    - NO ERRORS
    - Client gets no data, no errors
    - In my lab (no virtualization) or EC2
- Basically, H2O can mimic a DDOS attack
    - And Linux will "cheat" on the TCP protocol
    - And cancel valid, in-progress, TCP handshakes
    - Verified w/wireshark

TCP Fails

- Any formal verification? (yes lots)
- Of **recent** Linux kernals?
  - Ones with DDOS-defense built-in?