深入Java多线程和并发编程

ver 1.1

一粟

追風堂

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背景

- 高并发请求的Online应用
  - CPU密集型
  - IO密集型
- 大数据量和计算量的Offline应用
- 培训目的: 建立系统知识，掌握方法

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一些相关知识

- CPU
- 操作系统
  - 中断处理
  - 调度
    - 抢占式
    - 协作式
- 原子操作
  - CAS

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多任务

- 操作系统任务调度
  - 抢占式
  - 协作式
- 多进程
- 多线程
- 协程(coroutine)/纤程(fiber)

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多任务

- 并发 (Concurrency)
  - 一个处理器“同时”处理多个任务
- 并行 (Parallelism)
  - 多个处理器（或多核）“同时”处理多个任务

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多线程的优势

- 可并行处理任务，减少单个任务的等待时间
- 线程较进程或子进程开销小
- 线程间可共享资源
- 多核情况下可充分利用CPU资源

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多线程带来的问题

- 访问冲突
- 锁竞争
  - 死锁
  - 锁粒度
- 上下文切换开销
- 同步/内存拷贝开销

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线程安全

- Java 内存模型
  - working memory & main memory (Heap)
- Just-in-time(JIT)编译器优化
- 代码重排 reorder
- 变量可见性

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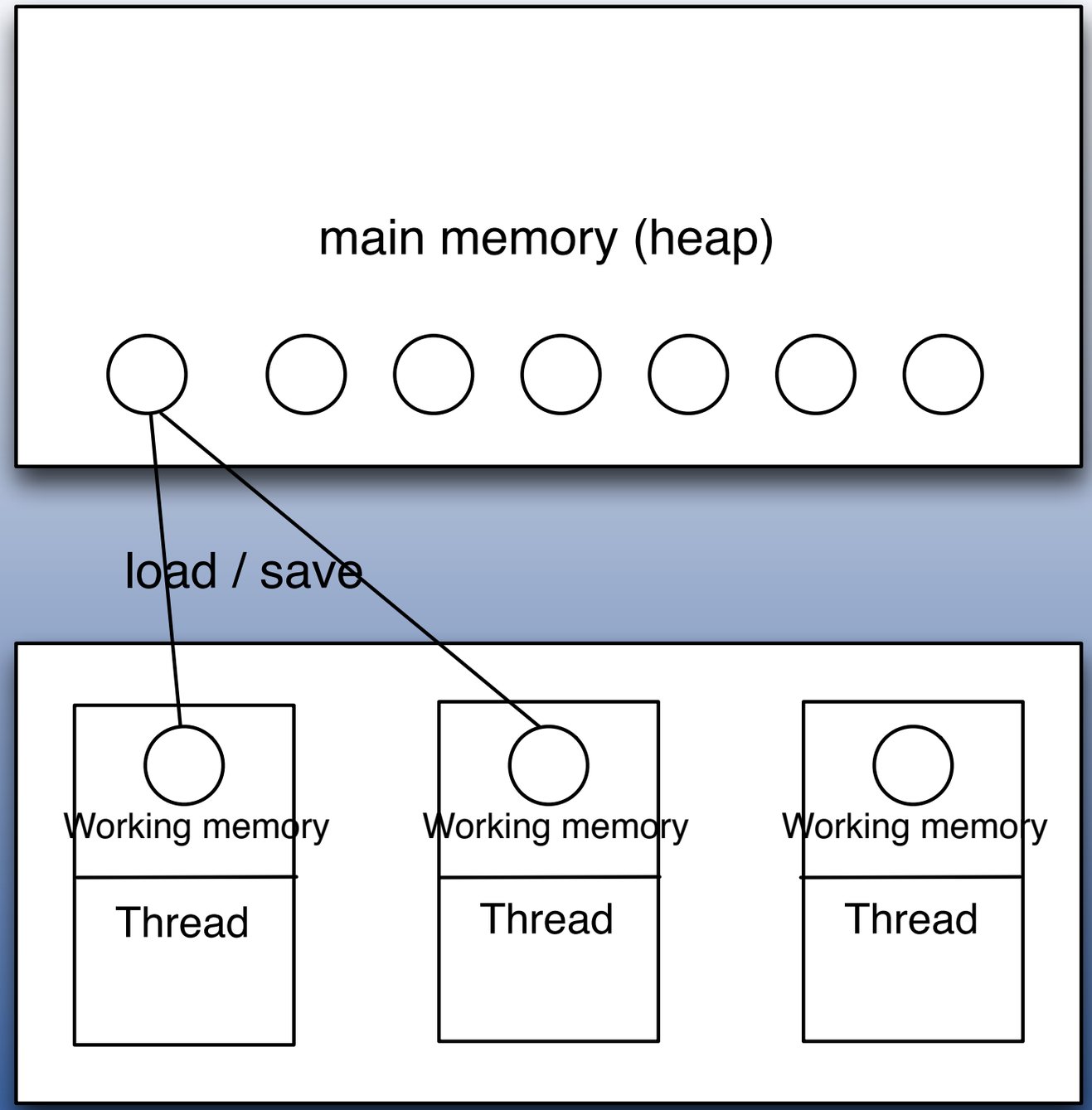

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happens-before

- 排序原则
  - 对象监视器的解锁发生在等待获取该锁的线程获得锁之前；
  - volitile变量写入操作发生在该变量的读取之前

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```
1  public class NoVisibility {
2      private static boolean ready;
3      private static int number;
4      private static class ReaderThread extends Thread {
5          public void run() {
6              while (!ready) {
7                  Thread.yield();
8              }
9              System.out.println(number);
10         }
11     }
12     public static void main(String[] args) throws Exception {
13         new ReaderThread().start();
14         number = 1;
15         ready = true;
16     }
17 }
```

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Java并发工具

- 同步容器类
- 支持并发的容器类
- 线程池 ExecutorService
- BlockingQueue
- 可重入锁 ReentrantLock，读写锁
- 同步器: CountdownLatch, Semaphore

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同步容器类

- 采用同步锁解决线程安全性能低
- 需要注意多个连续调用仍有线程安全问题
- 迭代过程仍然需要同步

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线程不安全的用法

```
1  public class NotThreadSafe {
2      List<String> list = new ArrayList<String>();
3      Map<String, String> map = new HashMap<String,String>();
4
5      public String getLast() {
6          return list.get(list.size()-1);
7      }
8
9      public void addValue(String key, String value) {
10         for(Map.Entry entry: map.entrySet()) {
11             ...
12         }
13     }
14 }
15
```

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并发容器类

- ConcurrentHashMap
  - 细粒度的锁
  - 弱一致性
- CopyOnWriteArrayList
  - 冗余，不变性

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线程池

```
1 public ThreadPoolExecutor(int corePoolSize,
2                           int maximumPoolSize,
3                           long keepAliveTime,
4                           TimeUnit unit,
5                           BlockingQueue<Runnable> workQueue,
6                           ThreadFactory threadFactory,
7                           RejectedExecutionHandler handler)
```

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线程池配置

- 行为
  - core size不到时候，创建新线程
  - core size到了，任务被放入队列
  - core size到了，并且队列满了，创建新线程直到max size
  - 如果队列满了，max size也达到了，那就开始拒绝任务了...

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线程池配置

- Importance of core size
  - ThreadPoolExecutor changes behavior dramatically around the core size
  - Below core size, threads are always created even if there are idle threads
- Above core size, the preferred behavior shifts to queuing
- Core size should be big enough to accommodate the anticipated average task throughput demand

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线程池配置问题

- 纯CPU计算的应用，线程池应该设多大?
- 一个一半时间都在等待IO的应用，线程池应该设多大?

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线程池配置问题

$$\text{Number of threads} = \frac{\text{Number of Available Cores}}{1 - \text{Blocking Coefficient}}$$

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生产者-消费者问题

- 两个线程
  - 生产者线程：读文件
  - 消费者线程：写文件

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```java
public class Producer extends Thread {
    private BufferedReader reader;
    Buffer buffer;
    public Producer(Buffer buffer) {
        reader = new BufferedReader(new InputStreamReader(System.in));
        this.buffer = buffer;
    }

    void send(String s) {
        buffer.send(s);
    }

    public void run() {
        try {
            while (true) {
                String line = reader.readLine();
                send(line);
            }
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}

```

```java
public class Consumer extends Thread {
    private BufferedWriter writer;
    Buffer buffer;

    public Consumer(Buffer buffer) {
        writer = new BufferedWriter(new OutputStreamWriter(System.out));
        this.buffer = buffer;
    }

    public String receive() {
        return buffer.receive();
    }

    public void run() {
        while (true) {
            String line = receive();
            if (line!=null) {
                try {
                    writer.write(line);
                    writer.flush();
                } catch (IOException e) {
                    e.printStackTrace();
                }
            }
        }
    }
}

```

```java
public class Main {
    public static void main(String[] args) {
        Buffer buffer = ...
        Producer producer = new Producer(buffer);
        Consumer consumer = new Consumer(buffer);
        producer.start();
        consumer.start();
    }
}

```

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Polling

```
1  public class PollingBuffer implements Buffer {
2      String line = null;
3
4      @Override
5      public void send(String s) {
6          while (line != null) {
7              pause(1);
8          }
9          line = s;
10     }
11
12     @Override
13     public String receive() {
14         while (line == null) {
15             pause(1);
16         }
17         String s = line;
18         line = null;
19         return s;
20     }
21
22     void pause(int ms) {
23         try {
24             Thread.sleep(ms);
25         } catch (InterruptedException e) {
26             e.printStackTrace();
27         }
28     }
29 }
30
```

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wait/notify/notifyAll

```
1  public class WaitNotifyBuffer implements Buffer {
2      String line;
3      @Override
4      public synchronized void send(String s) {
5          if (line != null) {
6              try {
7                  wait();
8              } catch (InterruptedException e) {
9                  e.printStackTrace();
10             }
11         }
12         line = s;
13         notify();
14     }
15
16     @Override
17     public synchronized String receive() {
18         if (line == null) {
19             try {
20                 wait();
21             } catch (InterruptedException e) {
22                 e.printStackTrace();
23             }
24         }
25         String s = line;
26         line = null;
27         notify();
28         return s;
29     }
30 }
31
```

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Semaphore

```java
public class SemaphoreBuffer implements Buffer {
    String line;
    Semaphore full;
    Semaphore empty;

    public SemaphoreBuffer() {
        full = new Semaphore(1);
        empty = new Semaphore(1);
    }

    @Override
    public void send(String s) {
        try {
            full.acquireUninterruptibly();
            line = s;
        }
        finally {
            empty.release();
        }
    }

    @Override
    public String receive() {
        try {
            empty.acquireUninterruptibly();
            return line;
        }
        finally {
            full.release();
            line = null;
        }
    }
}
```

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BlockingQueue

```
1  public class BlockingQueueBuffer implements Buffer {
2      BlockingQueue<String> queue;
3
4      public BlockingQueueBuffer (int capacity) {
5          queue = new ArrayBlockingQueue<String>(capacity);
6      }
7
8      @Override
9      public void send(String s) {
10         try {
11             queue.put(s);
12         } catch (InterruptedException e) {
13             e.printStackTrace();
14         }
15     }
16
17     @Override
18     public String receive() {
19         try {
20             return queue.take();
21         } catch (InterruptedException e) {
22             e.printStackTrace();
23         }
24         return null;
25     }
26 }
```

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多读少写的并发问题

1. 完全同步

```
1  class Synchronized {
2      private final List<String> list = new ArrayList<String>();
3
4      public synchronized void iterateOnList() {
5          for(String s: list) {
6              //do something with s
7          }
8      }
9
10     public synchronized void add(String value) {
11         list.add(value);
12     }
13 }
```

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多读少写的并发问题

2. 读写锁

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```
1  class UsingReadWriteLock {
2      private final List<String> list = new ArrayList<String>();
3      private final ReadWriteLock lock = new ReentrantReadWriteLock();
4
5      public void iterateOnList() {
6          lock.readLock().lock();
7          try {
8              for(String s: list) {
9                  //do something with s
10             }
11         } finally {
12             lock.readLock().unlock();
13         }
14     }
15
16     public synchronized void add(String value) {
17         lock.writeLock().lock();
18         try {
19             list.add(value);
20         } finally {
21             lock.writeLock().unlock();
22         }
23     }
24 }
25
```

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多读少写的并发问题

3. Copy On Write

```
1  class CopyOnWrite {
2      private volatile List<String> list = new ArrayList<String>();
3
4      public void iterateOnList() {
5          for(String s: list) {
6              //do something with s
7          }
8      }
9
10     public synchronized void add(String value) {
11         List<String> copy = new ArrayList<String>(list);
12         copy.add(value);
13         list = copy;
14     }
15 }
```

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原子性

```
1 public class CounterServlet implements Servlet {
2     private int count = 0;
3
4     public int getCount() { return count; }
5
6     public void service(ServletRequest req,
                          ServletResponse res) {
7         ++count;
8     }
9 }
10
```

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原子性

```
1 public class CounterServlet implements Servlet {
2     private int count = 0;
3
4     public synchronized int getCount() { return count; }
5
6     public synchronized void service(ServletRequest req,
                                       ServletResponse res) {
7         ++count;
8     }
9 }
10
```

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原子性

```
1 public class CounterServlet implements Servlet {
2     private volatile int count = 0;
3
4     public int getCount() { return count; }
5
6     public synchronized void service(ServletRequest req,
                                       ServletResponse res) {
7         ++count;
8     }
9 }
10
```

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案例

```
1 public class CounterServlet implements Servlet {
2     private AtomicInteger count = new AtomicInteger(0);
3
4     public int getCount() { return count.get(); }
5
6     public void service(ServletRequest req,
                          ServletResponse res) {
7         count.incrementAndGet();
8     }
9 }
10
```

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代码找错

```
1  //Bad code
2  public class Poll {
3      private final int MAX = 100;
4      private long count;
5
6      public Poll() {
7          new Thread(new Runnable() {
8              public void run() { add(); }
9          }).start();
10     }
11
12     public long getCountAvailable() { return count; }
13
14     public boolean take(int unit) {
15         if (unit > 0 && count > unit) {
16             count -= unit;
17             return true;
18         }
19         return false;
20     }
21
22     public void add() {
23         while(true) {
24             if (count < MAX) {
25                 count++;
26             }
27             try { Thread.sleep(1000l);} catch (InterruptedException e) {};
28         }
29     }
30 }
31
```

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```java
public class Poll {
    private final int MAX = 100;
    private final AtomicLong count = new AtomicLong(0);
    private final Timer timer = new Timer(true);

    private Poll() {}

    public void init() {
        TimerTask task = new TimerTask() {
            @Override
            public void run() {
                if (count.get() < MAX) {
                    count.incrementAndGet();
                }
            }
        };
        timer.scheduleAtFixedRate(task,0,1000);
    }

    public static final Poll create() {
        Poll poll = new Poll();
        poll.init();
        return poll;
    }

    public long getCountAvailable() {
        return count.get();
    }

    public boolean take(int unit) {
        long current = count.get();
        if (unit > 0 && current > unit) {
            return count.compareAndSet(current, current-unit);
        }
        return false;
    }
}
```

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另一些并发解决方法

- 不可改变对象 Immutable Object
- 无状态的函数式编程
- Java 7 Fork/Join Framework
  - work-stealing algorithm
- Clojure: STM
- Scala/Erlang: actor
- Kilim: coroutine

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Coroutine

- 像线程一样拥有自己栈和局部变量
- 轻量：创建和切换开销小
- 同一时刻只能运行一个协程
- 支持的语言：Lua，Ruby，Python，Go

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Lua Coroutine 例子

```
function receive ()
    local status, value = coroutine.resume(producer)
    return value
end

function send (x)
    coroutine.yield(x)
end

producer = coroutine.create( function ()
    while true do
        local x = io.read() -- produce new value
        send(x)
    end
end)
```

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Clojure STM

- Software Transactional Memory
- 类似数据库事务处理（ACID）
- Multiversion Concurrency Control (MVCC)

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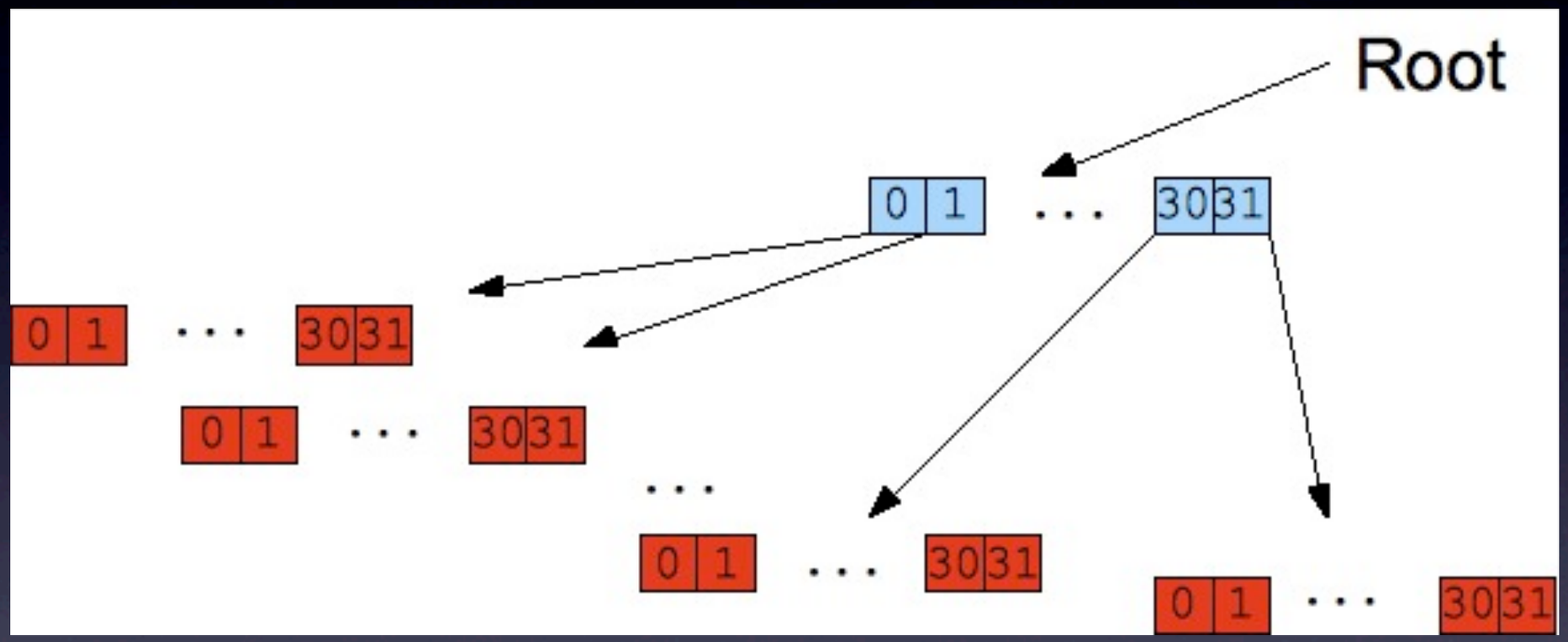
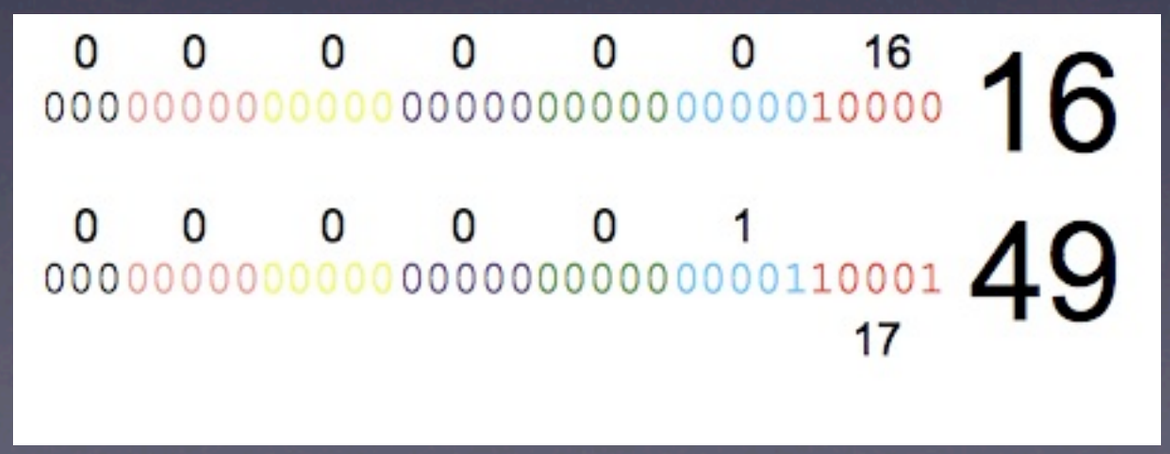
PersistentVector





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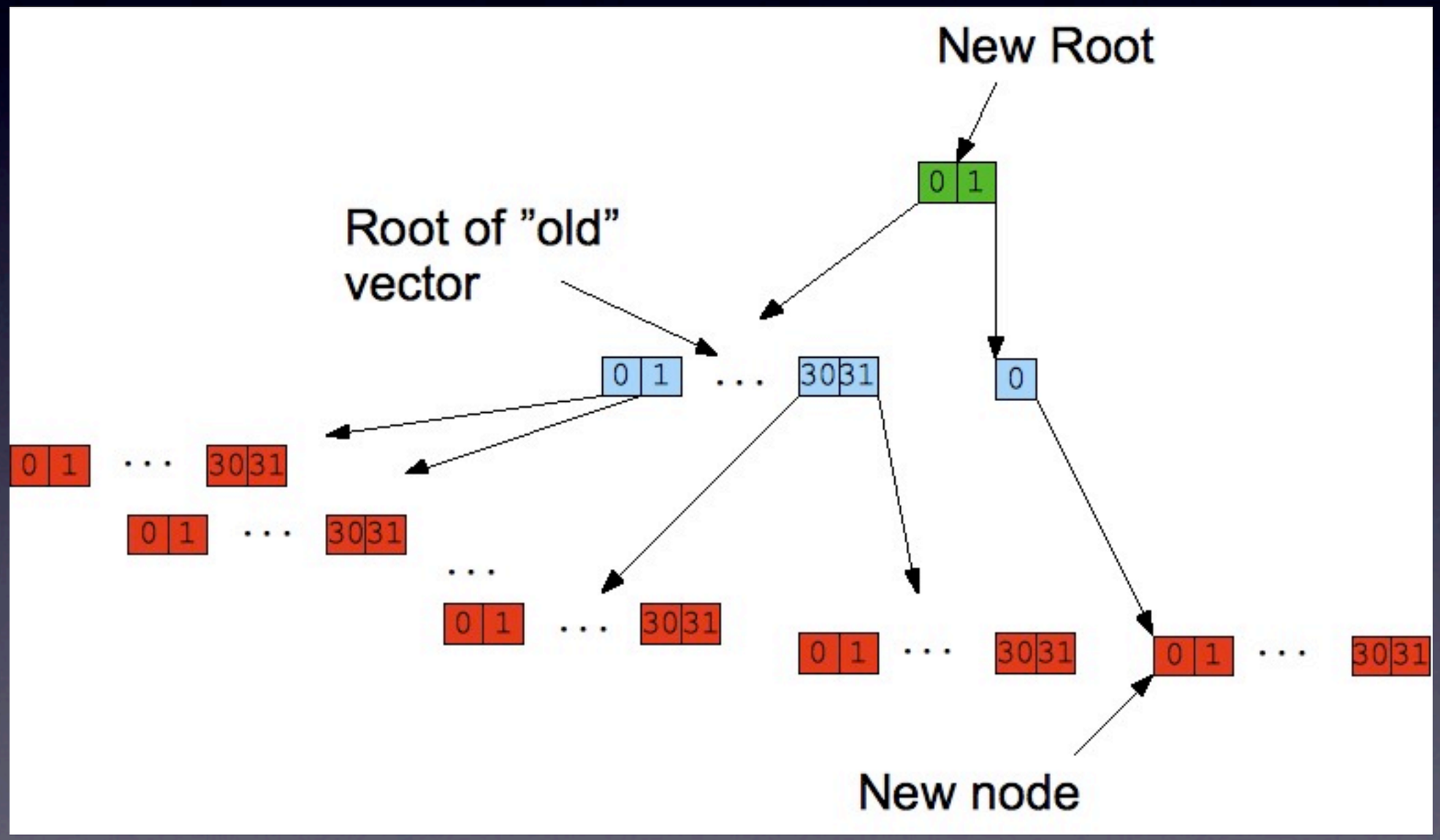
Insertion (put)



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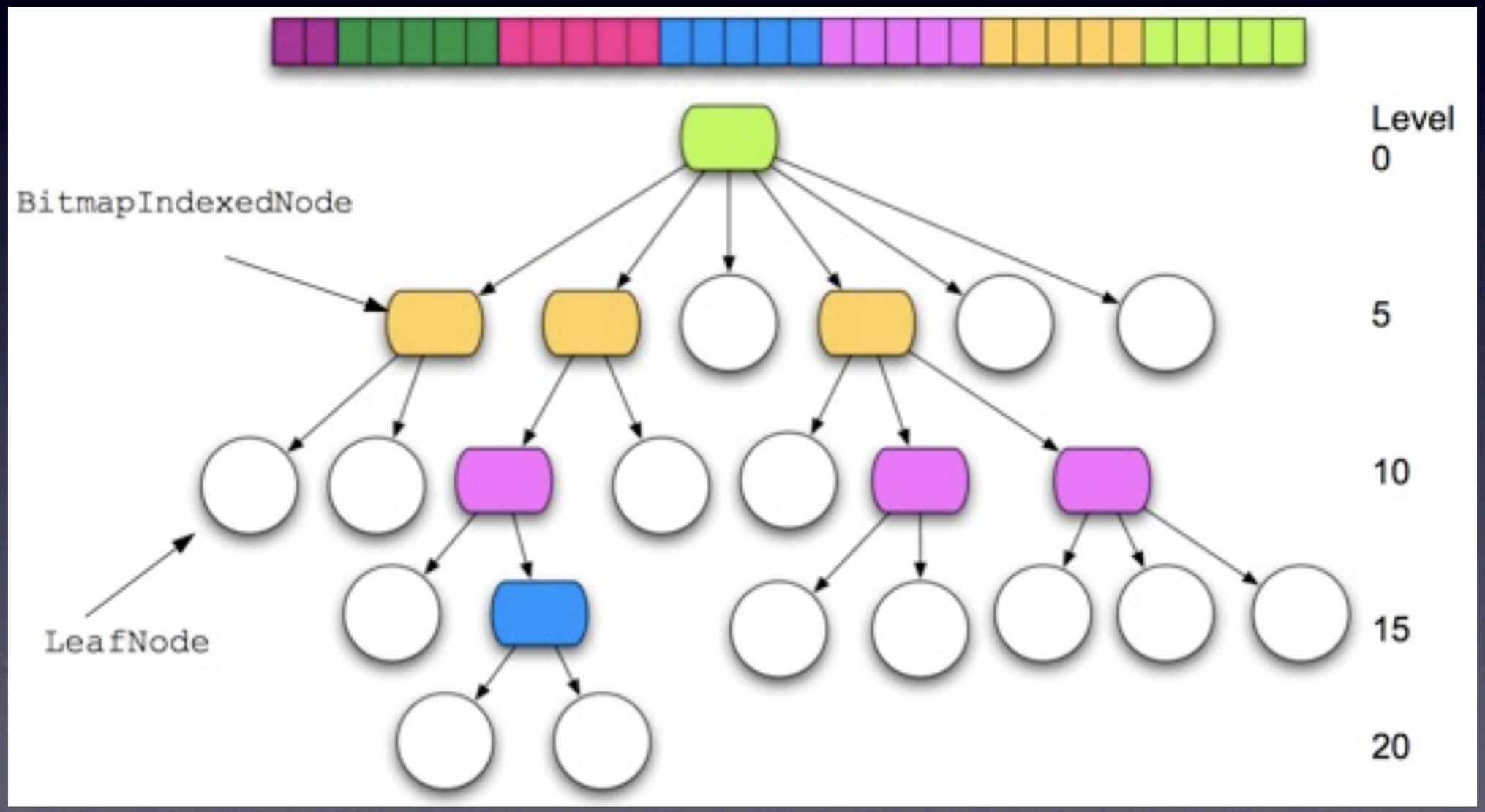
PersistentHashMap



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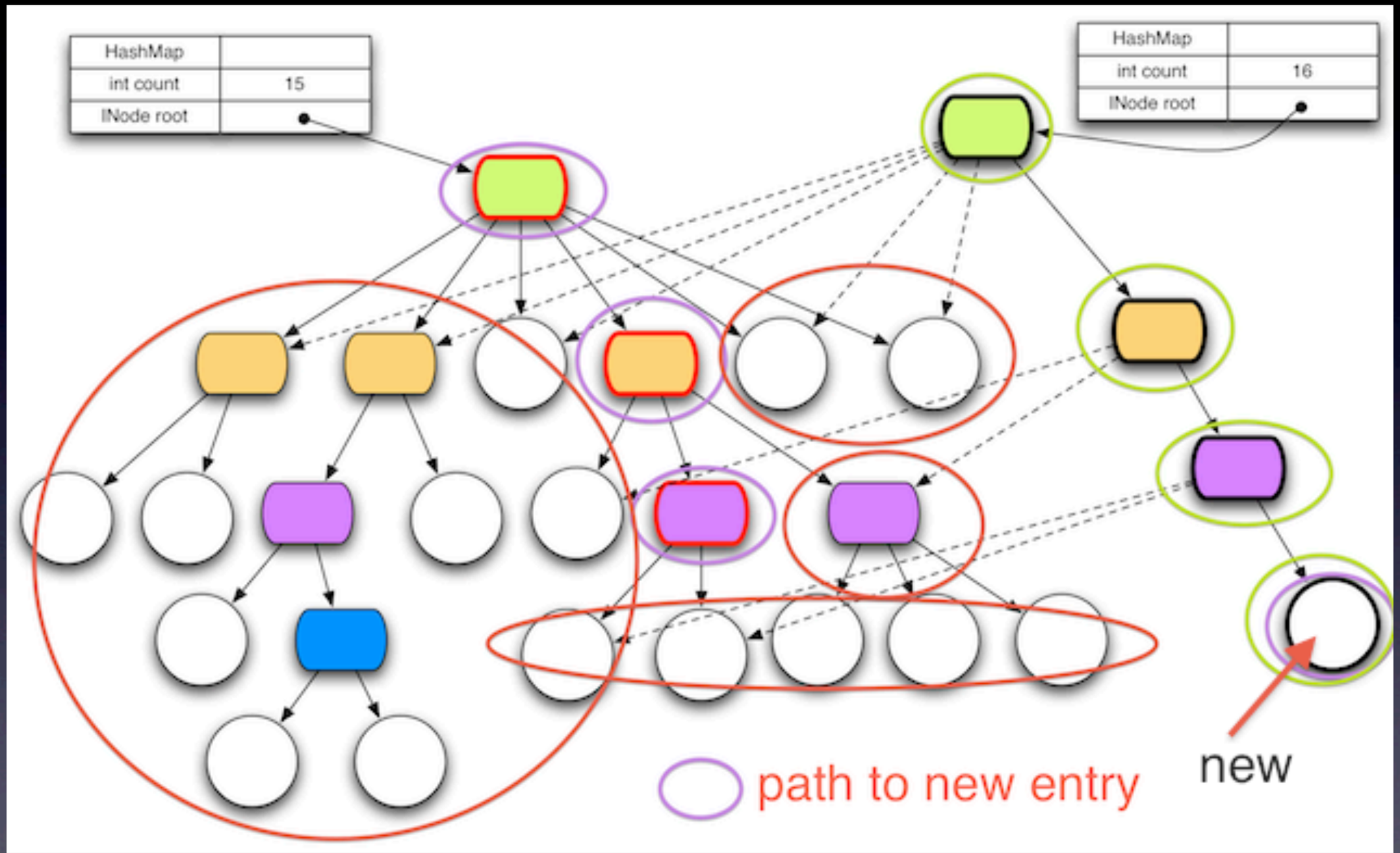

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并发编程模式

有状态(Stateful)	无状态(Stateless)
共享数据可变	共享数据不变
复杂，容易出错	简单
变量可能线程不安全	变量线程安全
不容易水平扩展	容易水平扩展

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讨论

- 计算在座各位的年龄总和?

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总结

- 划分任务
- 分析CPU和IO时间
- 设置合理的线程池大小
- 尽量用JUC包实现
- 避免共享的可变变量；尽量使用共享的不可改变变量或隔离的可变变量

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网络服务编程框架

同步 Synchronous	异步 Asynchronous
阻塞	非阻塞
流程驱动	事件驱动
JDBC	libevent, Twisted, EventMachine, Node.JS, Java NIO