Portable Resource Control in Java: Application to Mobile Agent Security

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Requirements for Mobile Agent Platforms

- Security
  - protect platform and mobile agents
  - ensure secrecy
  - ensure integrity
  - prevent denial-of-service attacks
  - prevent resource leaks
- Portability
- High performance

Why Java for Mobile Agents?

- Portable code
- Language safety
  - type safety
  - automatic memory management
  - memory protection
  - bytecode verification
- Multithreading
- Class-loader namespaces
- Serialization (weak mobility)
- Availability and performance

Caveats and Pitfalls

- JVM is not an operating system
- No protection domains
- Uncontrolled aliasing
- No ownership information in objects
- Covert channels (e.g., public static variables)
- No resource control
- Single heap

Solution: Portable Resource Control Layer for Java

- Resource control
  - resource accounting
  - enforcing resource limits
- Resources
  - physical (e.g., memory, CPU)
  - logical (e.g., threads)
  - communication (e.g., with services)
- Pure Java
  - no dependence on operating system
  - standard JVMs (state-of-the-art JIT compilers)
  - Java processors (e.g., embedded systems)

Benefits

- Prevention against denial-of-service attacks
- Billing for resource consumption
- Quality of service guarantees
- Monitoring and profiling of mobile agents

Implementation

- Accountability (objects belong to 1 domain)
- Reification of physical resources
  - bytecode rewriting
  - memory: check before allocation (JRes)
  - CPU: count bytecode instructions
- Compensation for native code
  - class-loading
  - deserialization
  - reflection

Memory Account (Simplified)

- Memory limit for multiple threads
- Synchronization
- Weak references to allocated objects

```
public final class Mem {
   public static Mem getOrCreate();

   public void setLimit(int limit);
   public void checkAllocation(int size)
          throws ResourceOveruseException;
   public void register(Object o);
}
```

CPU Account

- Separate account for each thread
- No synchronization
- Periodic scheduler thread (high priority)

```
public final class CPU {
   public static CPU getOrCreate();

   public volatile int usage;
}
```

Passing Accounting Objects

- Unmodified method

```
Object f(int x) {
   if (x < 0) return null;
   else return new Foo(g(x));
}
```

- Added accounting objects

```
Object f(int x, Mem mem, CPU cpu) {
   if (x < 0) return null;
   else return new Foo(g(x, mem, cpu), mem, cpu);
}
```

Rewriting for Memory Accounting (Simplified)

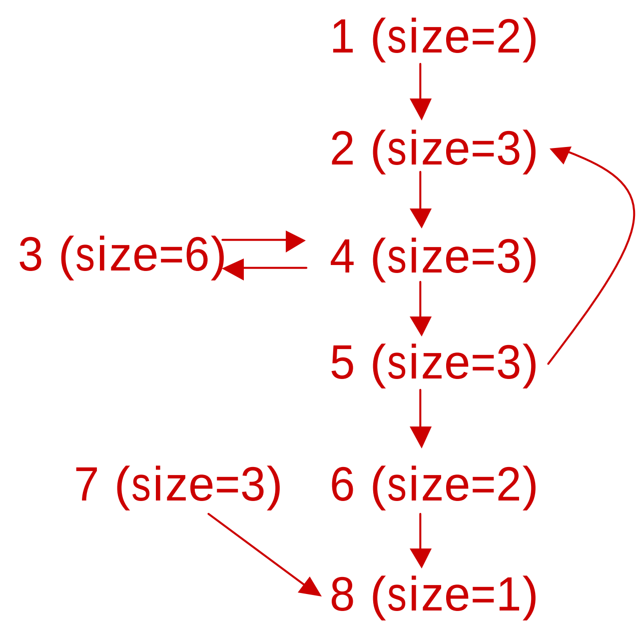
```
Object f(int x, Mem mem, CPU cpu) {
   if (x < 0) return null;
   else {
      int y = g(x, mem, cpu);
      mem.checkAllocation(SIZEOF_FOO);
      Object o = new Foo(y, mem, cpu);
      mem.register(o);
      return o;
   }
}
```

Rewriting for CPU Accounting

```
Object f(int x, Mem mem, CPU cpu) {
   cpu.usage += 8;
   if (x < 0) {
      cpu.usage += 8;
      return null;
   }
   else {
      cpu.usage += 26;
      int y = g(x, mem, cpu);
      mem.checkAllocation(SIZEOF_FOO);
      Object o = new Foo(y, mem, cpu);
      mem.register(o);
      return o;
   }
}
```

Accounting Block Analysis

```
1   0 bipush 10
    2 istore_1
2   3 iconst_1
    6 istore_3
    7 goto 25
3   10 invokestatic #2 <Method java.lang.Thread currentThread()>
    13 pop
    14 ldc2_w #3 <Long 100>
    17 bipush 100
    19 invokestatic #5 <Method void sleep(long, int)>
    22 iinc 3 1
4   25 iload_3
    26 iconst_1
    27 if_icmple 10
5   30 iload_2
    31 iconst_1
    32 if_icmpl1 3
6   35 iinc 2 -1
    38 goto 44
7   41 astore_2
    42 iconst_0
    43 istore 3
8   44 return
    Exception table:
       from   to   target   type
        3     38    41    <Class java.lang.Exception>
```



Invocations by Native Code

```
class A {
  void x() {
    B b = new B();
    b.y();
  }
}
class B {
  void y() {
    …
    …
  }
}
```

```
class A {
  void x(){x(CPU.getOrCreate());}
  void x(CPU cpu) {
    cpu.usage += 15;
    B b = new B(cpu);
    b.y(cpu);
  }
}
class B {
  void y(){y(CPU.getOrCreate());}
  void y(CPU cpu) {
    cpu.usage += 13;
    …
    cpu.usage += 18;
    …
  }
}
```

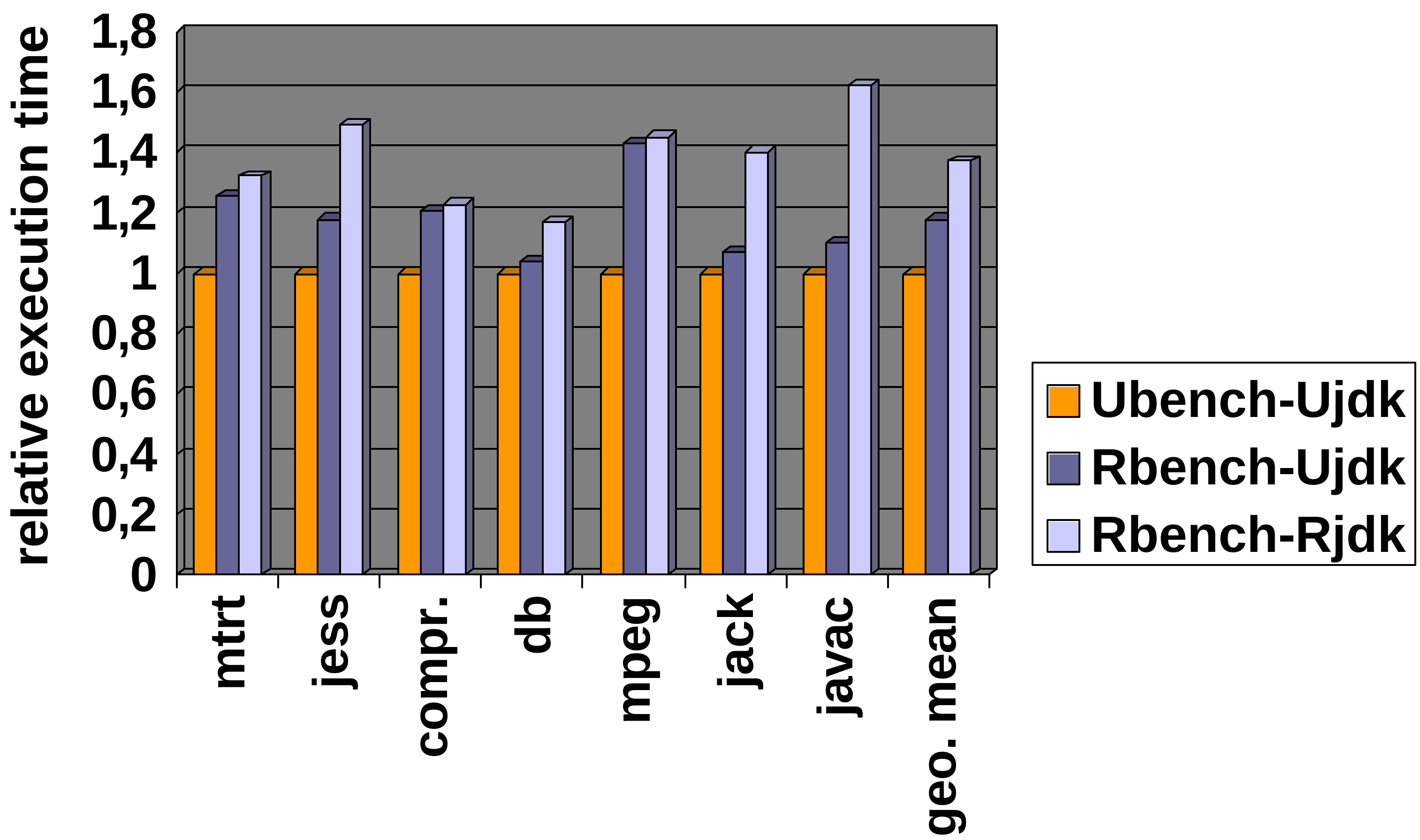
wrapper

account

modify invocations

account

Overhead of CPU Accounting



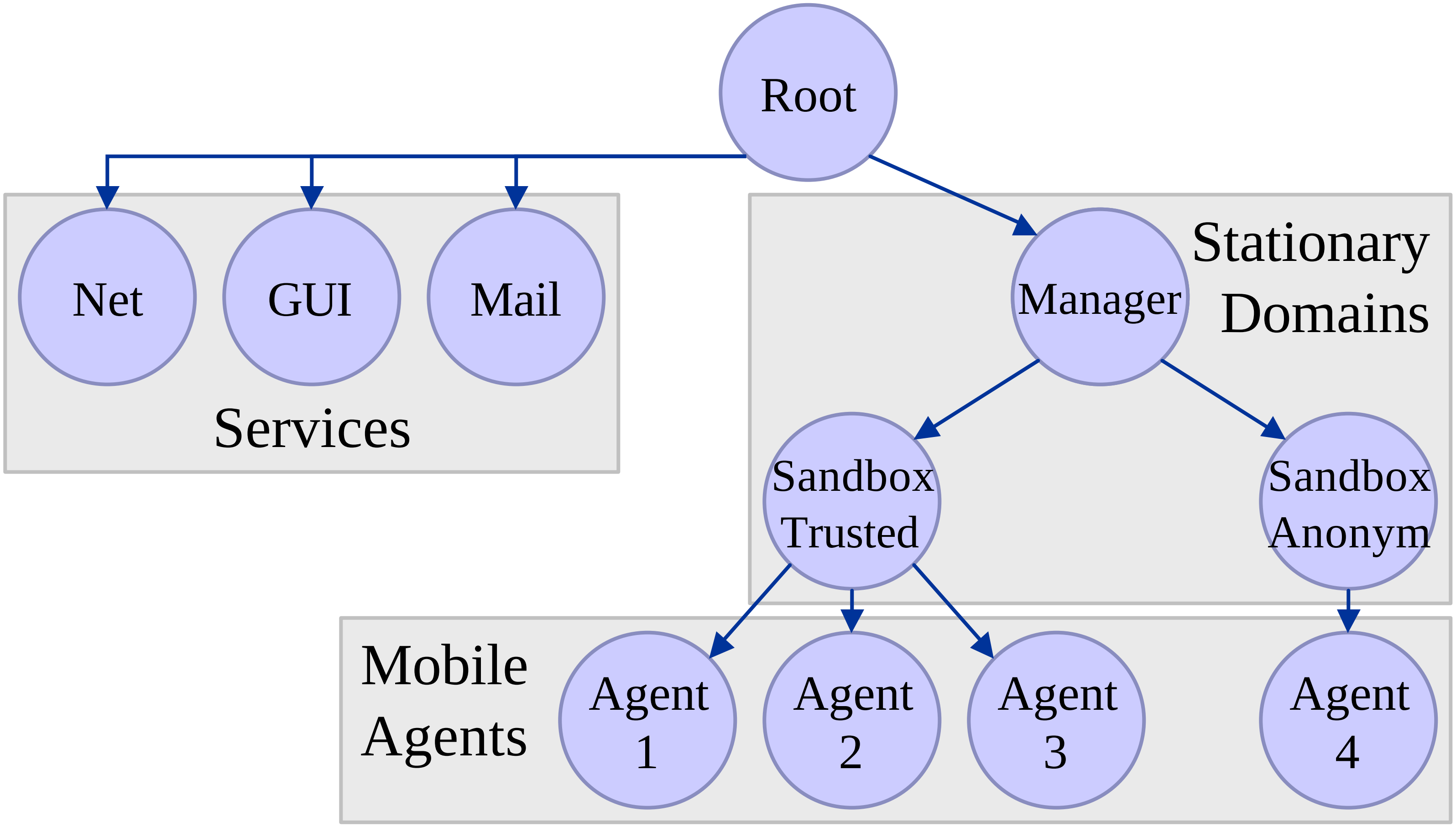
Case study: The J-SEAL2 Mobile Agent Kernel

- Operating system structure
  - isolated protection domains
  - safe domain termination
  - mediated communication
  - resource control
- Small micro-kernel (< 150 KB)
- Portable (pure Java)
- Flexible and extensible
- Efficient and scalable

Nested Protection Domains in J-SEAL2

- Hierarchy of protection domains
- Parent domain controls children
  - communication control
  - resource control
  - termination of sub-hierarchies
- Sandboxes with different privileges

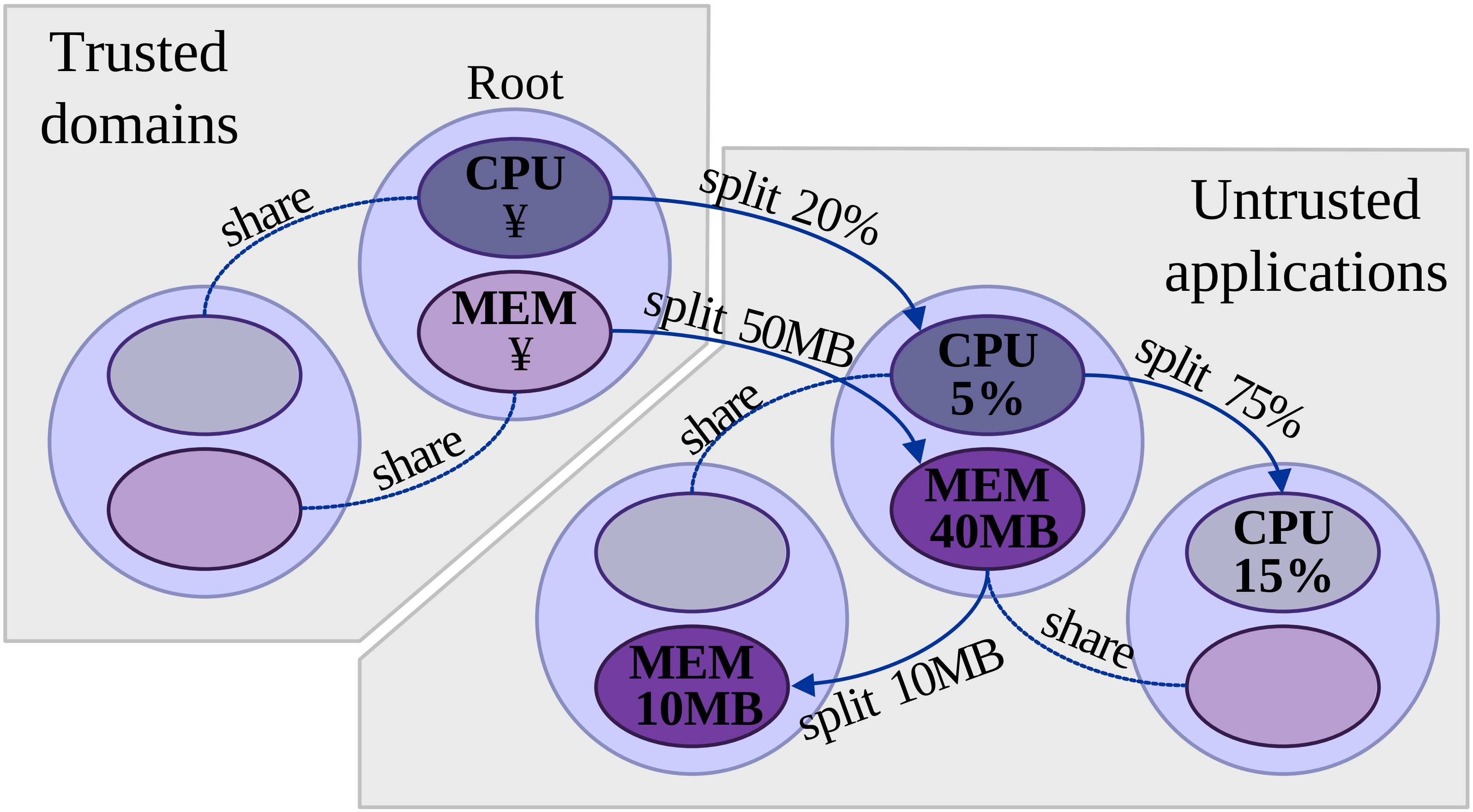
J-SEAL2 System Structure



Hierarchical Resource Control in J-SEAL2

- Startup
  - root domain owns all resources
- Subdomain creation
  - parent may donate resources to child
  - parent may share resources with child

Resource Donation and Sharing in J-SEAL2



Summary

- Mobile agent platform requirements
  - security
  - portability
  - high performance and scalability
- Resource control layer for Java
  - portable (pure Java)
  - reification of physical resources
  - bytecode rewriting
  - moderate overhead

Q&A