High Performance Java Remote Method Invocation for Parallel Computing on Clusters

Guillermo L. Taboada*, Carlos Teijeiro, Juan Touriño

computer architecture group

UNIVERSIDADE DA CORUÑA
SPAIN

taboada@udc.es

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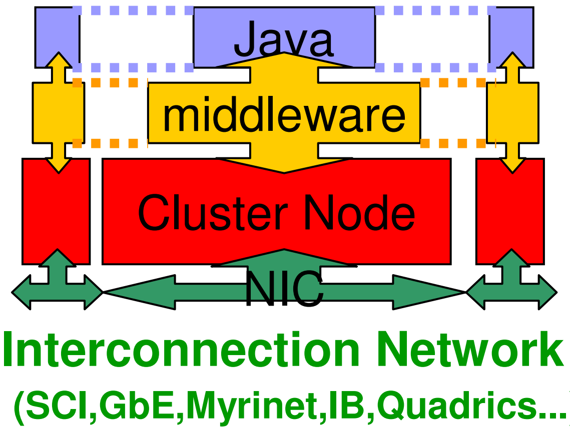
Outline

- Introduction
- Designing Java RMI Optimization
- Implementation: Opt RMI
  - Transport Protocol Optimization
  - Serialization Overhead Reduction
  - Object Manipulation Improvements
- Performance Evaluation
- Conclusions

Introduction (I)

- ↑ interest on clusters (↑ comput. ↓ cost)
- Growing solution:
  - Java (and HPC Java) on clusters
- Challenge: scalable peformance cluster+Java
  - Network performance is scalable
  - Java middleware less efficient than native code, especially Java RMI
    - → Java is not going to scale performance
    - High Performance Networks not supported or supported with poor performance
      - Ways of support:
        - IP Emulations
        - High Performance Sockets



Introduction (II)

- Target platform: High-speed Network Clusters
  - High-speed networks + associated software libraries play a key role in High Performance Clustering Technology
  - Diferent technologies:
    - Gigabit & 10Gigabit Ethernet
    - Scalable Coherent Interface (SCI)
    - Myrinet, Myrinet 2k, Myri-10G (10GbMyrinet & 10GbE)
    - Infiniband
    - Qsnet, Giganet, Quadrics, GSN - HIPPI
  - Small hw latencies (1.3-30us)
  - High bandwidths (>= 1Gbps)
  - Experimental results presented on Gigabit Ethernet and SCI

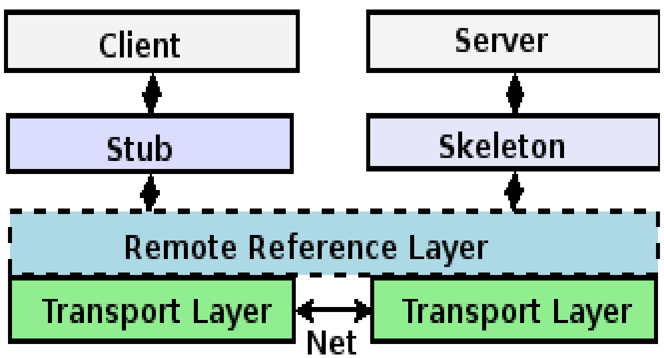
Introduction (III)

- Java RMI on Clusters
  - Java RMI is a framework for developing parallel and distributed applications. It's a higher level solution compared to sockets programming, allowing for rapid development.
  - But… inefficient protocol on clusters, showing high latencies
    - Considerable inefficiency on high-speed network clusters
    - Java's portability means in networking only TCP/IP support
    - High-speed network clusters use (inefficient) IP emulation libs.
      - SCIP, ScaIP, IPoGM, IPoMX, IPoIB

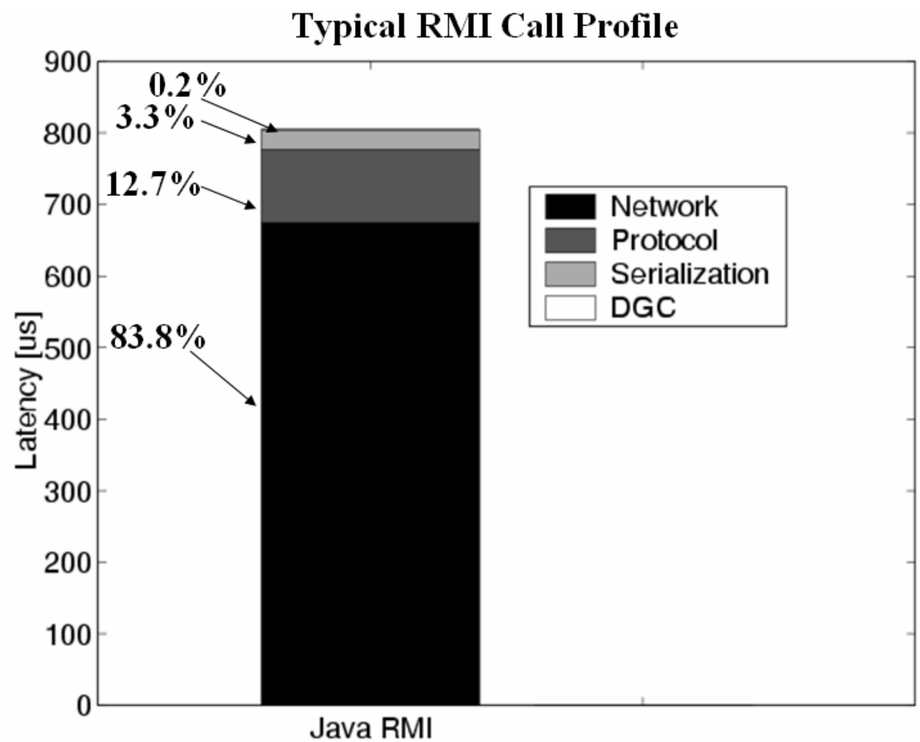
Introduction (&IV)

- Java RMI on clusters. Optimization projects:
  - **KaRMI** (JavaParty/Univ. Karlsruhe). RMI replacement for clusters. Good performance with small transfers and Myrinet support
  - **RMIX**. (Emory Univ. Atlanta) RMI extension including new communication protocols, but still inefficient on High-speed clusters (oriented to semantic protocols)
  - **Manta**. (Vrije Univ. Amsterdam) Java to native code compilation. Myrinet support.
  - **Ibis**. (Vrije Univ. Amsterdam) RMI extension for grid computing. Myrinet support.

Designing Java RMI Optimization (I)



- **Java RMI layered architecture**



- **Profiling 3KB Object call on SCI**

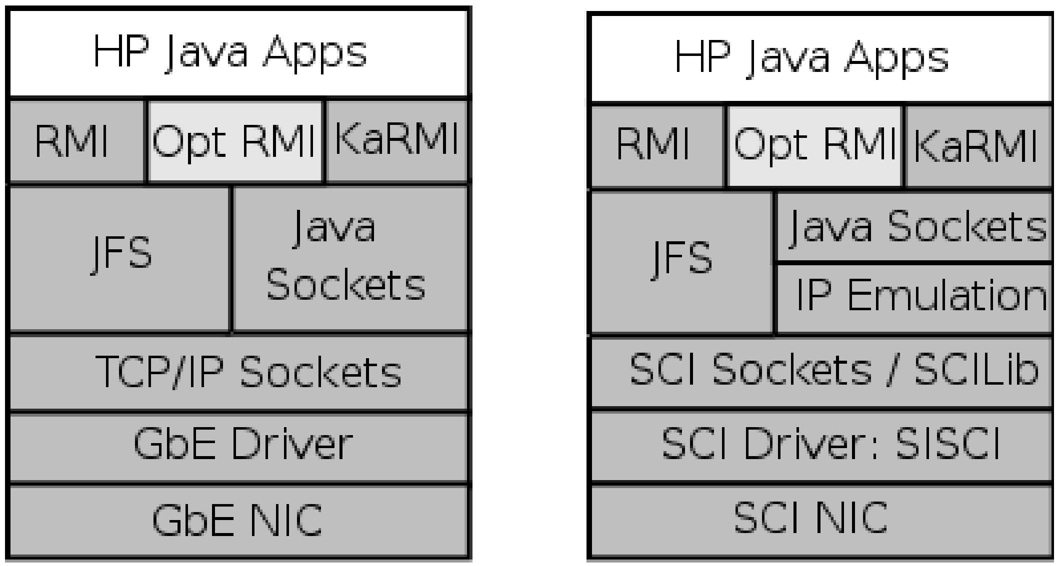
Designing Java RMI Optimization (II)

- **Java RMI Optimization tailored for High performance Java parallel applications on Clusters:**
  - **Restricted to the most typical configuration in a cluster**
  - **Goal: higher performance with little tradeoffs**
  - **Assumptions:**
    - **Shared file system for class loading**
    - **Homogeneous architecture of compute nodes**
    - **Use of a single JVM version**

Designing Java RMI Optimization (&III)

- **Java RMI Optimizations**
  - **Transport Protocol Optimizations**
    - ***High Performance Sockets Support***
    - ***Block-data information reduction*****: minimizing block-data control in serialization. Avoid block-data buffering for serialized data**
  - **Serialization Overhead Reduction**
    - ***Native Array Serialization.*** **A high-performance sockets implementation allows for sending primitive data types directly**
  - **Object Manipulation Improvements**
    - ***Versioning Information Reduction*** **(description of serialized class)**
    - ***Class Annotation Reduction*** **(class location)**
    - ***Array Processing Improvement***

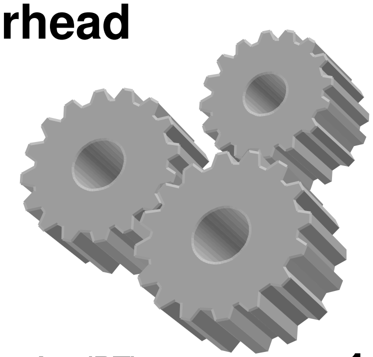
Java RMI Parallel Application Stack



- **Software architecture overview**

Transport Protocol Optimization (I)

- **High Peformance Sockets Support with Java Fast Sockets (JFS):**
  - **1st High Performance Java Sockets implementation**
  - **High Performance Network libraries support**
    - **Through native libraries on SCI, MX & native Sockets**
  - **Implements an API widely spread (Java Sockets)**
  - **Avoids the use of IP emulations (less efficient protocol for error-prone environments, with several layers)**
    - **Numerous libraries → ↑ communication overhead**



Transport Protocol Optimization (&II)

- **Java Fast Sockets (JFS) implements Java Sockets API in a way:**
  - **Efficient & portable through:**
    - **general "pure" Java solution**
    - **Specific solutions that access native communication libraries (SCI Sockets), reducing data copies**
    - **The fail-over approach applied to the selection of libraries: the system tryes to use native communication libraries with higher performance. If this is not possible, JFS uses the "pure" Java general solution**
  - **User transparency:**
    - **Setting *JFSFactory* as the default Sockets Factory in a small launcher application with Socket.setSocketImplFactory().**
      - **This application will invoke using reflection the main method. All Sockets communications wil use JFS from then on.**
        - **user@host $ java Application parameter0 …**
        - **user@host $ java jfs.runtime.RunApp Application parameter0**

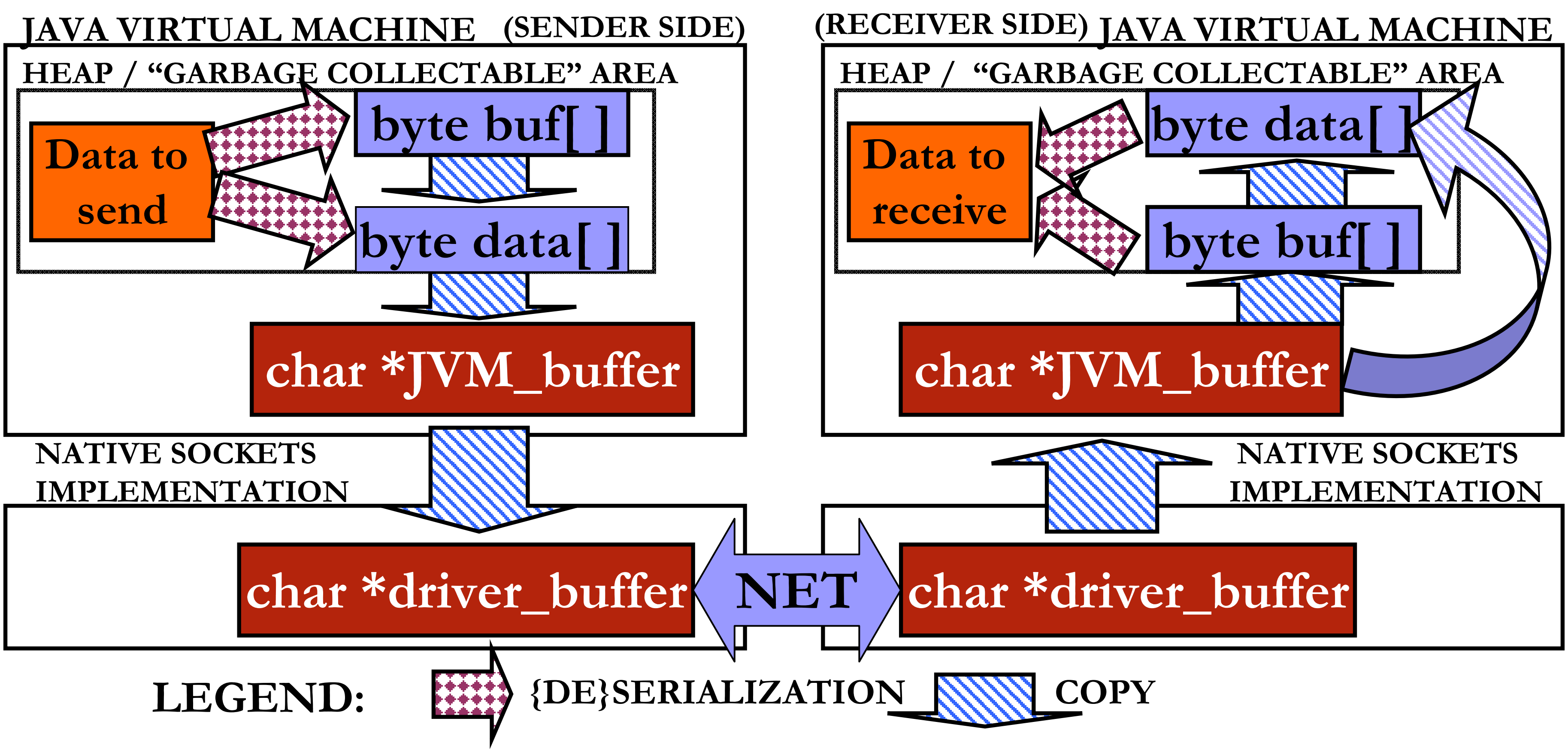
Serialization Overhead Reduction (I)

- **Java Sockets restriction: sending only byte[]**
  - **Primitive datatype arrays have to be serialized**
    - **Optimized in Java for int[] and double[] (native serialization)**
    - **JFS avoids serialization by throwing away the restriction!**

JFSOUTPUTSTREAM
+ write(int array[])
+ write(long array[])
+ write(double array[])
+ write(float array[])
+ write(short array[])
+ write(ByteBuffer directBB, int position, int size)
+ write(Object array, int pos, ByteBuffer directBB, int init, int size)

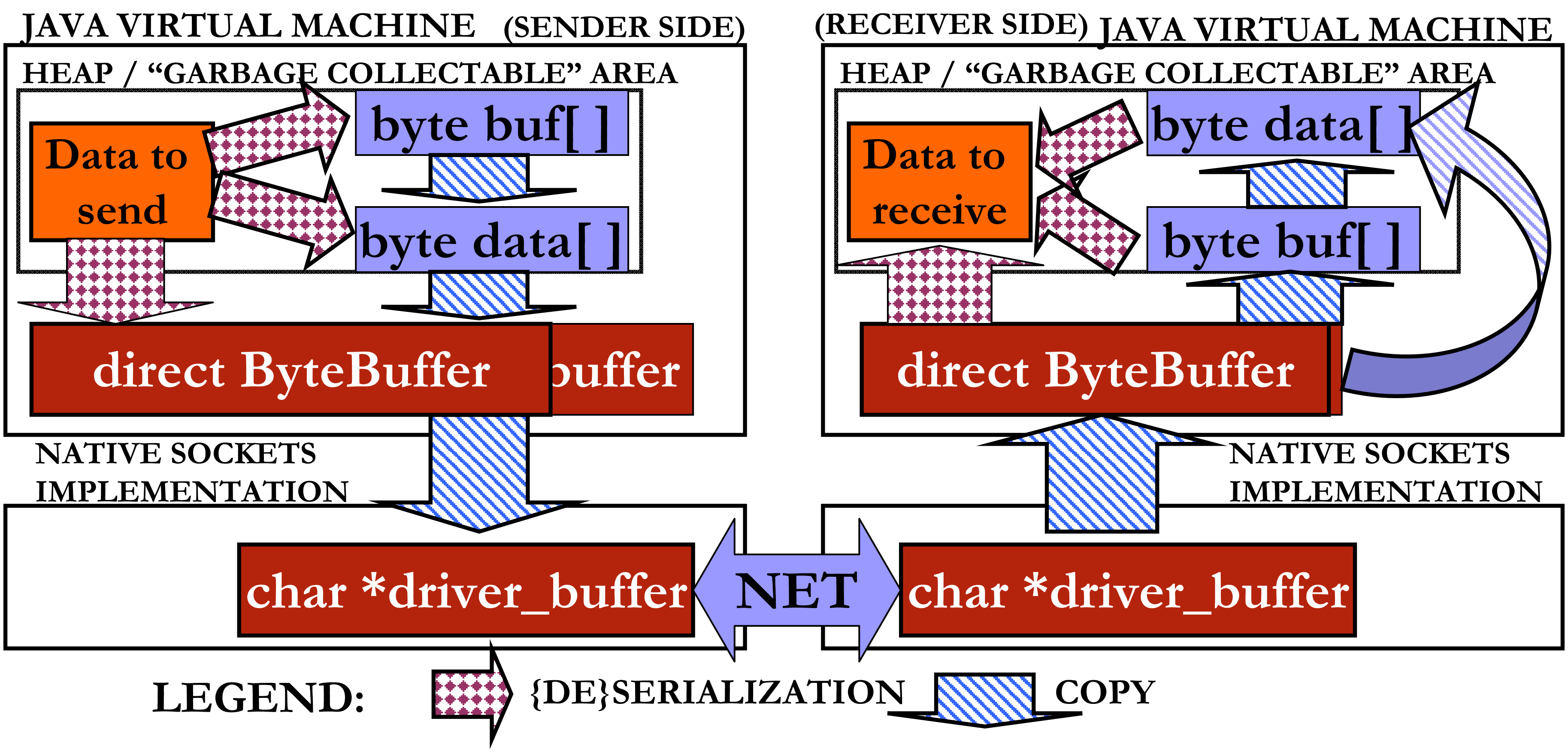
Serialization Overhead Reduction (II)

- **Default scenario in Sun's Java Sockets communication**



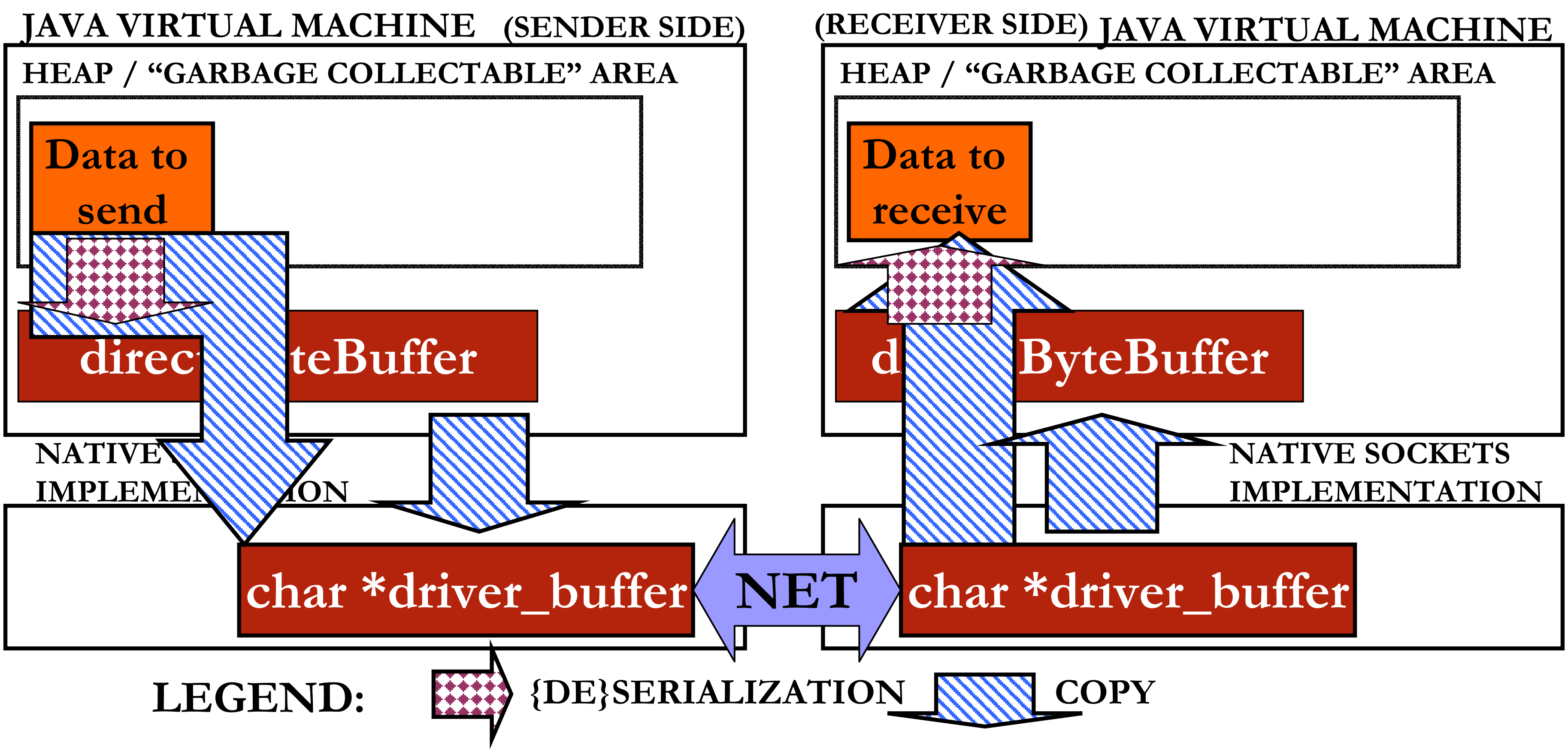
Serialization Overhead Reduction (III)

- **JFS communication using Java NIO direct ByteBuffer**



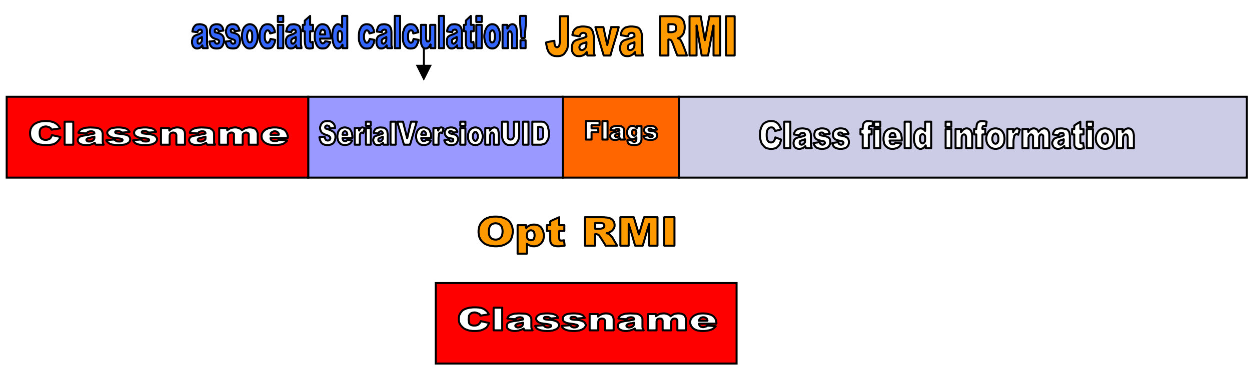
Serialization Overhead Reduction (&IV)

- **JFS zero-copy communication. Avoids copying and serialization**



Object Manipulation Improvements (I)

- **Versioning Information Reduction**
  - **Send only the class name. Important payload reduction.**
  - **With a shared file system + single JVM reconstruction is possible**



Object Manipulation Improvements (&II)

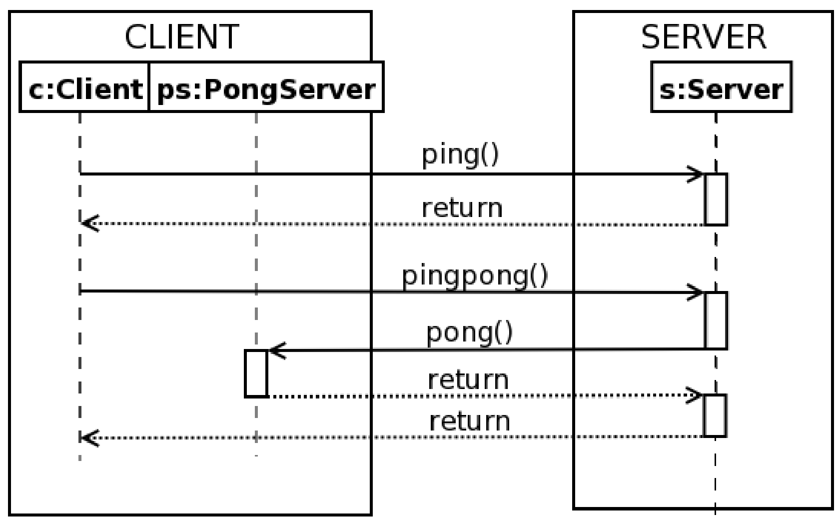
- Class annotation reduction
  - Location (String) to load a class object from
  - With a single JVM it is guaranteed that java.* classes can be loaded by the default class loader
  - Avoid serialization of java.* class names
- Array processing improvement
  - Common communication pattern in parallel applications
  - By default arrays are handled as generic objects
  - Specific method for dealing with arrays
    - Early detection of arrays (cast)
    - Optimized data type checking (common case first)
    - JFS array type processing (avoids serialization and “extra copies)

Performance Evaluation (I)

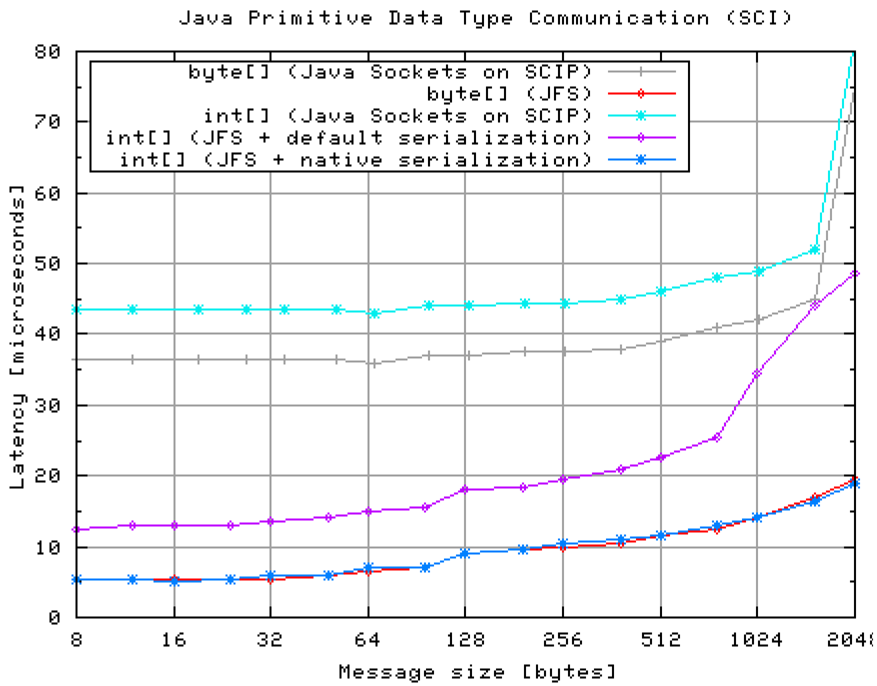
- **Experimental configuration:**
  - PIV Xeon at 3.2 GHz 2GB mem (hyperthreading disabled)
  - SCI (Dolphin), GbE (Intel PRO/1000 MT 82546 GB)
  - Java: Sun JVM 1.5.0_05
  - gcc 3.4.4
  - Libraries:
    - SCI SOCKET 3.0.3
    - DIS 3.0.3 (IRM/SISCI/SCILib/Mbox)
    - KaRMI 1.07i
  - Linux CentOS 4.2 kernel 2.6.9

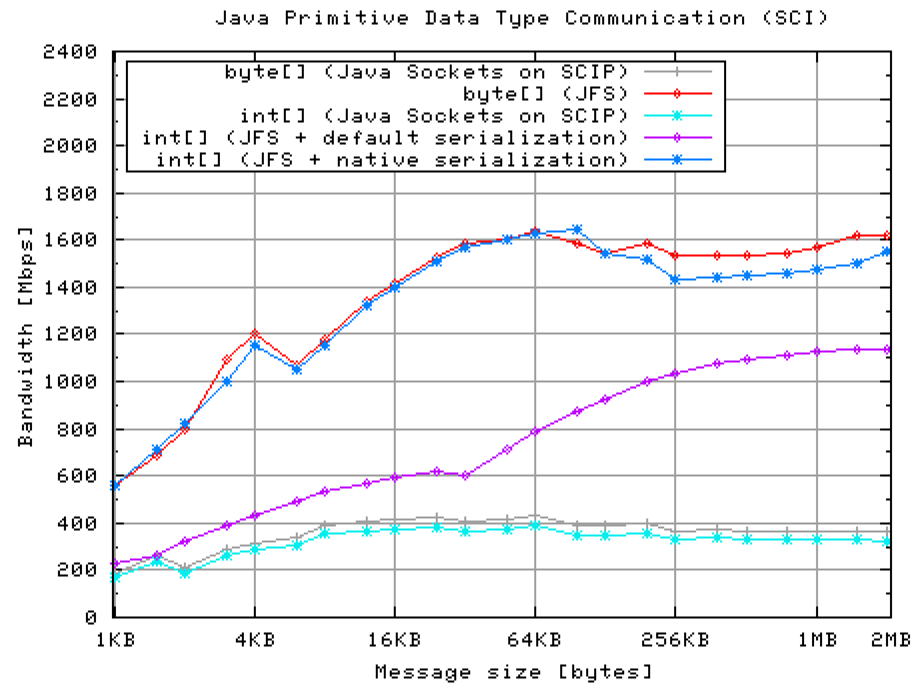
Performance Evaluation (II)

- **Benchmarking**:
  - NetPIPE Java RMI and Java sockets
    - Ping and ping-pong test
    - Java Just in Time (JIT) compiler (warm-up 10000iter.)



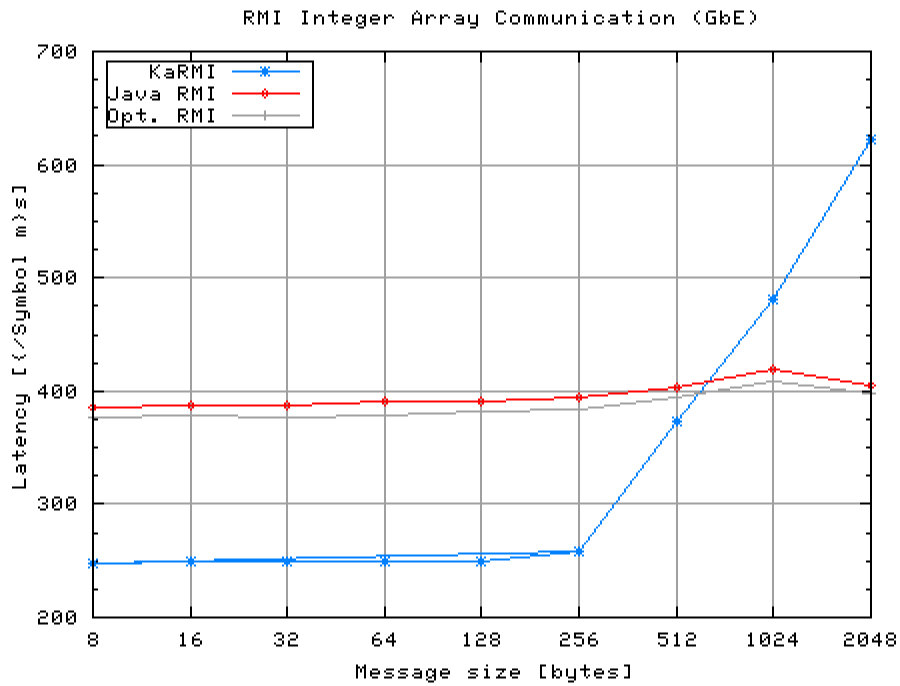
Performance Evaluation (III)

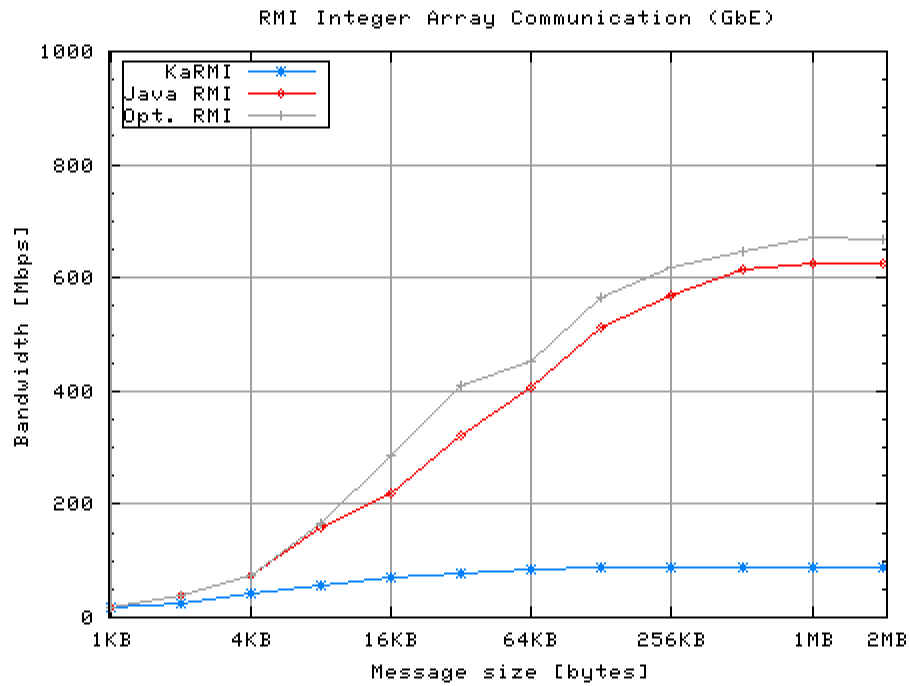




- **JFS can avoid native serialization -> sending int[] is the same as byte[]**
- **JFS avoids TCP/IP processing (Java Sockets not, SCIP) and “extra” copies**

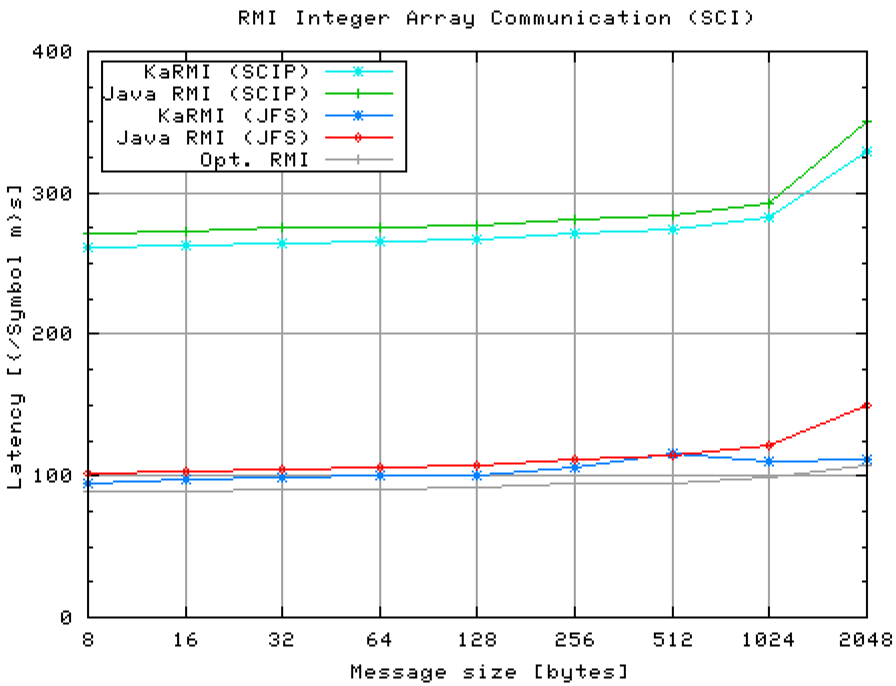
Performance Evaluation (IV)

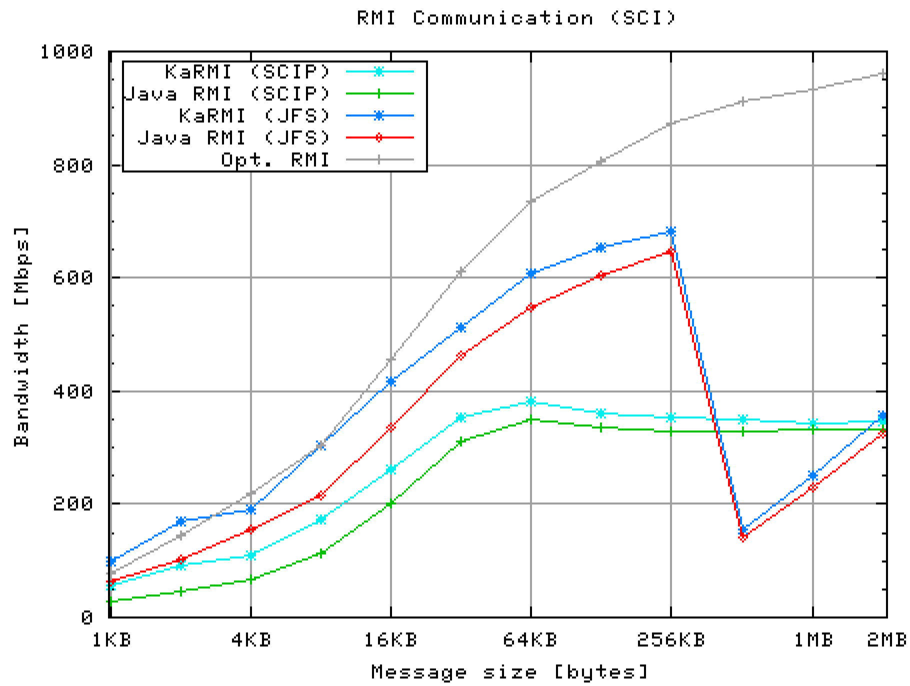




- **KaRMI shows low latencies but also low bandwidths.**
- **Opt. RMI and Java RMI results are similar for short messages, and for long messages Opt. RMI slightly outperforms Java RMI**

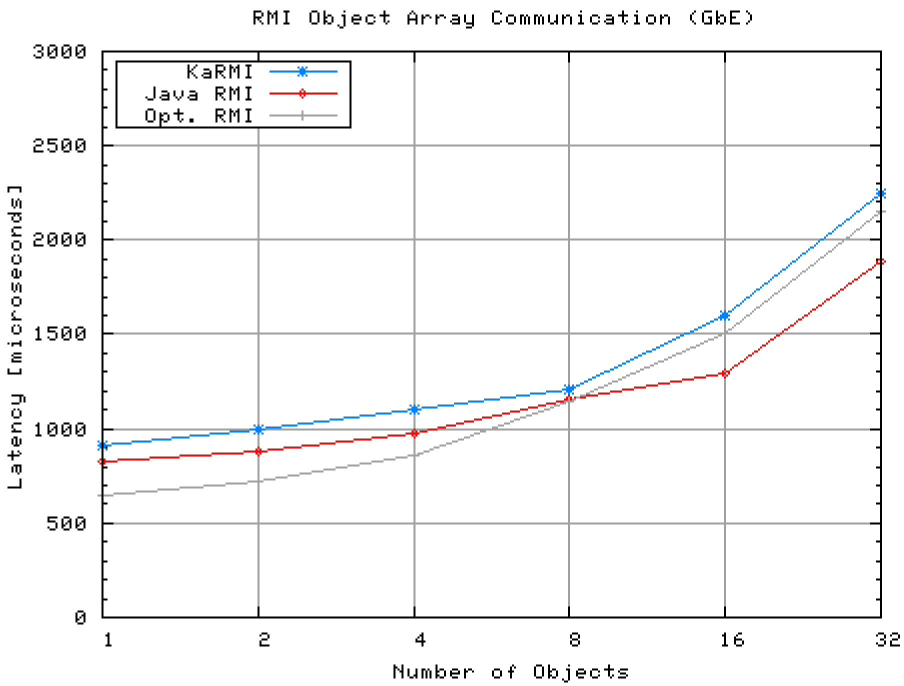
Performance Evaluation (V)

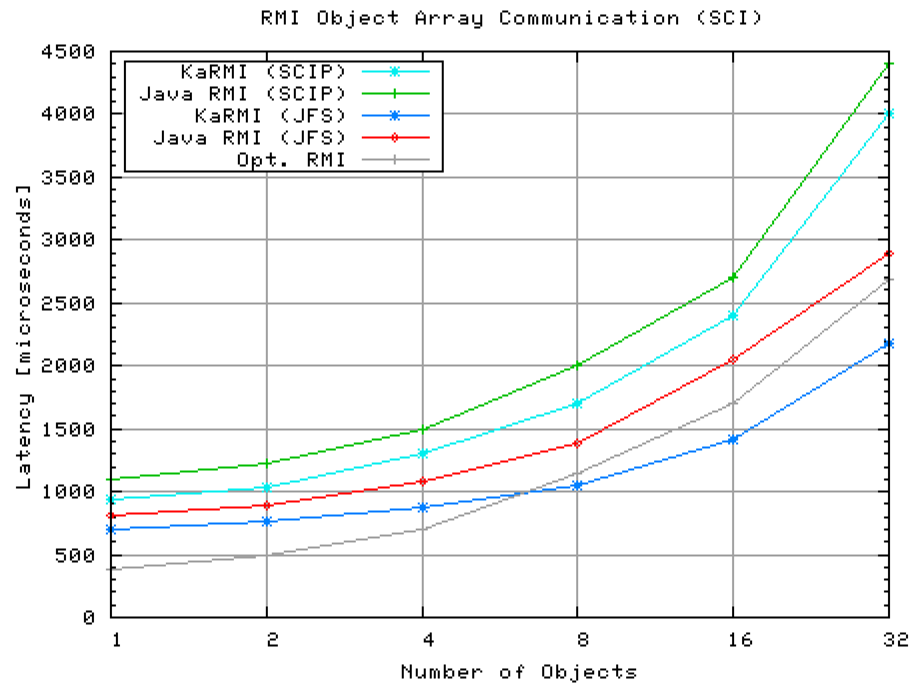




- **KaRMI performs much better on SCI. It has been designed with high performance libraries in mind.**
- **SCIP is not competitive as transport layer**
- **Opt. RMI improve performance for long messages**

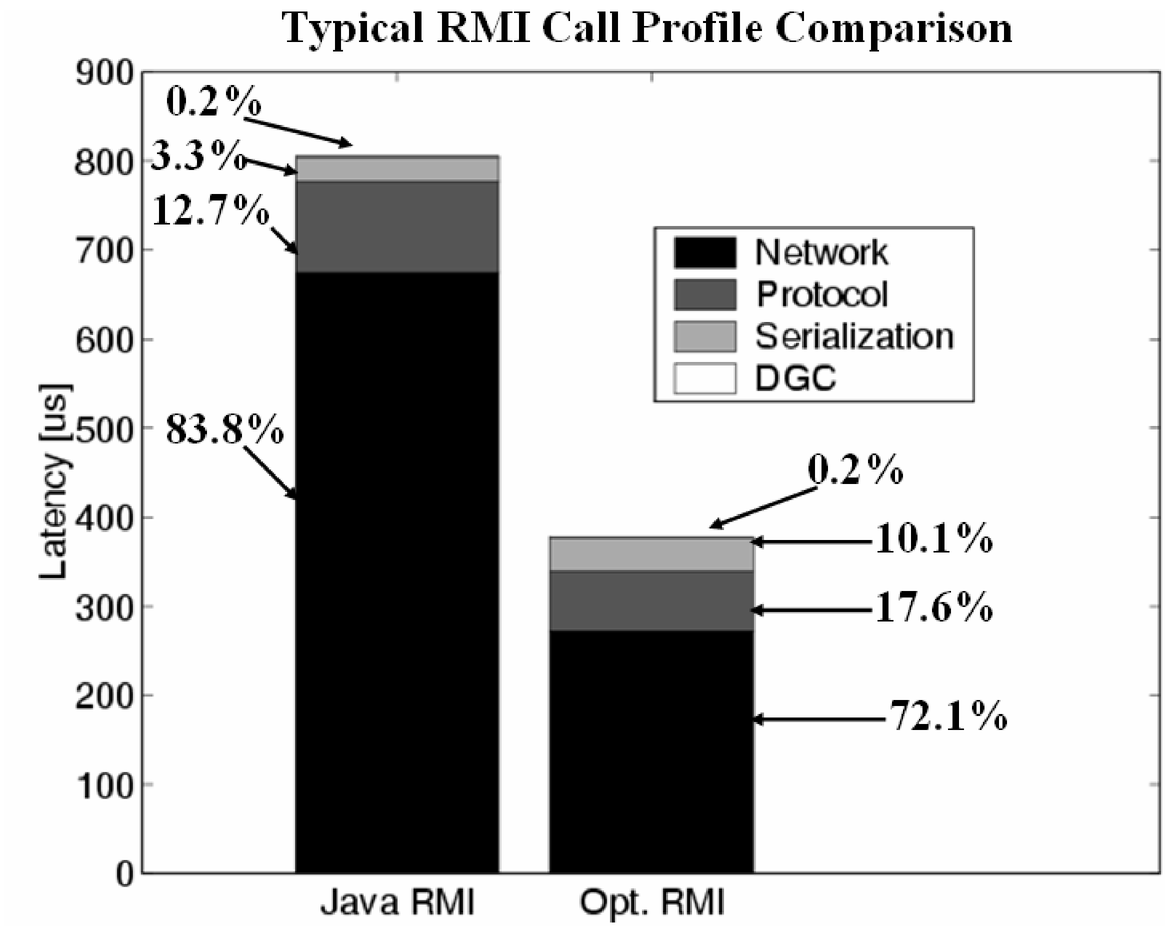
Performance Evaluation (VI)





- **Opt RMI. optimizes RMI calls with small number of objects. Sending 1 object the most common case!**

Performance Evaluation (VII)



- **Profiling of a 3KB Object call on SCI**

Conclusions (I)

- Presented a more efficient Java RMI implementation (Opt RMI)
  - Transparent to the user
  - Interoperable with other systems
  - No source code modification
  - Widely spread API
- Opt RMI protocol tailored for high-speed clusters
  - Basic assumptions about the target architecture reduce protocol overhead (trade-off interoperability vs. performance)
  - Optimizing the "most common case" for parallel computing: primitive datatype arrays
  - Implementing the protocol on top of Java Fast Sockets (JFS)
    - Avoiding serialization
    - Reducing unnecessary copies
- Protocol optimizations focused on:
  - Reducing block-data information
  - Reducing versioning information
  - Reducing class annotations

Conclusions (&II)

- The Opt RMI protocol reduces RMU call overhead, mainly on high-speed interconnection networks and for common communication patterns in Java parallel applications
- Experimental results on Gigabit Ethernet and SCI have shown significant performance increase, both for basic data type arrays and objects

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