Linux Kernel Performance Measurement and Evaluation

Duc Vianney, Sandra Baylor, Bill Hartner
IBM Linux Technology Center
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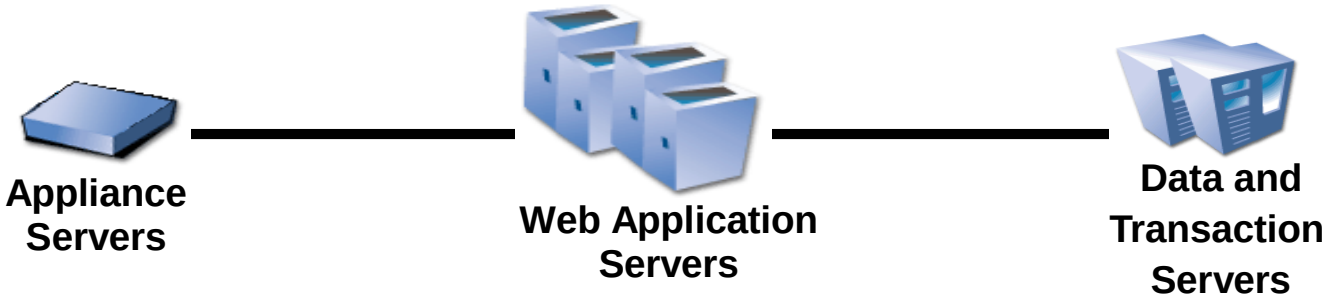
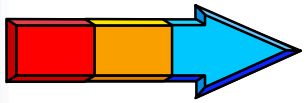
Enterprise Linux Requirements



- RAS Trend →
  - reliability, availability, servicability
- Interoperability
- Scalability
  - horizontally scalable (SMPs)
  - vertically scalable (clustering)



Team focuses on "**horizontal scalability**"

Linux Scalability Work Synopsis

- Ultimate goal is to increase overall system and application performance:
  - driven by benchmark analysis and/or customer workloads
- Three major categories need to be addressed
  - resource scalability
  - SMP scalability
  - absolute performance
- Ensure the full utilization of resources (cpu, memory, devices)
- In a perfect world: Linear Scalability

Linux Scalability Community

- **Most scalability work at IBM consists of Open Source projects**
- **Available under:**
  - http://lse.sourceforge.net
  - http://lbs.sourceforge.net
- **Active participants in this effort are:**
  - IBM, SGI, HP, Intel, Hitachi, NEC, SUSE
  - Many individuals out there
- **Strong interactions among participants**
  - to agree on and do the right thing
  - tremendous sharing of code / results / tools
  - regular conference calls and meetings

LTC Kernel Performance Team

- **Mission**
  - To make Linux better by improving Linux kernel performance, with special emphasis on SMP scalability.
- **Methodology**
  - Measure, analyze and improve the performance and scalability of the Linux kernel
  - Focus on platform-independent issues
  - Benchmarks that provide coverage for data center, carrier space and web server workloads
  - Migration to newer kernels will occur as needed
- **Plan Assumptions**
  - Work items may change based on IBM strategy and acceptance from the open source community
  - Work items may change as measurement results unfold and/or hardware requirements increase
  - Baseline measurements currently on Linux 2.4 and 2.5 kernel.org

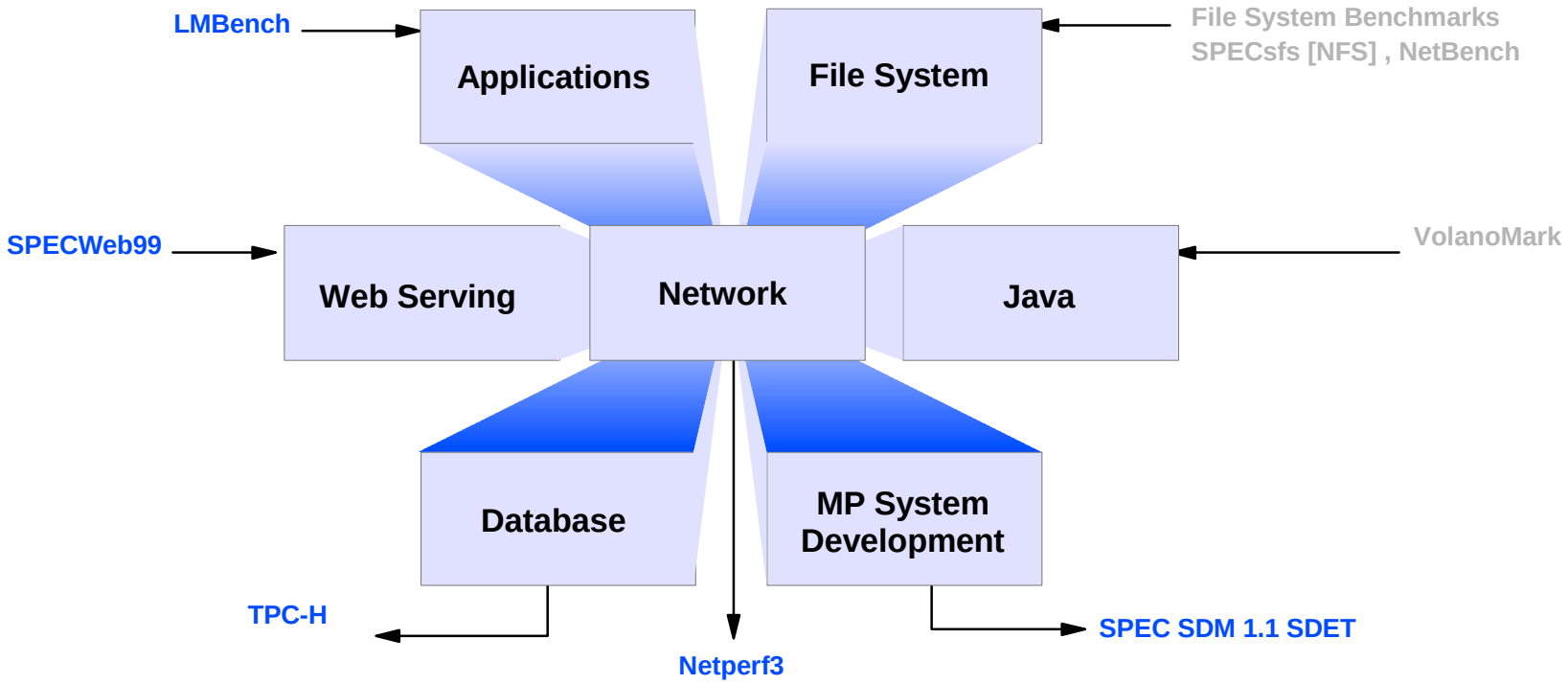
Linux Kernel Focus

- **File System**
  - Local file systems: ext2, ext3, jfs, reiserfs
  - Network file systems: nfs, smb and virtual: vfs
- **Base Kernel**
  - Scheduler
  - Memory Management (large memory support, page cache)
- **Buffer Cache**
- **Peripheral Manager**
  - Block device interface
- **Network Manager**
  - 100 Mbps and 1000 Mbps Ethernet
  - TCP/IP
- **Machine Interface**
  - Interrupt manager (APIC, soft IRQ/bottom half)

High Priority "Enterprise" Workloads

- **Web Serving**
  - Where Linux is traditionally strong
  - Web server; infrastructure servers such as DNS, mail, file/print, etc.
  - Typically 4-way SMP, horizontal scaling
  - Improvement still required for larger SMP, security, Web App serving, Java™,...
- **Backend DB (addresses many other enterprise workload reqs)**
  - DB2®/Oracle/Sybase
  - Typically 8-way SMP or higher, vertically scaled
  - Transaction, backend DB serving - as opposed to high-end decision support (typically requiring horizontally scaled cluster)
- **Telco Carrier Network/Network Infrastructure**
  - Typically 4-way SMP systems deployed in the core Telco network (e.g., softswitches, wireless base station controllers, etc.)
  - HA middleware dependencies (IP spraying, replicated in-mem DBs, DB fast failover...)

Benchmarks and Workloads



- **LMBench [atomic API test]**
  - Open Source benchmark
  - Linux APIs
- **SPECWeb99 [web serving]**
  - SPEC Industry standard benchmark
  - TCP/IP, network device drivers, memory management, file system
- **TPC-H**
  - industry standard benchmark
  - file system
- **Netperf**
  - open source
  - TCP/IP, network device drivers, memory management
- **SPEC SDM1.1 SDET [multiprocessing system development]**
  - deprecated SPEC benchmark
  - file system, scheduler, memory management

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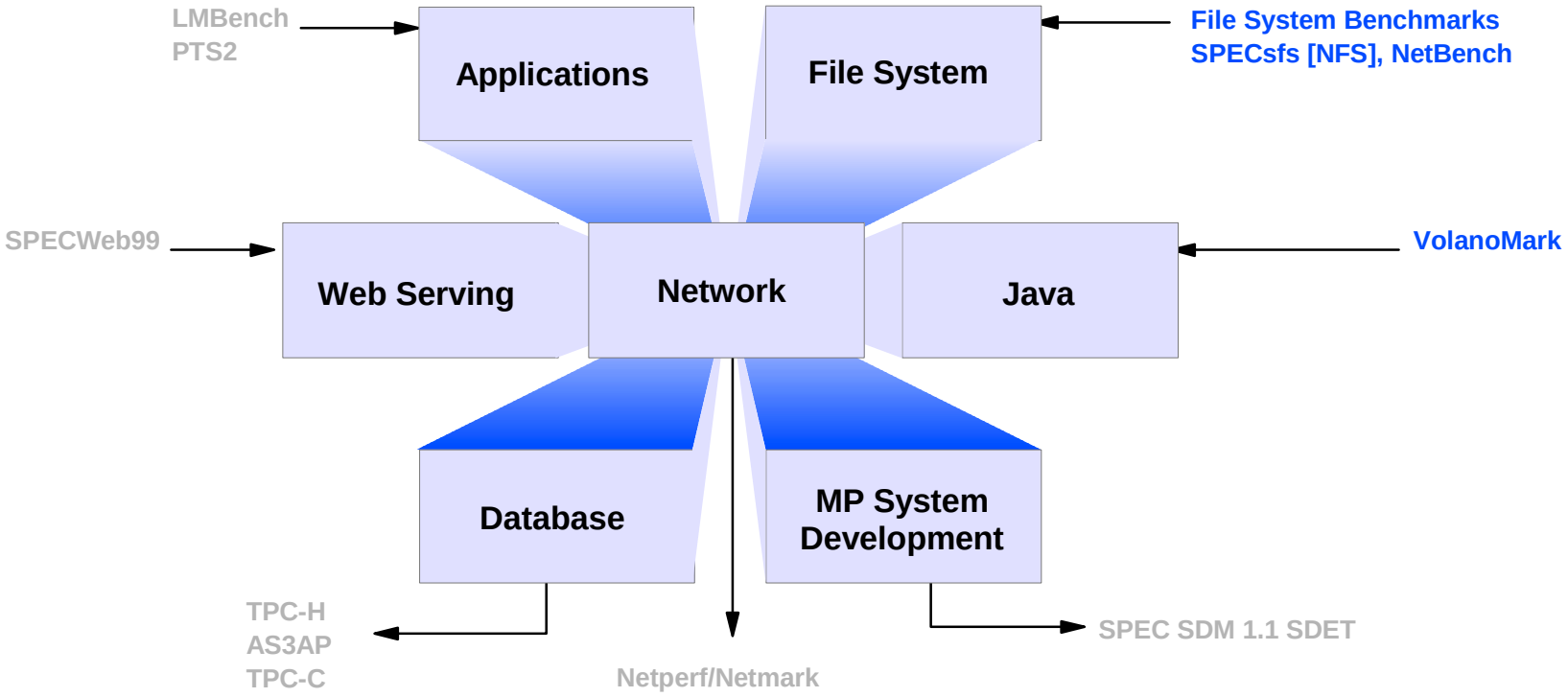
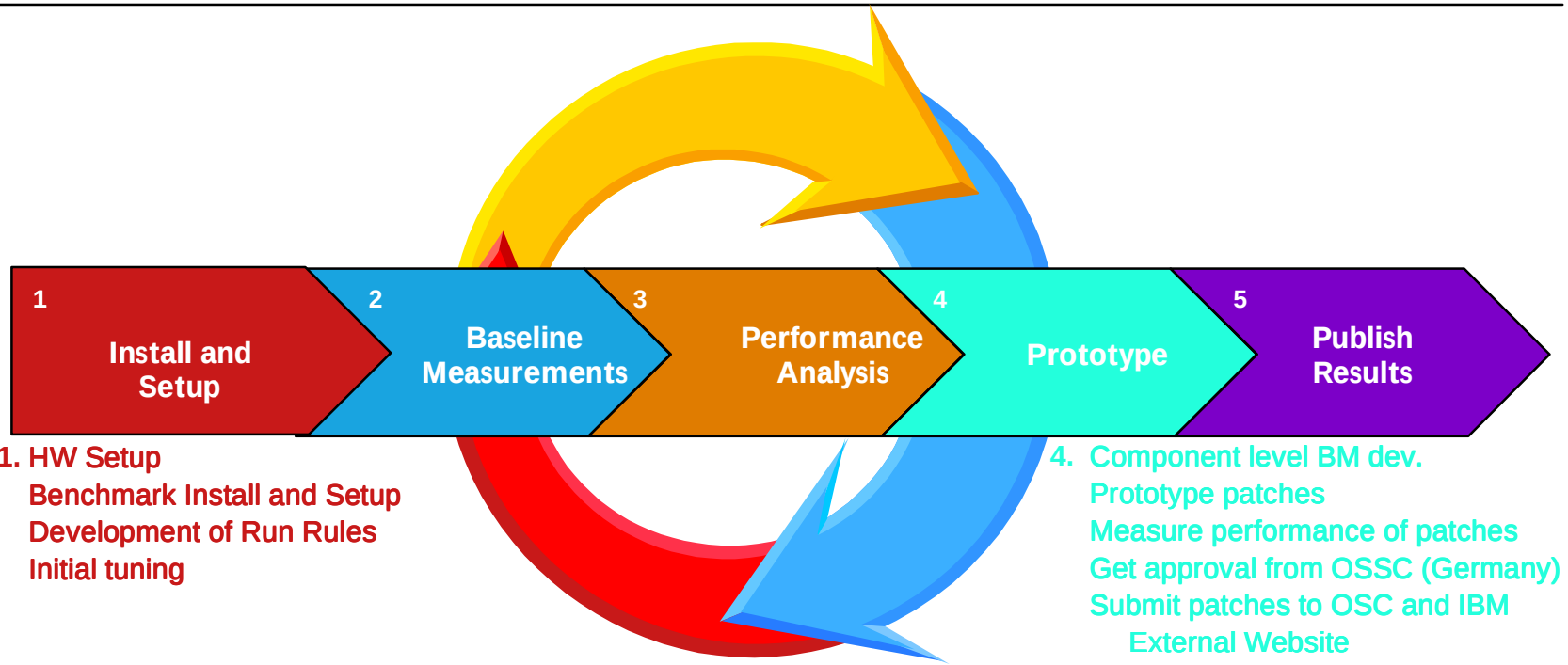
Benchmarks and Workloads



- **VolanoMark [Java]**
  - industry standard benchmark
  - Java, scheduler, TCP/IP, network device drivers
- **File System Benchmarks**
  - Open Source benchmarks (e.g., dbench, bonnie, iozone, postmark)
  - file system - virtual file system, buffer cache, page cache, block device interface, memory management
- **SPECsfs [NFS file servicing]**
  - SPEC Industry standard benchmark
  - NFS, file system, TCP/IP, network device drivers, memory management
- **NetBench 7.0 w/Samba 2.0.7**
  - Ziff Davis benchmark
  - TCP/IP, network device drivers, memory management, file system

Benchmark Activities



1. HW Setup
   - Benchmark Install and Setup
   - Development of Run Rules
   - Initial tuning

2. Baseline performance/scalability measurements
   - Initial publication of benchmark results to OSC
   - Announcement of BM to OSC
   - Collaboration with OSC

3. Collection of performance analysis data
   - System and benchmark tuning (from analysis data)
   - Performance/scalability re-measurements
   - Identification of potential performance bottlenecks
   - Development of kernel component analysis tools
   - Detailed analysis of potential performance bottlenecks
   - Collaboration with OSC

4. Component level BM dev.
   - Prototype patches
   - Measure performance of patches
   - Get approval from OSSC (Germany)
   - Submit patches to OSC and IBM External Website
   - Collaboration with OSC

5. Publication of papers etc.

Hardware and Software Tuning

- Before any measurements are made, tune HW and SW configurations prior to analysis of performance and scalability
- **Tuning**
  - An iterative cycle of tuning and measuring
  - Involves measuring components of the system
  - CPU utilization, memory usage, etc.
  - Involves possibly adjusting system hardware parameters, system resource parameters, and middleware parameters
  - One of the first steps in performance analysis
- **Performance and scalability analysis**
  - Understand benchmark and workload tested
  - Initial analysis conducted against tuned system
  - Requires a set of performance tools

Performance Tools

- /proc file system - meminfo, slabinfo, interrupts, network stats, io stats, etc.
- profile and readprofile
- SGI's lockmeter - SMP lock analysis
- SGI's kernel profiler (kernprof) - time based profiling, performance counter based profiling, annotated call graph (ACG) of kernel space only
- Ad hoc performance tools are developed to further understand a specific aspect of the system. Examples are:
  - sstat - collects scheduler statistics
  - schedret - determines which kernel functions are blocking for investigation of idle time
  - acgparse - post-processes kernprof ACG
  - copy in/out instrumentation - determines alignment of buffers, size of copy and CPU utilization of copy in/out algorithm

Summary of Activities

- **Linux is regarded as a stable, highly-reliable operating system for web servers -->** low-end to mid range systems
- **More work is needed for Linux to be ready for enterprise markets**
- **LTC Linux Kernel Performance team focuses on addressing issues for enterprise markets**
  - 8-way SMP scalability and beyond
  - Web server, carrier space, database and other workloads
  - Strategy includes the measurement, analysis, and improvements, through kernel patches, to the Linux kernel, focusing on architecture-independent issues
  - Incorporated several optimizations and patches that improve performance of our benchmarks
    - processor and IRQ affinity
    - bounce buffer patch to IPS RAID driver
  - Making great progress towards addressing issues, improving the performance and scalability of Linux so that it is ready for enterprise markets

Volanomark Benchmark Overview

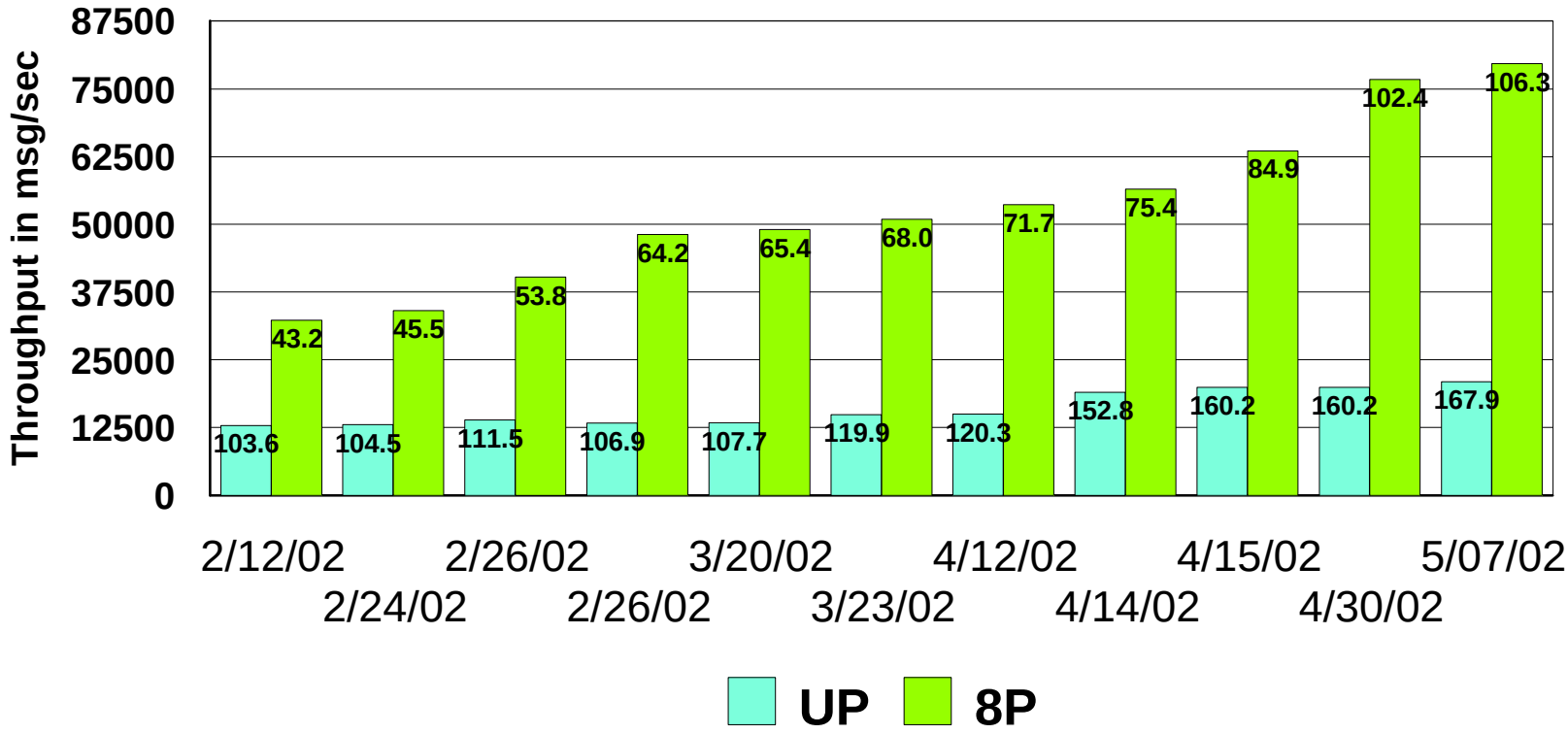
- **Volanomark is a benchmark of a chatroom server**
  - Developed by Volano, LLC
  - Java TCP messaging benchmark (chat room server)
  - Large number of TCP connections and Java threads
  - The benchmark simulates the users in a number of chat rooms.
  - Throughput in messages / second
  - http://www.volano.com
- **Benchmark environment**
  - Hardware:
    - Netfinity® 8500R server, 8x700 MHz, 1 MB L2, 4 GB RAM
  - Software:
    - IBM® JRE 1.3.x
    - Red Hat 7.1 Linux
    - Kernel.org version 2.4.x and 2.5.x

VolanoMark Scalability

VolanoMark Loopback

UP Target: 12,500 msg/sec 8P Target: 75,000 msg/sec

Data Preliminary



Netfinity 8500R, 8-Way 700 MHz Pentium(TM) III with 2MB L2 Cache, 4 GB RAM
Red Hat 7.1, Linux Kernel 2.4.17 + Patches + Tuning
Numbers inside the bars represent % of target achieved

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VolanoMark Performance Issues

- **Signals**
  - JVM using Linux threads make more system calls for signal handling
- **TCP/IP**
  - loopback code path inefficient
  - send and receive thread executed on different cpus
- **Scheduler**
  - runq length
  - Load balancing
  - Priority Preemption

8-way VolanoMark Performance

- **Changes Made to Reach the Most Recent Milestone**
  - Added Priority Preemption patch
  - Added TCP/IP soft affinity patch
  - Tuned TCP/IP (timestamps,softack,hot_list_length)
  - Set the Loopback MTU to 512
  - Tuned Client messages
  - O(1) scheduler and scalable counters
  - JVM 1.3.1
- **Next Steps Towards Improving Performance**
  - NGPT (Next Generation Pthreads): faster locking, and M:N threading will reduce number of kernel thread
- **Investigate TCP/IP optimizations**
  - send/recv code path
  - cache line efficiency
  - loopback driver code path

LTC Kernel Performance Team Contacts

- **Tech Lead:** Bill Hartner - bhartner@us.ibm.com
- **Datacenter/Scalable:** TPC-H (Peter Wong - wpeter@us.ibm.com)
- **Telco Carrier Space:** Netperf3 (Mala Anand - manand@us.ibm.com) and VolanoMark (Partha Narayanan - partha@us.ibm.com)
- **Web Serving:** SPECweb99 (Troy Wilson - wilsont@us.ibm.com)
- **File Serving:** SPECsfs and Netbench (Andrew Theurer - atheurer@us.ibm.com)
- **Realtime, Filesystem and API Benchmarks:** LMBench, IOzone, etc. (Duc Vianney - dvianney@us.ibm.com)
- **I/O Benchmarks:** block I/O, async I/O (Helen Pang - hpang@us.ibm.com)
- **Other Activities:** NUMA (Theurer/Wong), IA64 (Vianney), SPECjAppServer (Ruth Forester - rsf@us.ibm.com)
- http://oss.software.ibm.com/developerworks/opensource/linuxperf
- http://oss.software.ibm.com/developerworks/projects/linuxperf

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