Hubertus Franke, Ph.D.
IBM T.J. Watson Research Center
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Education

06/1989-12/1992   Ph.D. Electrical Engineering,
Vanderbilt University, Nashville, TN.
Thesis: *"PREMOS: Tools for Model-Based Programming"*
GPA 4.0/4.0

The thesis defines a novel programming environment and approach to building complex computer integrated systems, such as complete chemical plant controls. In such environments, the system, the software and their interactions are modeled explicitly and evolve together. Once the models are verified, the software system and the hardware interlinks are synthesized into an actor execution environment. The complexity of the environment arises out of the fact that all models are domain specific. In PREMOS, a programmable meta layer allows the automatic synthesis of the tool chain, including graphical model builder, model verifiers, and model interpreters and synthesizers from abstract domain specifications. Once a tool set is generated for a particular domain, specific applications are modeled and synthesized in that domain.

08/1987-05/1989   Master of Science Electrical Engineering,
Vanderbilt University, Nashville, TN.
Thesis: *"Implementation of a Neural Networks on a Transputer System"*.
GPA 4.0/4.0

The Transputer chip enabled the construction of distributed systems that map a CSP (Communicating Sequential Processes) model on to hardware and communication channels. This method was used to provide a neural network environment to enable dynamic efficient loading and execution of neural networks.

09/1982-07/1987   Diplom Informatik (equivalent to Master in Computer Science),
Technical University of Karlsruhe, Karlsruhe, Germany
Thesis: *"Sensor-based Industrial Robot Path Planning"*.
Graduated 1st in class among ~400 students.
GPA 4.0/4.0

A complete path planning system for an industrial KUKA robot was implemented. The system uses a sensor to track the prescribed path at low speed followed. High motion speed can lead to undesired inaccuracies in any of the six degrees of freedom (position and rotation) due to the increased interpolation steps. Taking the maximum acceleration for each axis into account, the planning system computes the optimal motion speed at all times that does not violate any prescribed accuracy requirements. The completed system was subsequently used for wind shield gluing in the German automobile industry.

Work Experience   (details follow for the first two)

01/1993-present   IBM T.J.Watson Research Center
Distinguished Research Staff Member
Manager and Senior Manager, Master Inventor, Member of IBM Academy of Technology.
High Performance Computing, Operating Systems, Computer Architectures, Network Appliances, Software Defined Environments and Cloud Operating Systems, Cloud Strategy, Invention Development

05/2011-present   New York University, Courant Institute
Adjunct Full Professor, Computer Science
Teaching Master's level classes year round (3 semesters per year)

08/1987-12/1992   Vanderbilt University, Department of Electrical Engineering.
Research Assistant.
Process control and software engineering for industrial applications.

05/1991-08/1991   IBM T.J.Watson Research Center. Summer Internship.
Debugging Environment for highly concurrent systems.

05/1990-08/1990   IBM T.J.Watson Research Center. Summer Internship.
Cross Compiler between Unix and Transputer Systems.

05/1989-08/1989   IBM T.J.Watson Research Center. Summer Internship.
Robot Simulation system on a 256-node Transputer System

01/1986-08/1987   Fraunhofer Institute, Karlsruhe, Germany. Student Staff.
Industrial Sensor Based Robot Path Planning.

03/1983-12/1986   Technical University of Karlsruhe, Germany. Student Staff.
Language Design and Compiler Construction for a Robot Programming Language

IBM T.J. Watson Research Center   (01/1993 – present)
Distinguished Research Staff Member.

Since joining the IBM T.J.Watson Research Center as a Research Staff Member in 1993, I was involved in many systems and computer architecture related projects. In these projects I took on positions as technical lead and also served as a manager and senior manager between 2001 and 2014 before being elevated to a Distinguished Research Staff Member. The projects and their impact in chronological order.

From 1993-1997, I worked on the IBM SP1/SP2 supercomputer system. The IBM SP was the first supercomputer constructed as a cluster based on off-the-shelf computing nodes (Power Systems) and a standard software stack (AIX operating system). Besides standard networking, the cluster was also connected via a custom high performance network switch and associated optimized packet networking software. While today's supercomputers are essentially all following this principle, at the time, this was a novel approach. In this context, I implemented the first fully natively supported MPI (Message Passing Standard) stack on any commercially available supercomputer and supported it at several international supercomputing centers. Furthermore, I co-implemented a gang scheduling based job scheduling system that became part of the Load Leveler system and the theory and the system primitives behind this work also became part of several generally supported scheduling systems (Cornell, Argonne National Lab).

Due to the system work involved with the IBM SP, my interests increasingly turned to operating systems and computer architectures and the optimizations possible at their boundaries. In 1997, I co-founded the K42 project with the intent to provide a scalable operating system for next generation servers ranging from small-scale multiprocessors that we expected will become ubiquitous, to very large-scale non-symmetric multiprocessors that became increasingly important in both commercial and technical environments. By designing the system from the start for multiprocessors, we achieved a high degree of spatial and temporal locality in code and data. This locality resulted in substantial performance advantages, even on small-scale servers. To support large servers, K42 was designed to scale to hundreds of processors and to address the reliability, fault-containment, and fault-tolerance requirements of large commercial applications. K42 employed building-block technology based on object oriented design principled to allow applications to customize and thus optimize the OS services they required.

In 1999 it became obvious that Linux could and would be a disruptive technology and I took the opportunity to build and lead a research team to address Linux scalability and enterprise capabilities. Working in the open community, my first contribution in this field was the assessment of the scheduler scalability limits and the prototyping of a scalable multi core scheduler, which ultimately lead to the generation of the O(1) scheduler by the Linux community. A second contribution to this field was the introduction of futexes, which are fast user level locking mechanisms that avoid the mandatory kernel call of synchronization mechanisms available at the time, for instance System-V semaphores. Futex usage in the Linux ecosystem is now in wide spread use. For instance the pthread mutex and condition variable implementation, the system V IPC semaphore implementation and the Linux version of Grand Central Dispatch (MacOS) utilize futexes to reduce kernel call overhead when

unnecessary. Other outcomes of my Linux work was the full kernel code coverage support and highly efficient, nonblocking in kernel buffering schemes. In 2004, virtualization became a hot research topic coinciding with the emergence of Linux based Intel servers for enterprise services beyond file and print serving. I started two main research projects. The first was CKRM (class based kernel resource management). Rather than utilizing virtual machines, classes containerized resources on the same linux kernel and allocated resource shares to each class. Other academic and industry research group experimented with similar constructs (e.g. OpenVZ, zones). A consolidation of several of these projects and ideas in 2010 lead to many of the underlying namespace and cgroup facilities that today's container services is built upon (I wrote the PID namespace in 2006). Another project I founded was collaborative memory management that was targeted towards IBM's zSeries VM based Linux servers. We extended the zSeries hypervisor and the Linux guest operating system to avoid double paging which had proven to be a significant overhead in highly utilized systems. Instead guest and host share the status of guest pages. If a page is clean the host can simply discard the page, while the guest on touch will fetch it from file storage. In turn the guest can ignore pages already swapped out by the host during its aging process. Together these additions significantly reduce double paging in virtualized environments.

Orthogonal to these projects, in 2000, we built a novel expanded memory sub system (MXT) that compressed L3 cache lines before writing to memory and uncompress blocks when fetching from memory. In real hardware, we demonstrated that for typical workloads we can expand the memory by a factor of at least two without performance impact. One of the challenges of such a system is the varying compression ratio of data and the possibility for the operating system to run out of physical memory as the combined compression ratio drops below the assigned memory overcommitment ratio. We solved this problem by introducing ballooning. The OS receives threshold interrupts from the memory controller that then trigger the OS to inflate the balloon, i.e. allocating pages and reserving pages that are zeroed for high compressibility, aka balloon inflation. This in turn forces the OS to free pages from file system caches and applications in standard manner. When the pressure resides, the balloon is deflated. Memory ballooning has become a staple of modern system virtualization such as VMware ESX (2002) and KVM (2009).

In 2006, I had the opportunity to take a leading role in the design and implementation of a novel wirespeed processing system that was built around a system on a chip, known as the PowerEN system. PowerEN was targeted towards network facing applications that we believed will become a large part of IT deployments, whether in IoT applications or at the perimeters of datacenters, where wirespeed processing is paramount. Wirespeed applications often exhibit a large degree of concurrency and thus we were able utilize high core counts and reduce power (130W for system board) and frequency (upto 2.3Ghz). We examined multiple network applications such as commercially available intrusion prevention systems (IPS) (IBM ISS) and enterprise buses (IBM Datapower). Through detailed analysis we were able to identify the overhead of components that could be offloaded to accelerators such as compression/decompression, regex, XML and host ethernet. We integrated these accelerators onto the chip together with 16 embedded cores. Novel to this system is that accelerators were tightly integrated with the programming model and all addressing and instructions were user level based to reduce latencies and avoid the overhead of system calls or programmed address translation which was now conducted via a regular TLB fronting the accelerators

without requiring memory to be pinned. Many low level features were integrated into the chip for fast thread synchronization, often required in highly parallel applications. A full system stack and eco system was built and besides the applications mentioned earlier we also demonstrated that applications such as high frequency ultra low latency trading were possible on this system rivaling custom implementation based on FPGA. Though this chip never became commercially available, many of its concept are now available in high end Power chips.

Since 2012-current, I focus on research strategy and execution related to cloud computing, and more specific on infrastructure and cloud operating systems. In 2013, I co-lead a year long process known as "Global Technology Outlook". The GTO is IBM Research's vision of the future for IT. It highlights approximately five emerging technology trends that will impact the industry in the next 3-10 years. I co-lead the software defined environment trend, where we projected how future cloud systems and infrastructure will become fully software defined based on utilizing software defined compute, storage and network subsystems that can be reconfigured and optimized dynamically for the task at hand. Since then, I am a technical lead of a team of researchers that implements this vision in collaboration with our cloud division. Specific projects relate to composable rackscale server architectures, container services, scalable programmable switches and scalable system management in particular based on OpenStack.

Finally, since 2009, based on my domain expertise, I have been part of the IBM Invention Development Team (IDT) as an evaluator for internally filed patent applications in the domains of operating systems, computer architectures and networking.

New York University, Courant Institute   (05/2011 – present)
Adjunct Full Professor, Computer Science

Since Summer of 2011, I have been continuously teaching Master's Level Computer Science classes during the Spring, Summer and Fall semesters at the Courant Institute of the New York University reaching the level of Adjunct Full Professor. My dominant class is the Operating Systems class, though I have also taught Computer Architectures (Fall 2011), Gaming (Spring 2012) and Compiler Construction (Spring 2013). Class sizes range between 15 to 80 students dependent on the semester. Teaching one evening a week gives me the opportunity to work with the next generation of computer scientists and pass along some of the lessons I learned firsthand during my 32 year long career.

Honors

[1] 25th Patent Plateau recognizing 167 original patents granted (2021)
[2] ACM Distinguished Engineer (2016)
[3] IBM Master Inventor (2011-present), renewed every 3 years
[4] IBM Academy of Technology (2009-)
[5] Recipient of the Annual Outstanding Achievement Award of the German Computer Science Research Institute in Karlruhe. This award is given to the top class graduate of each year (1988)
[6] Nominated for the National Fraunhofer Award (Germany) (1988)

[7] OTAA: "IBM Research Leadership in Bringing Kubernetes to IBM Public Cloud" (2021)
[8] OTAA: "Leading the Next Generation Cloud Infrastructure" (2019)
[9] OTAA: "Research Leadership for Cognitive Systems and Software in IBM Hybrid Cloud" (2019)
[10] OTAA: "Research Contributions to Swift@IBM" (2017)
[11] OTAA: "z/VM – Linux CMM" (2006)
[12] Most Valuable Patent Award for US6681305 (2005)
[13] IBM Research Division Award for contributions to the Memory eXpansion Technology (2003)
[14] OTAA: for "LLNL Gang Scheduler" (2000)
[15] OTAA: "Message Passing Interface: Design and Implementation" (1995)

(*) OTAA == IBM Outstanding Technical Achievement Award

Program Committee, Review Activities and Community Service

General Chair:
       ACM International Conference on Computing Frontiers 2013
       ACM OASIS Workshop on Operating Systems and Architectural Support 2004

Program Chair:
       ACM Computing Frontiers 2016, 2015, 2010

Steering Committee:
       ACM International Conference on Computing Frontiers (permanent/vice-chair)

Program Committee Member:

Conference	Years
ACM Computing Frontiers	2010-2021
CCGRID	2019, 2018
ISC	2018
ICCD	2019, 2018, 2017, 2016, 2015, 2014, 2013, 2012
IA^3	2016
IPDPS	2015
PDCN	2012, 2008, 2007
IoT-App	2012
ICS	2012
SYSTOR	2010
MTAAP	2009, 2008, 2006
OSRLK	2008
ASPLOS	2006
ICPP	2005
ICPADS	2005
ICAC	2005
SHAMAN	2002
HASE	1998
ECBS	1998

Reviewer (outside committee):

ACM Transactions on Architecture and Code Optimization (TACO)	
IEEE Transactions on Parallel and Distributed Systems (TPDS)	
IEEE Transactions on Computers (TC)	
IEEE Micro	
HPCA	2015
EuroPar	2014, 2005, 2004
HiPEAC	2010
SAC	2007
ICPADS	2006
PDCN	2006

Keynote Talks:
        BigSystem 2014 (HPDC), SBESC 2012

Lead Guest-Editor:
        [1] International Journal of Parallel Programming:
            Special Issue on Computing Frontiers 2016, online in preparation
        [2] International Journal of Parallel Programming:
            Special Issue on Computing Frontiers 2015, online
        [3] IBM Journal of Research and Development:
            Software Defined Environments, Vol 58-2/3, 2014
        [4] International Journal of Parallel Programming:
            Special Issue on Computing Frontiers 2012, December 2012, Volume 40, Issue 6
        [5] IBM Journal of Research and Development:
            Commercial Software for Multicore Systems, Vol 54-5, 2010

Community Service:
        IBM Family Science (2000-present), an annual 8 week long weekend program where we
        teach 4th graders about aspects of science in a hand-on and fun manner. I lead the math and
        algorithms section.

University Relations:
        Advisory Board, Rutgers University, Department of Electrical and Computer Engineering
        (2011-present)

Patents (Total Granted Patents 168)

[1] "A Method and Apparatus of Tracing Code and Data Pages for Generating Representative Microbenchmarks", US 11074155, July 2021

[2] Managing Bare Metal Networking in a Cloud Computing Environment", US 11050635, June 2021

[3] "Method and Apparatus for Power Savings in Communications Equipment", US 11042210, June 2021

[4] "Provide Access to Data Storage Services in a Network Environment", US 11032263, June 2021

[5] "Crash Recoverability for Graphics Processing Units (Gpu) in a Computing Environment", US 11016861, May 2021

[6] "Providing Remote, Reliant and High Performance Pci Express Device in Cloud Computing Environments", US 10936535, Mar 2021

[7] "Method and System for Providing Security within a Software-Defined Infrastructure", China ZL201680017564.3, Dec 2020

[8] "System, Method, and Recording Medium for Common Memory Programming", US 10838872, Nov 2020

[9] "Dynamic Update of The Number of Architected Registers Assigned to Software Threads Using Spill Counts", US 10831537, Nov 2020

[10] "Method to Reduce Reactivation Time of Cloud Based Services", US 10834228, Nov 2020

[11] "Provisioning a Bare-Metal Server", US 10834178, Nov 2020

[12] "Reducing Service Downtime During Service Migration", US 10831533, Nov 2020

[13] "Extending Existing Storage Devices in Virtualized Environments", US 10768862, Sep 2020

[14] "Security within Software-Defined Infrastructure", Japan 6730997, July 2020

[15] "Reducing Service Downtime During Service Migration", US 10698727, June 2020

[16] "Facilitating Processing within Computing Environments Supporting Pageable Guests", US 10684800, June 2020

[17] "Method to Reduce Reactivation Time of Cloud Based Services", United Kingdom 2545068, May 2020

[18] "System, Method and Computer Program Product for Instantiating Blocks of a Solid-State Disk to Include Different Flash Characteristics", US 10642497, May 2020

[19] "Extending Existing Storage Devices in Virtualized Environments", US 10628087, Apr 2020

[20] "Individual Online Price Adjustments in Real Time", US 10621631, Apr 2020

[21] "Creating a Dynamic Huffman Table", Japan 6681313, Mar 2020

[22] "Hybrid Memory Access Frequency", US 10599576, Mar 2020

[23] "Provide Access to Data Storage Services in a Network Environment", US 10601804, Mar 2020

[24] "Reducing Service Downtime During Service Migration", US 10565008, Feb 2020
[25] "Method and Apparatus for Power Savings in Communications Equipment", US 10558256, Feb 2020
[26] "Method and Apparatus for Power Savings in Communications Equipment", US 10545567, Jan 2020
[27] "Security within a Software-Defined Infrastructure", US 10546121, Jan 2020
[28] "Security within a Software-Defined Infrastructure", US 10534911, Jan 2020
[29] "Power Shifting in Multicore Platforms by Varying SMT Levels", US 10444812, Oct 2019
[30] "Creating New Cloud Resource Instruction Set Architecture", US 10432464, Sep 2019
[31] "Outcome-Based Software-Defined Infrastructure", US 10423457, Sep 2019
[32] "Scalable End-To-End Quality of Service Monitoring and Diagnosis in Software Defined Networks", US 10425302, Sep 2019
[33] "Method to Reduce Reactivation Time of Cloud Based Services", US 10397365, Aug 2019
[34] "In-Place Data Compression With Small Working Memory", US 10374628, Aug 2019
[35] "Network Data Processing System", Germany 102012219705.2, July 2019
[36] "System, Method, and Recording Medium for Common Memory Programming", US 10353821, July 2019
[37] "Provisioning a Bare-Metal Server", US 10348813, July 2019
[38] "Providing Remote, Reliant and High Performance Pci Express Device in Cloud Computing Environments", US 10303644, May 2019
[39] "Providing Remote, Reliant and High Performance Pci Express Device in Cloud Computing Environments", US 10303645, May 2019
[40] "Creating a Dynamic Huffman Table", Germany 102016220801.2, May 2019
[41] "Creating New Cloud Resource Instruction Set Architecture", China ZL201610137210.4, Apr 2019
[42] "Extending Existing Storage Devices in Virtualized Environments", US 10248360, Apr 2019
[43] "Efficient and Secure Direct Storage Device Sharing in Virtualized Environments", US 10216628, Feb 2019
[44] "Outcome-Based Software-Defined Infrastructure", US 10216544, Feb 2019
[45] "Efficient and Secure Direct Storage Device Sharing in Virtualized Environments", US 10169231, Dec 2018
[46] "Effective Indexing of Protocol Information", US 10164818, Dec 2018
[47] "Facilitating Processing within Computing Environments Supporting Pageable Guests", US 10133515, Nov 2018
[48] "Method for Sorting Data", US 10089379, Oct 2018
[49] "Creating New Cloud Resource Instruction Set Architecture", US 10084648, Sep 2018
[50] "Hybrid Compression for Large History Compressors", US 10067705, Sep 2018
[51] "Security within a Software-Defined Infrastructure", US 10043007, Aug 2018

[52] "Creating New Cloud Resource Instruction Set Architecture", US 9967146, May 2018

[53] "Extending Existing Storage Devices in Virtualized Environments", US 9940072, Apr 2018

[54] "Efficient and Secure Direct Storage Device Sharing in Virtualized Environments", US 9892037, Feb 2018

[55] "Creating a Dynamic Huffman Table", United Kingdom 2544587, Feb 2018

[56] "Efficient and Secure Direct Storage Device Sharing in Virtualized Environments", US 9858184, Jan 2018

[57] "Capability-Based Abstraction of Software-Defined Infrastructure", US 9851933, Dec 2017

[58] "Maintaining Versions of Data in Solid State Memory", US 9817581, Nov 2017

[59] "Performing Server Migration and Dependent Server Discovery in Parallel", US 9804879, Oct 2017

[60] "Performing Server Migration and Dependent Server Discovery in Parallel", US 9785461, Oct 2017

[61] "Maintaining Versions of Data in Solid State Memory", US 9778873, Oct 2017

[62] "Outcome-Based Software-Defined Infrastructure", US 9729421, Aug 2017

[63] "Power Shifting in Multicore Platforms by Varying SMT Levels", US 9710044, July 2017

[64] "Extending Existing Storage Devices in Virtualized Environments", US 9665309, May 2017

[65] "Apparatus for Individual Online Price Adjustments in Real Time", US 9659317, May 2017

[66] "Security within a Software-Defined Infrastructure", US 9652612, May 2017

[67] "Storage Device Control", US 9626331, Apr 2017

[68] "Creating a Dynamic Huffman Table", US 9584156, Feb 2017

[69] "Graphical User Passwords", US 9582653, Feb 2017

[70] "Maintaining Versions of Data in Solid State Memory", US 9582511, Feb 2017

[71] "Maintaining Versions of Data in Solid State Memory", US 9575682, Feb 2017

[72] "Maintaining Versions of Data in Solid State Memory", US 9460802, Oct 2016

[73] "Optimization of Mixed Database Workload Scheduling and Concurrency Control by Mining Data Dependency Relationships Via Lock Tracing", US 9436721, Sep 2016

[74] "Load Synchronization With Streaming Thread Cohorts", US 9417882, Aug 2016

[75] "Dynamic Tuning of Internal Parameters for Solid-State Disk Based on Workload Access Patterns", US 9244831, Jan 2016

[76] "System and Method for An Efficient Query Sort of a Data Stream With Duplicate Key Values", US 9235622, Jan 2016

[77] "Facilitating Processing within Computing Environments Supporting Pageable Guests", US 9183027, Nov 2015

[78] "Storing Multi-Stream Non-Linear Access Patterns in a Flash Based File-System", US 9164676, Oct 2015

[79] "Flash Translation Layer System for Maintaining Data Versions in Solid State Memory", US 9135161, Sep 2015

[80] "Maintaining Versions of Data in Solid State Memory", US 9135163, Sep 2015

[81] "Data Versioning in Solid State Memory", US 9135162, Sep 2015
[82] "Data Versioning in Solid State Memory", US 9122581, Sep 2015
[83] "File System for Maintaining Data Versions in Solid State Memory", US 9122582, Sep 2015
[84] "Maintaining Versions of Data in Solid State Memory", US 9116793, Aug 2015
[85] "Method of Adaptive Spill Queue for Stateful Hardware Accelerators", China ZL201010271150.8, Aug 2015
[86] "Dynamic Tuning of Internal Parameters for Solid-State Disk Based on Workload Access Patterns", US 9098400, Aug 2015
[87] "False Sharing Detection Logic for Performance Monitoring", US 9058270, June 2015
[88] "Power Shifting in Multicore Platforms by Varying SMT Levels", US 9003218, Apr 2015
[89] "Network Data Packet Processsing", US 8959224, Feb 2015
[90] "Method and System for Lazy Data Serialization in Computer Communications", US 8949783, Feb 2015
[91] "Maintaining a Cache of Blocks from a Plurality of Data Streams", US 8918588, Dec 2014
[92] "Canonicalization of Network Protocol Headers", US 8902886, Dec 2014
[93] "Request Controlling", US 8856461, Oct 2014
[94] "Network Intrusion Protection", China ZL200980145011.6, Sep 2014
[95] "Encoded Data Processing", US 8832046, Sep 2014
[96] "Network Intrusion Protection", Germany 602009025668.8, July 2014
[97] "Network Intrusion Protection", EP 2289221, July 2014
[98] "Network Intrusion Protection", United Kingdom 2289221, July 2014
[99] "Method to Embed a Light-Weight Kernel in a Full-Weight Kernel to Provide a Heterogeneous Execution Environment", US 8789046, July 2014
[100] "Encoded Data Processing", US 8756208, June 2014
[101] "Facilitating Processing within Computing Environments Supporting Pageable Guests", US 8752053, June 2014
[102] "Network Data Packet Processing", United Kingdom 2496958, May 2014
[103] "Method and Apparatus for Managing Software Controlled Cache of Translating The Physical Memory Access of a Virtual Machine Between Different Levels of Translation Entities", US 8688953, Mar 2014
[104] "Network Intrusion Protection", US 8677473, Mar 2014
[105] "Scan Sharing for Query Predicate Evaluations in Column-Based In-Memory Database Systems", US 8631000, Jan 2014
[106] "Assigning Work from Multiple Sources to Multiple Sinks Given Assignment Constraints", US 8532129, Sep 2013
[107] "Assignment Constraint Matrix for Assigning Work from Multiple Sources to Multiple Sinks", US 8391305, Mar 2013
[108] "Facilitating Processing within Computing Environments Supporting Pageable Guests", US 8387049, Feb 2013
[109] "Database Table Look-Up", US 8359316, Jan 2013

[110] "Dual Scheduling of Work from Multiple Sources to Multiple Sinks Using Source and Sink Attributes to Achieve Fairness and Processing Efficiency", US 8295305, Oct 2012

[111] "Method and Apparatus for Managing Software Controlled Cache of Translating The Physical Memory Access of a Virtual Machine Between Different Levels of Translation Entities", US 8275971, Sep 2012

[112] "Method and Apparatus for Concurrent and Stateful Decompression of Multiple Compressed Data Streams", US 8244911, Aug 2012

[113] "Storage Allocation", US 8122219, Feb 2012

[114] "Facilitating Processing within Computing Environments Supporting Pageable Guests", China ZL200680027589.8, Jan 2012

[115] "Method of Virtualization and OS-Level Thermal Management and Multithreaded Processor With Virtualization and OS-Level Thermal Management", US 7886172, Feb 2011

[116] "Method of Constructing An Approximated Dynamic Huffman Table for Use in Data Compression", US 7834781, Nov 2010

[117] "Method and Apparatus for Data Decompression in The Presence of Memory Hierarchies", US 7692561, Apr 2010

[118] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Switzerland 1904926, Mar 2010

[119] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Czech Republic 1904926, Mar 2010

[120] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Germany 602006012843.6, Mar 2010

[121] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Estonia E004612, Mar 2010

[122] "Facilitating Processing within Computing Environments Supporting Pageable Guests", EP 1904926, Mar 2010

[123] "Facilitating Processing within Computing Environments Supporting Pageable Guests", France 1904926, Mar 2010

[124] "Facilitating Processing within Computing Environments Supporting Pageable Guests", United Kingdom 1904926, Mar 2010

[125] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Hungary 1904926, Mar 2010

[126] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Ireland 1904926, Mar 2010

[127] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Iceland 1904926, Mar 2010

[128] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Luxembourg 1904926, Mar 2010

[129] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Netherlands 1904926, Mar 2010

[130] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Portugal 1904926, Mar 2010

[131] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Romania 1904926, Mar 2010

[132] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Sweden 1904926, Mar 2010

[133] "Facilitating Processing within Computing Environments Supporting Pageable Guests", Slovakia 1904926, Mar 2010

[134] "Method and Apparatus for Anonymous Group Messaging in a Distributed Messaging System", US 7512788, Mar 2009

[135] "Method and Apparatus for Anonymous Group Messaging in a Distributed Messaging System", China ZL200310117234.6, Mar 2009

[136] "Method of Securely Sharing Information Over Public Networks Using Untrusted Service Providers and Tightly Controlling Client Accessibility", US 7315950, Jan 2008

[137] "System and Method on Generating Multi-Dimensional Trace Files and Visualizing Them Using Multiple Gantt Charts", US 7131113, Oct 2006

[138] "Method and Apparatus for Efficient Virtual Memory Management.", US 6886085, Apr 2005

[139] "Method for Operating System Support of Memory Compression", China ZL01120823.6, Feb 2005

[140] "Method for Operating System Support of Memory Compression", Japan 3643318, Feb 2005

[141] "Method and Apparatus for Image Stabilization in Display Device", China ZL99125345.0, Dec 2004

[142] "Verfahren Und Vorrichtung Zur Bildstabilisierung in Einer Anzeigeeinheit / Method and Apparatus for Image Stabilization in Display Device", Germany 10003376.8, Aug 2004

[143] "Method for Operating System Support of Memory Compression", Korea 0444093, Aug 2004

[144] "Method and Fr Tag Apparatus for Measurement of Physical Product Data and for Determination of Dynamic Properties of Perishable Consumer Products", US 6712276, Mar 2004

[145] "An Apparatus and Method for Partitioned Memory Protection in Cache Coherent Symmetric Multiprocessor Systems", China ZL00104744.2, Mar 2004

[146] "Method for Operating System Support of Memory Compression", US 6681305, Jan 2004

[147] "Cache Architecture to Enable Accurate Cache Sensitivity", China ZL99106950.1, Jan 2004

[148] "Apparatus and Method for Partitioned Memory Protection in Cache Coherent Symmetric Multiprocessor Systems", Japan 3501357, Dec 2003

[149] "Method and Apparatus for Efficient Cache Management and Avoiding Unnecessary Cache Traffic", US 6643741, Nov 2003

[150] "Method for Distributing Digital Tv Signal and Selection of Content", US 6636533, Oct 2003

[151] "Technique for Efficiently Transferring Moderate Amounts of Data Across Address Space Boundary", US 6601146, July 2003

[152] "Locally Made, Globally Coordinated Resource Allocation Decisions Based on Information Provided by The Second-Price Auction", US 6587865, July 2003

[153] "Optimistic, Eager Rendezvous Transmission Mode and Combined Rendezvous Modes for Message Processing Systems", US 6542513, Apr 2003

[154] "Cache Architecture to Enable Accurate Cache Sensitivity", Taiwan NI-165240, Mar 2003

[155] "Method and Apparatus for Asset Tracking of Network Attached Devices", US 6507869, Jan 2003

[156] "Method and Apparatus for Image Stabilization in Display Device", Taiwan NI-161782, Dec 2002

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