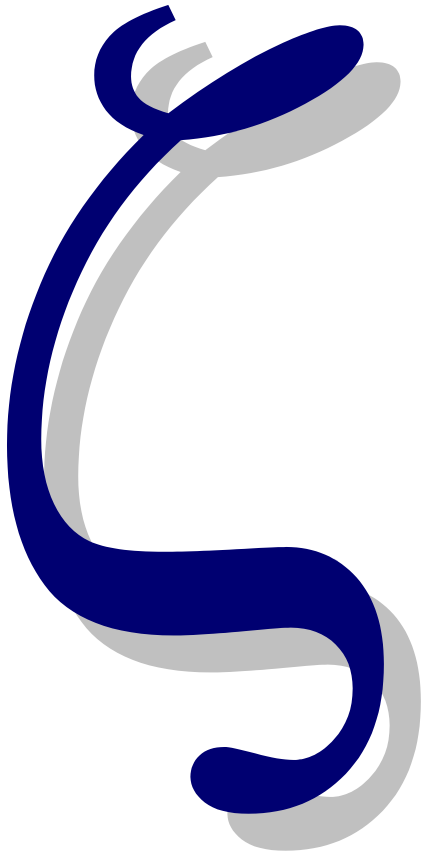
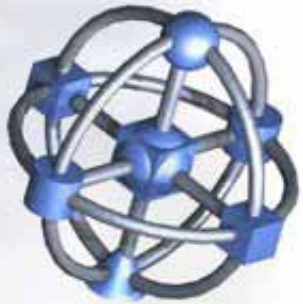


Grid Computing



ZetaGrid
Experiences with the Grid for everybody

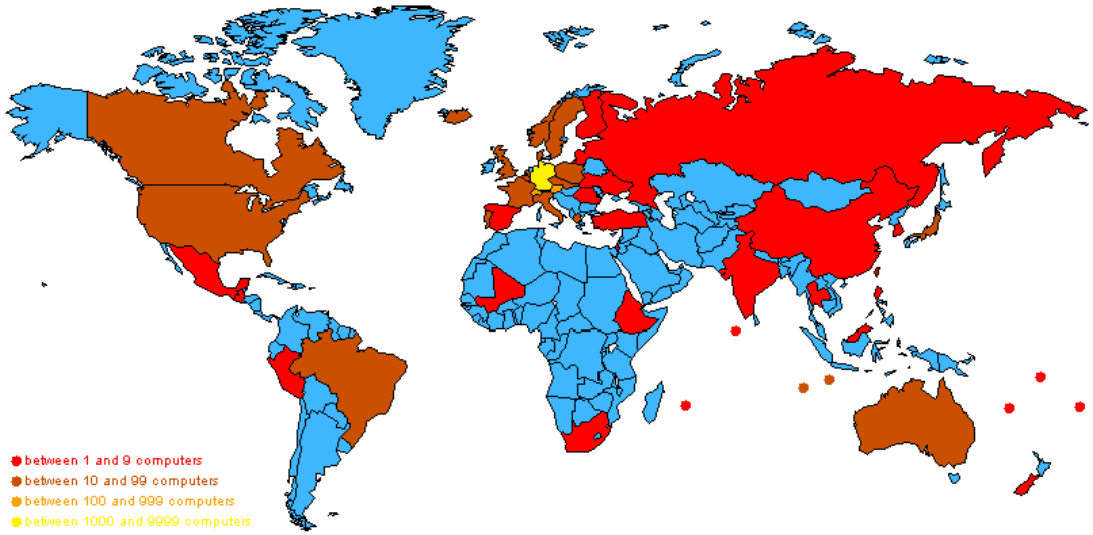
Dr. Sebastian Wedeniwski
Consulting IT Architect

Agenda

1	**Overview**
2	**Examples**
3	**Technical Details**
4	**Security & Privacy**
5	**ZetaGrid Directions**

Worldwide dynamic computation

- ZetaGrid shows a real-life example of a Grid application platform as an outstanding contribution to the joint Böblingen Lab GRID activities.
- The first problem solved with this platform was a mathematical one - the zeta function. That's where the name comes from.
- ZetaGrid runs on more than 8,000 computers in more than 70 countries.



ZetaGrid platform

ZetaGrid distinguishes from traditional client-server solutions by:

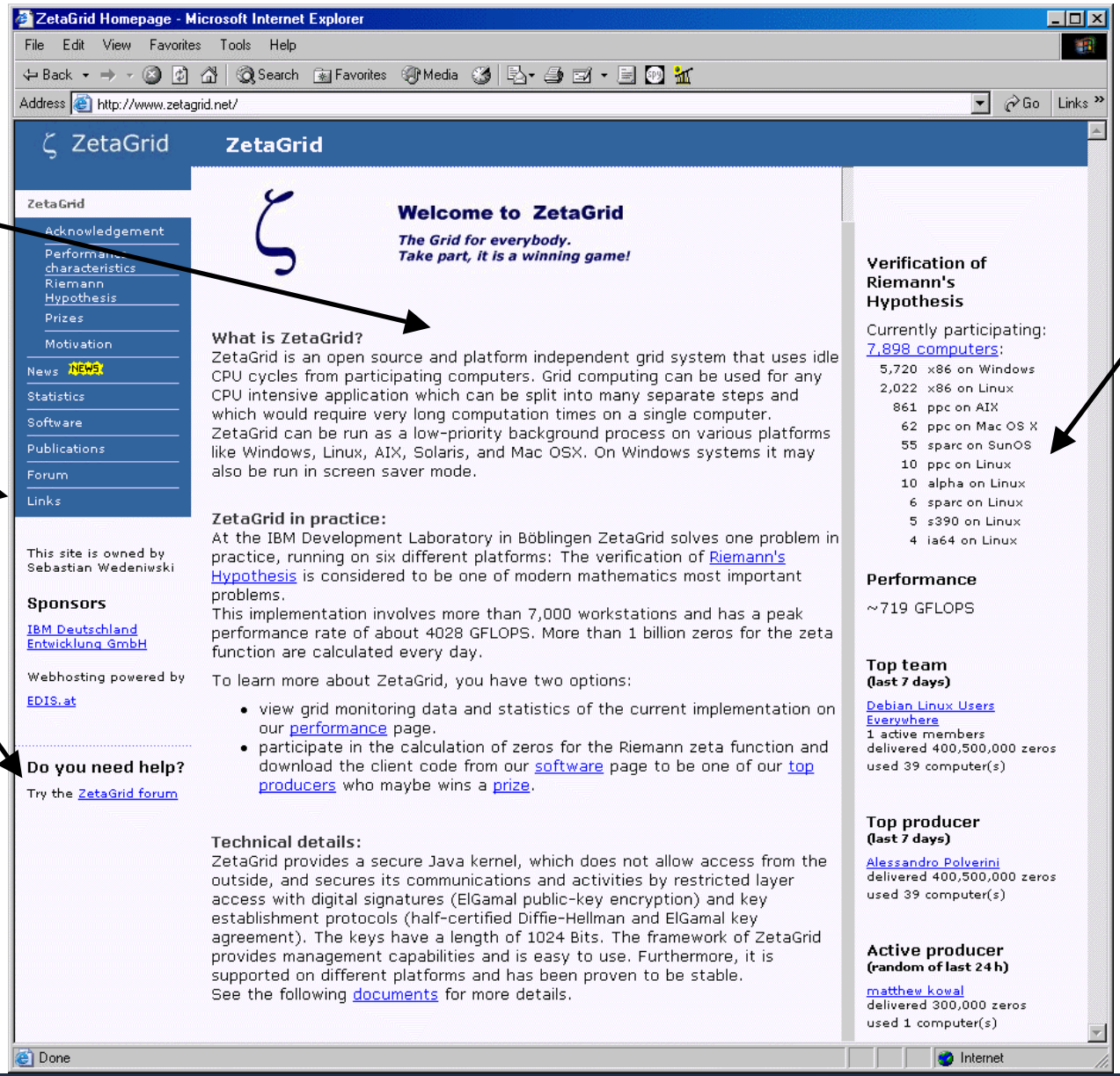
- simultaneous use of large numbers of dynamic resources,
- dynamic resource requirements,
- use of resources from multiple administrative domains,
- complex communication structures,
- and stringent performance requirements.

ZetaGrid home

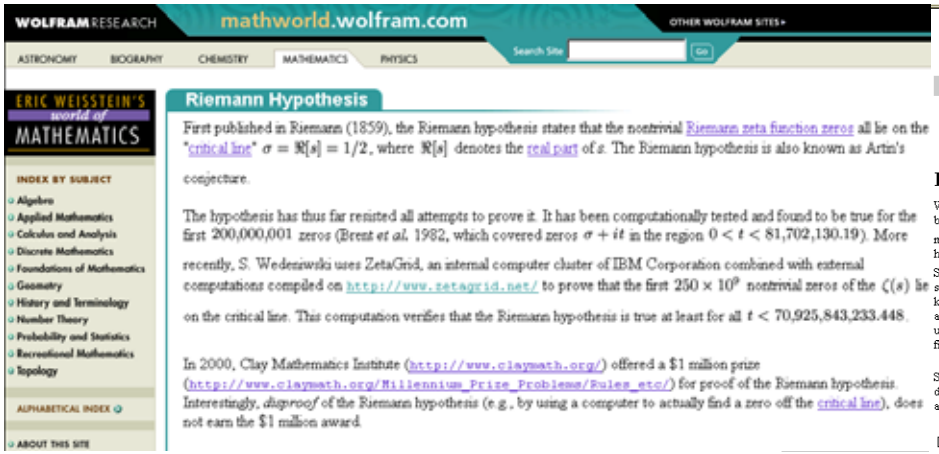
Introduction

Links to the communities

Summary of the statistics



ZetaGrid reputation (7,810 Google results)



Magazin für Computer Technik
c't 26/2001

Scientific American, Crunching Numbers, May 2003

A volunteer effort is under way to verify the famous Riemann Hypothesis by using distributed computer software to search for the zeros of the Riemann zeta function. [German mathematician Bernhard Riemann hypothesized in 1859 that all the nontrivial zeros of the function fall on a particular line. See "Math's Most Wanted," Reviews, on page 84.] To date, more than 5,000 participating computers have found more than 300 billion zeros. For more information, visit www.zetagrid.net

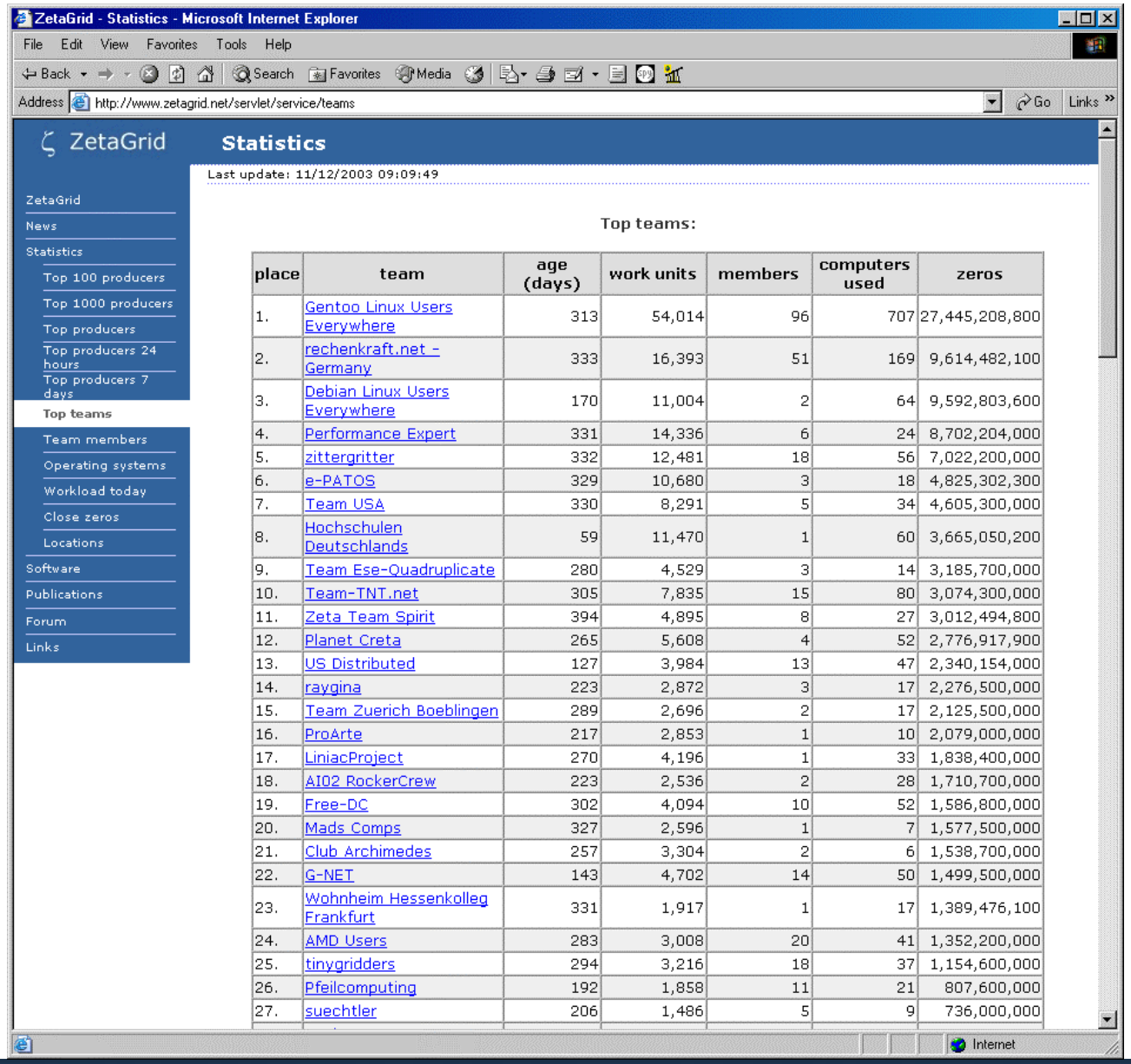
PC Magazin 05/2003

Die fünf wichtigsten DC-Projekte

Einen gute Übersicht der gängigen DC.Projekte liefert www.rechenkraft.de. Unsere Liste stellt subjektiv die großen, die innovativen und die heimischen Projekte zusammen.

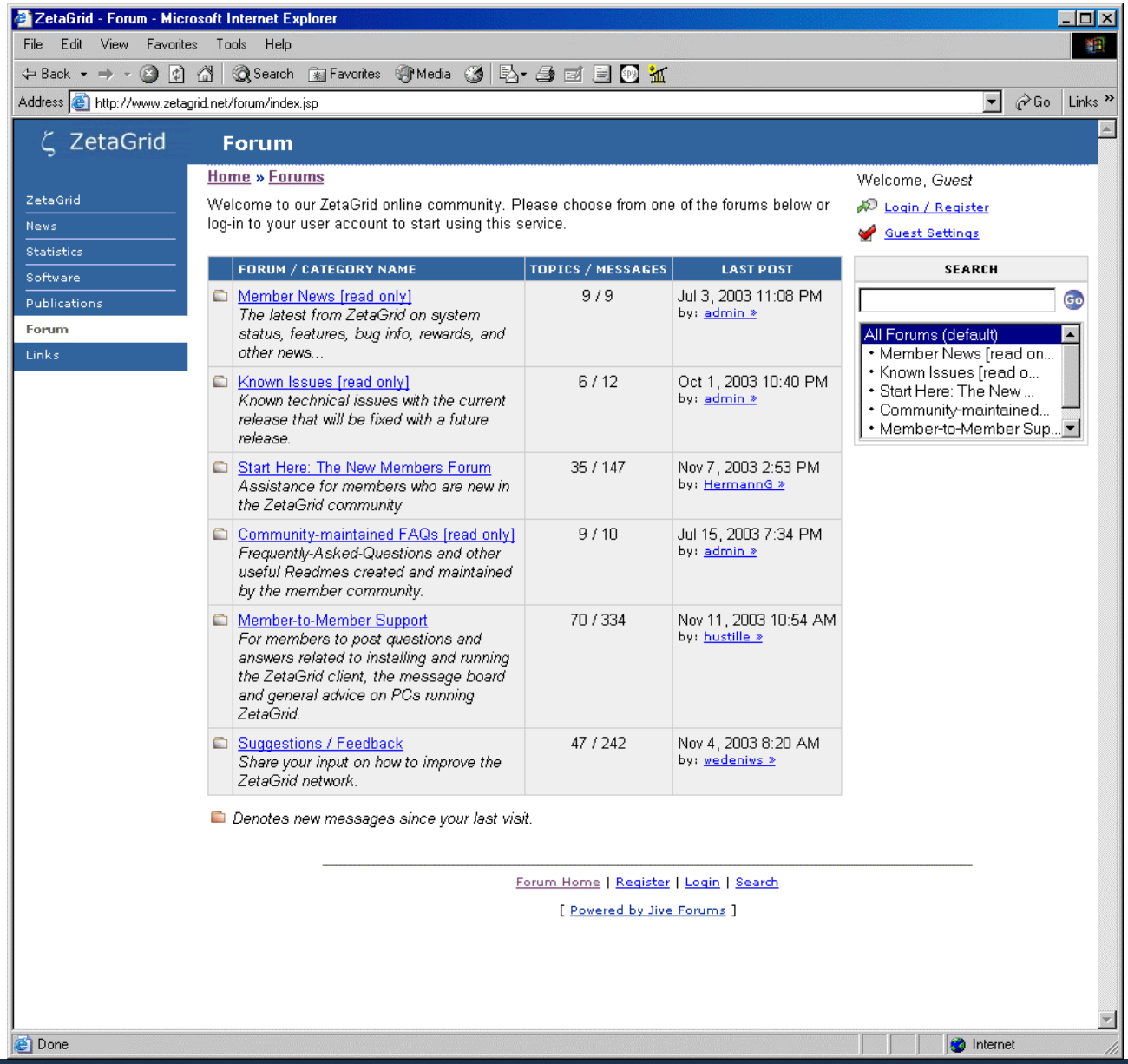
Name	Folding@home/ Genome@home	SETI@home	Zetagrid	Moneybee	Distributed.net
Kategorie	Medizin	Suche nach Außerirdischen	Mathematik	Finanzen	Verschlüsselung
Ziel	Simulation von Faltungsvorgängen bei Proteinen	Finden regelmäßiger Signale in Daten von Radioteleskopen	Verifizierung der Riemannschen Hypothese	Prognose von Aktienkursen, Indizes und anderen Wirtschaftsparametern	Finden des Schlüssels für eine RC5-72-kodierte Nachricht
Teilnehmer	186.241	4.276.801	4312 (Computer)	ca. 12.000	10.478
kommerziell	–	–	–	✓	–
Web	http://folding.stanford.edu/	www.setiathome.ssl.berkeley.edu/	www.zetagrid.net/	http://de.moneybee.net	www.distributed.net/rc5/index.html.de
Begründung	Große wissenschaftliche Erfolge	Hat DC wirklich publik gemacht	Relativ großes deutsches Projekt	Deutsches kommerzielles Projekt	Technische Neuerungen und Details für die Clientprogramme „erfunden"

ZetaGrid communities: 135 teams

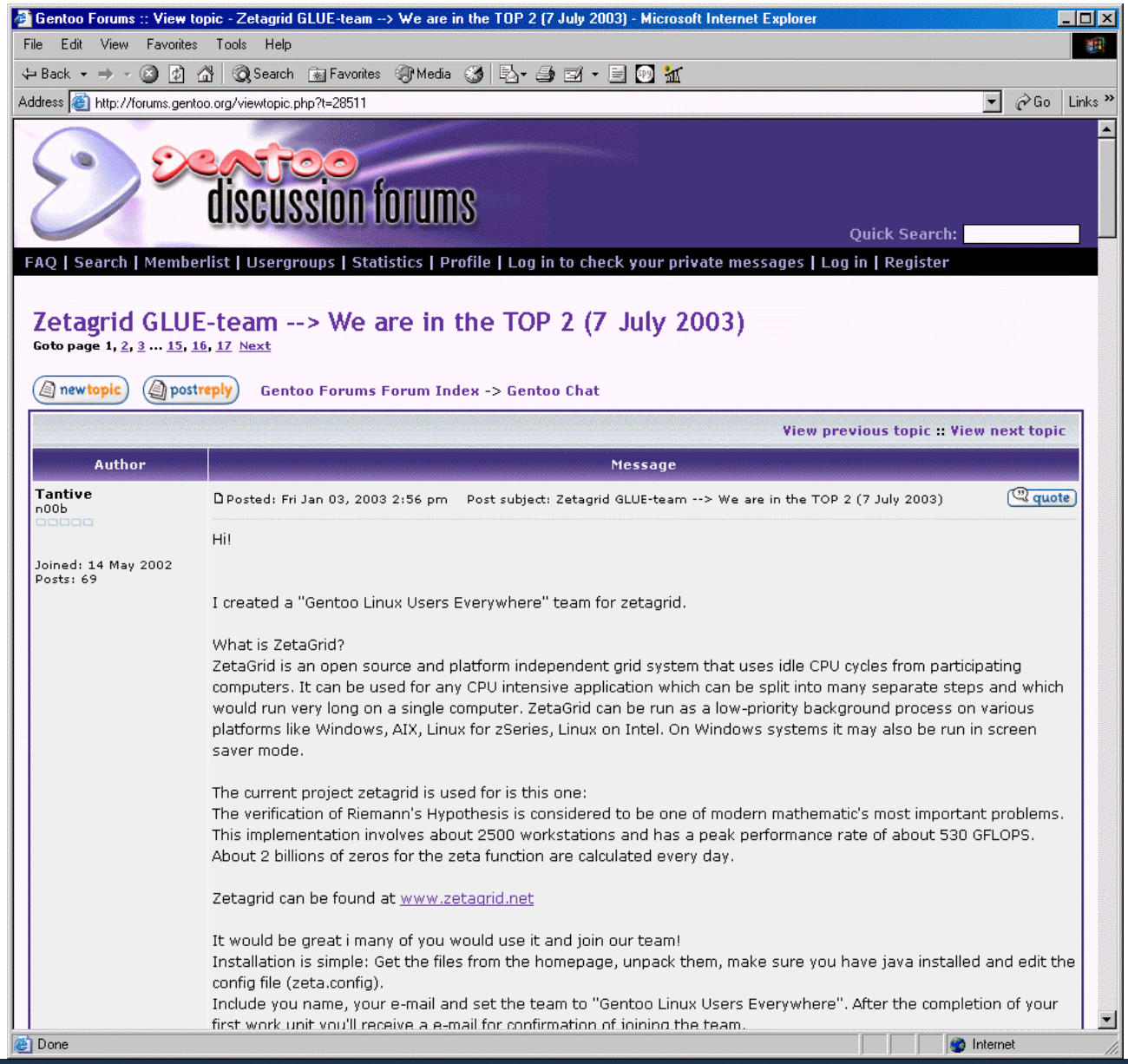


place	team	age (days)	work units	members	computers used	zeros
1.	Gentoo Linux Users Everywhere	313	54,014	96	707	27,445,208,800
2.	rechenkraft.net - Germany	333	16,393	51	169	9,614,482,100
3.	Debian Linux Users Everywhere	170	11,004	2	64	9,592,803,600
4.	Performance Expert	331	14,336	6	24	8,702,204,000
5.	zittergritter	332	12,481	18	56	7,022,200,000
6.	e-PATOS	329	10,680	3	18	4,825,302,300
7.	Team USA	330	8,291	5	34	4,605,300,000
8.	Hochschulen Deutschlands	59	11,470	1	60	3,665,050,200
9.	Team Ese-Quadruplicate	280	4,529	3	14	3,185,700,000
10.	Team-TNT.net	305	7,835	15	80	3,074,300,000
11.	Zeta Team Spirit	394	4,895	8	27	3,012,494,800
12.	Planet Creta	265	5,608	4	52	2,776,917,900
13.	US Distributed	127	3,984	13	47	2,340,154,000
14.	raygina	223	2,872	3	17	2,276,500,000
15.	Team Zuerich Boeblingen	289	2,696	2	17	2,125,500,000
16.	ProArte	217	2,853	1	10	2,079,000,000
17.	LiniacProject	270	4,196	1	33	1,838,400,000
18.	AI02 RockerCrew	223	2,536	2	28	1,710,700,000
19.	Free-DC	302	4,094	10	52	1,586,800,000
20.	Mads Comps	327	2,596	1	7	1,577,500,000
21.	Club Archimedes	257	3,304	2	6	1,538,700,000
22.	G-NET	143	4,702	14	50	1,499,500,000
23.	Wohnheim Hessenkolleg Frankfurt	331	1,917	1	17	1,389,476,100
24.	AMD Users	283	3,008	20	41	1,352,200,000
25.	tinygridders	294	3,216	18	37	1,154,600,000
26.	Pfeilcomputing	192	1,858	11	21	807,600,000
27.	suechtler	206	1,486	5	9	736,000,000

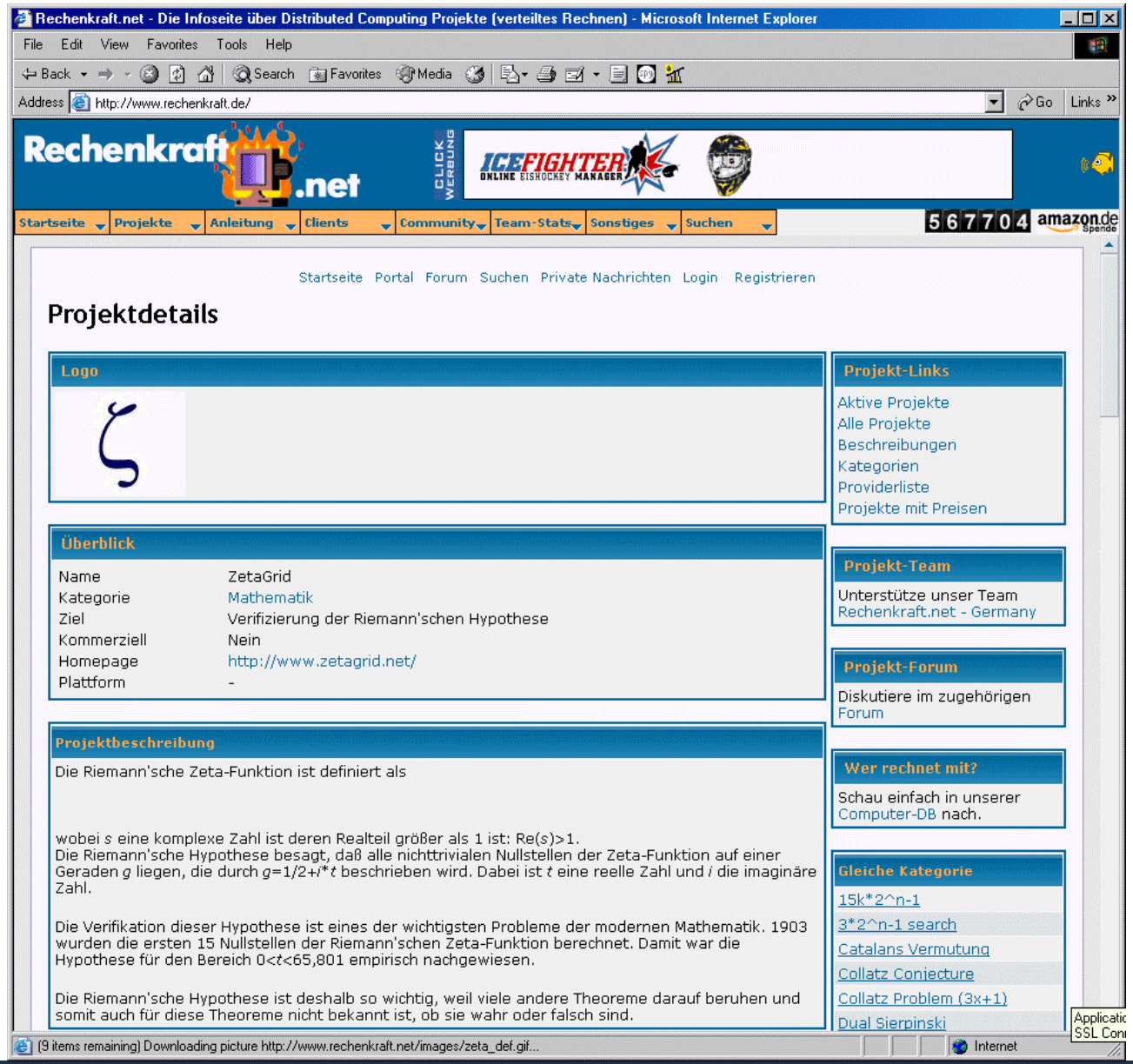
ZetaGrid communities



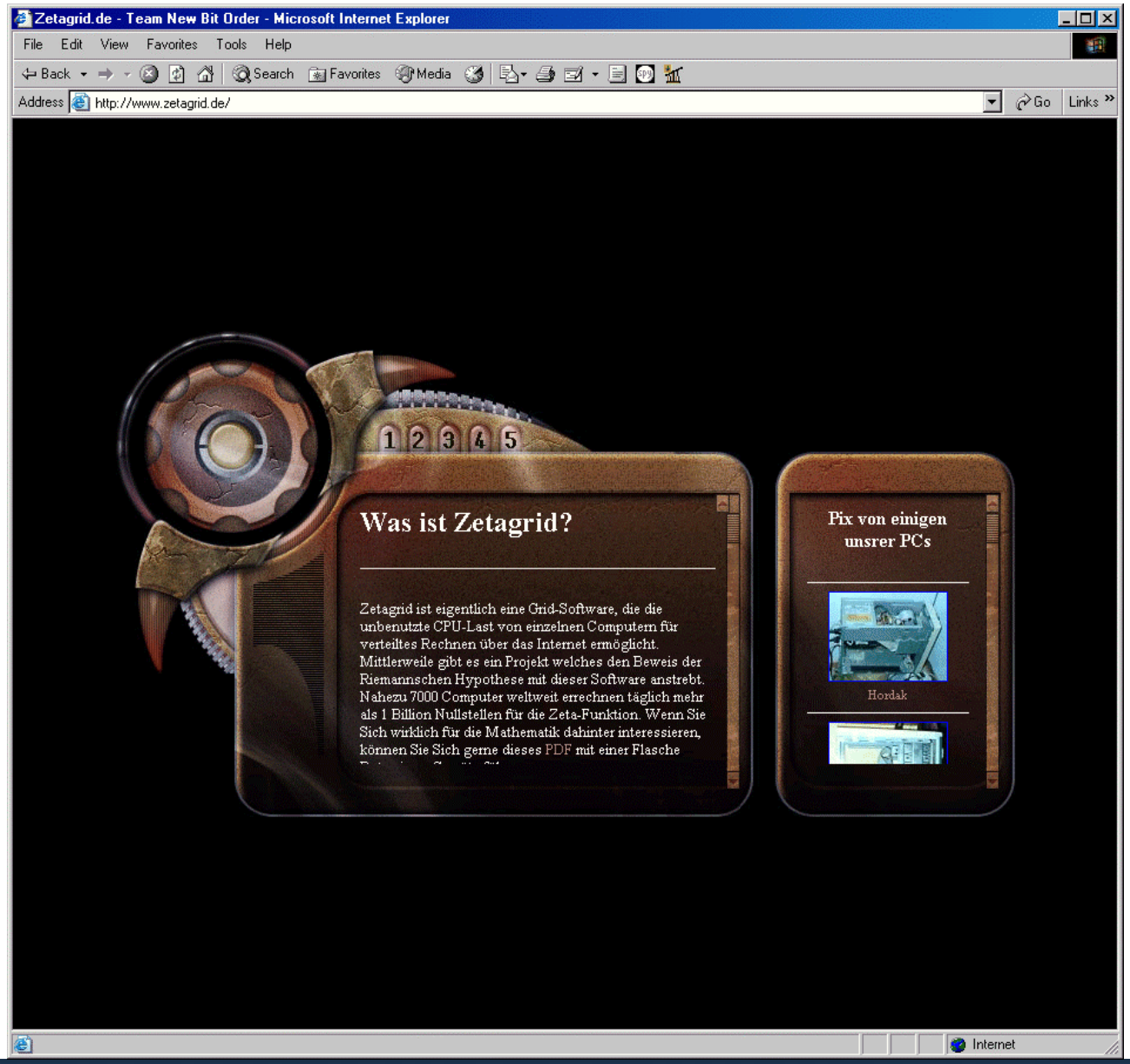
ZetaGrid communities



ZetaGrid communities



ZetaGrid communities



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Some examples

- Verification of

- In cooperation with the University Freiburg, Institute for Biology (Zoology):
  Deconvolution of images from microscopes in a Life Imaging Center.

- In cooperation with the University of Tübingen, Institute for Computer Science (Symbolic Computation):
  Realization of a SAT Grid with the ZetaGrid platform for hardware verification.

- Proposal for distributed computational fluid dynamics for automotive industries, i.e. solving fluid flow problems.

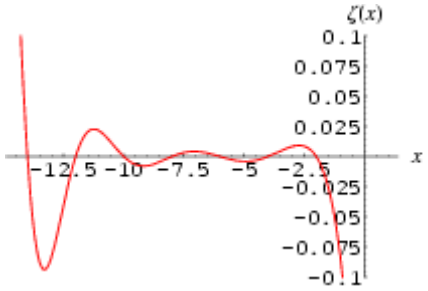
Riemann zeta function

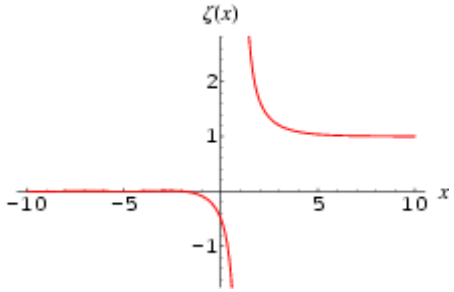
- Let s be a complex number with Re(s)>1. Then the Riemann zeta function is defined by (Euler ~1730)

$$\zeta(s) = \sum_{k=1}^{\infty} \frac{1}{k^s}$$

and is extended to the rest of the complex plane (except for s=1) by analytic continuation.

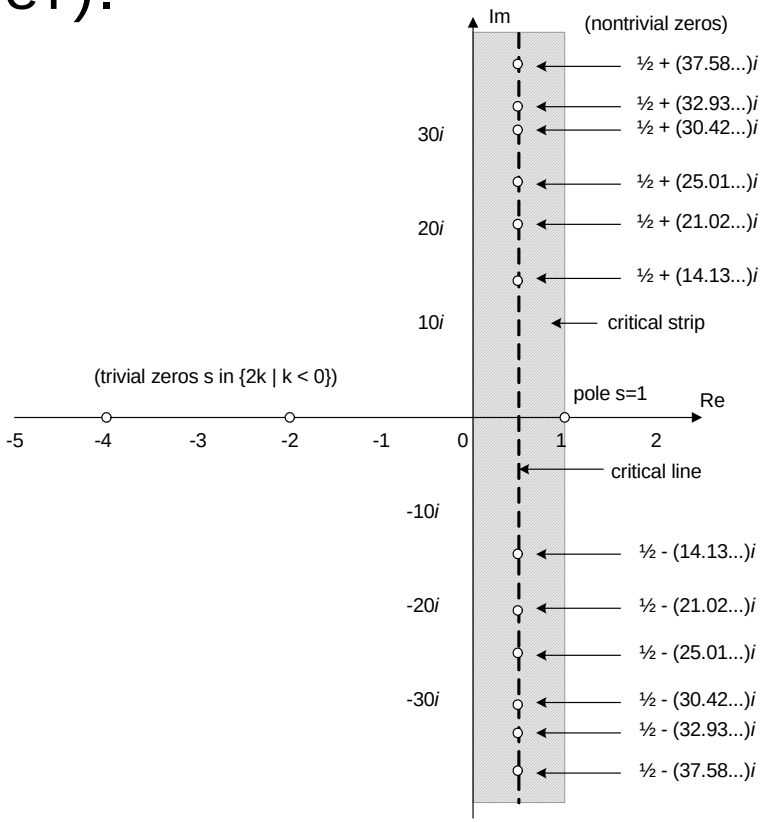
$$\zeta(1-s) = 2(2\pi)^{-s}\cos(\tfrac{1}{2}s\pi)\Gamma(s)\zeta(s)$$





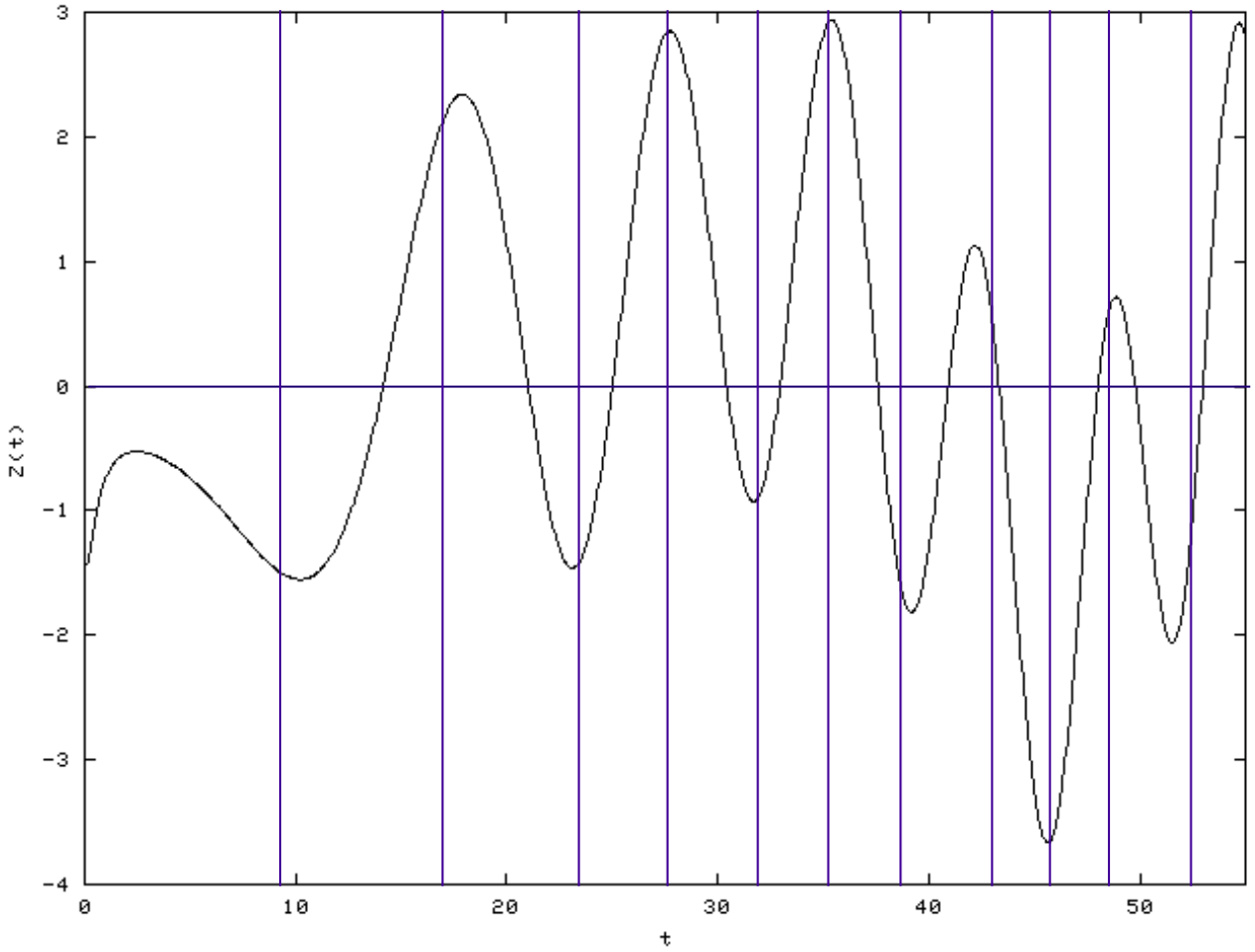
The Riemann Hypothesis

- The Riemann Hypothesis (formulated in 1859) asserts that all nontrivial zeros of the zeta function are on the critical line (1/2+it where t is a real number).



The zeros of Z(t)

- There exists at least one zero between two values with different sign.



The first 11 non-trivial zeros:

$\rho_1 \approx 1/2 + 14.135i$
$\rho_2 \approx 1/2 + 21.022i$
$\rho_3 \approx 1/2 + 25.011i$
$\rho_4 \approx 1/2 + 30.425i$
$\rho_5 \approx 1/2 + 32.935i$
$\rho_6 \approx 1/2 + 37.586i$
$\rho_7 \approx 1/2 + 40.919i$
$\rho_8 \approx 1/2 + 43.327i$
$\rho_9 \approx 1/2 + 48.005i$
$\rho_{10} \approx 1/2 + 49.774i$
$\rho_{11} \approx 1/2 + 52.970i$

History and milestones of ZetaGrid

- Feb. 1998 to Nov. 2001: Working on the necessity of the Extended Riemann Hypothesis for Miller's primality test (Dissertation "Primality Tests on Commutator Curves")
- February 2001: First implementation of ZetaGrid and synchronization with the Fortran-Code of J. van de Lune, H. J. J. te Riele, D. T. Winter
- August 2001: Starting ZetaGrid on 10 computers in IBM Laboratory Böblingen
- February 2002: Distributing ZetaGrid on 500 computers in IBM Germany
- September 2002: Availability of ZetaGrid in the Internet at http://www.zetagrid.net

History of the verified zeros

Year	Author	Starting zero number	Number of zeros ρ with $Im(\rho) > 0$
1903	J. P. Gram	0	15
1914	R. J. Backlund	0	79
1925	J. I. Hutchinson	0	138
1935	E. C. Titchmarsh	0	1,041
1953	A. M. Turing	0	1,104
1955	D. H. Lehmer	0	10,000
1956	D. H. Lehmer	0	25,000
1958	N. A. Meller	0	35,337
1966	R. S. Lehman	0	250,000
1968	J. B. Rosser, J. M. Yohe, L. Schoenfeld	0	3,500,000
1977	R. P. Brent	0	40,000,000
1979	R. P. Brent	0	81,000,001
1982	R. P. Brent, J. van de Lune, H. J. J. te Riele, D. T. Winter	0	200,000,001
1983	J. van de Lune, H. J. J. te Riele	0	300,000,001
1986	J. van de Lune, H. J. J. te Riele, D. T. Winter	0	1,500,000,001
1989	A. M. Odlyzko	10^{20}	70,000,000
1992	A. M. Odlyzko	10^{20}	175,000,000
2001	A. M. Odlyzko	10^{22}	10,000,000,000
2001	J. van de Lune	0	10,000,000,000
2002	A. M. Odlyzko	10^{23}	20,000,000,000
2002	S. Wedeniwski	0	75,000,000,000
2003	S. Wedeniwski	0	200,000,000,000

Performance characteristics

- Participating in ZetaGrid (11/11/2003): 3,038 users and 7,899 computers

- 1.8×10^{19} floating-point operations for calculating about 561 billion zeros of the Riemann zeta function in 805 days
  - ~261 GFLOPS
  - ~29 days maximal performance of IBM ASCI White, 8192 Power3 375 MHz processors (place 2, 06/2002, www.top500.org)
  - ~2304 years maximal performance of one Intel Pentium 4 with 2 GHz processors, 250 MFLOPS

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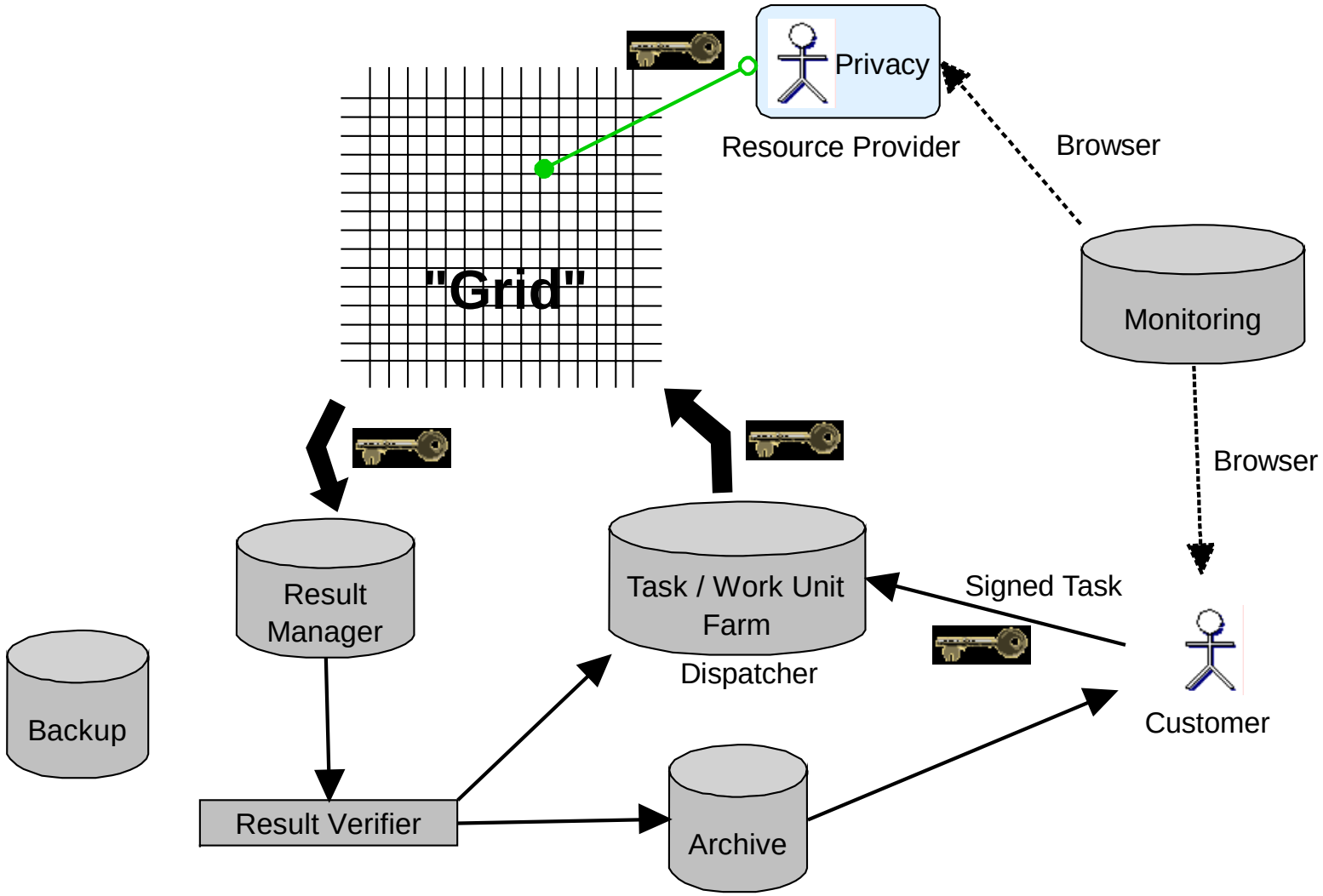
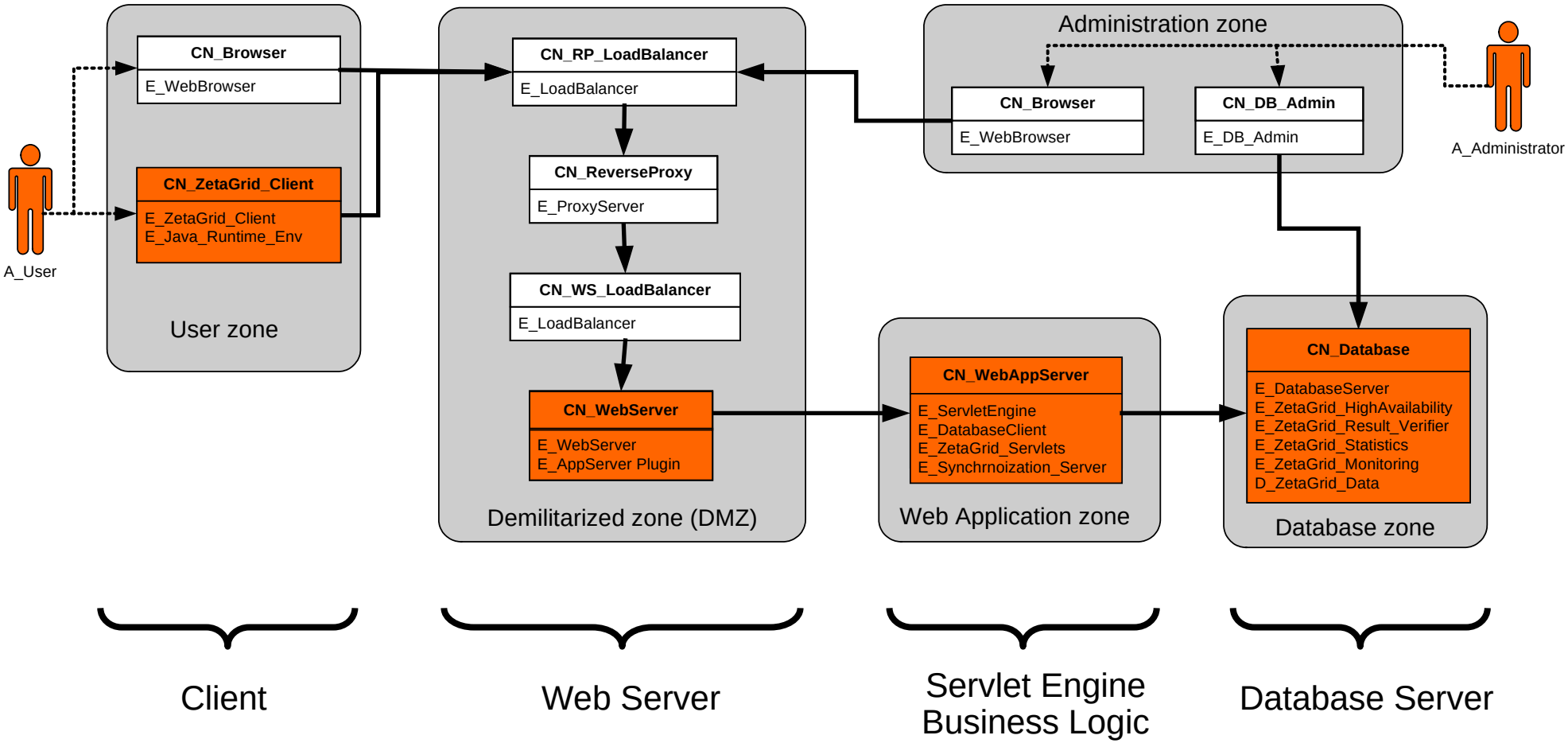
ZetaGrid architecture overview



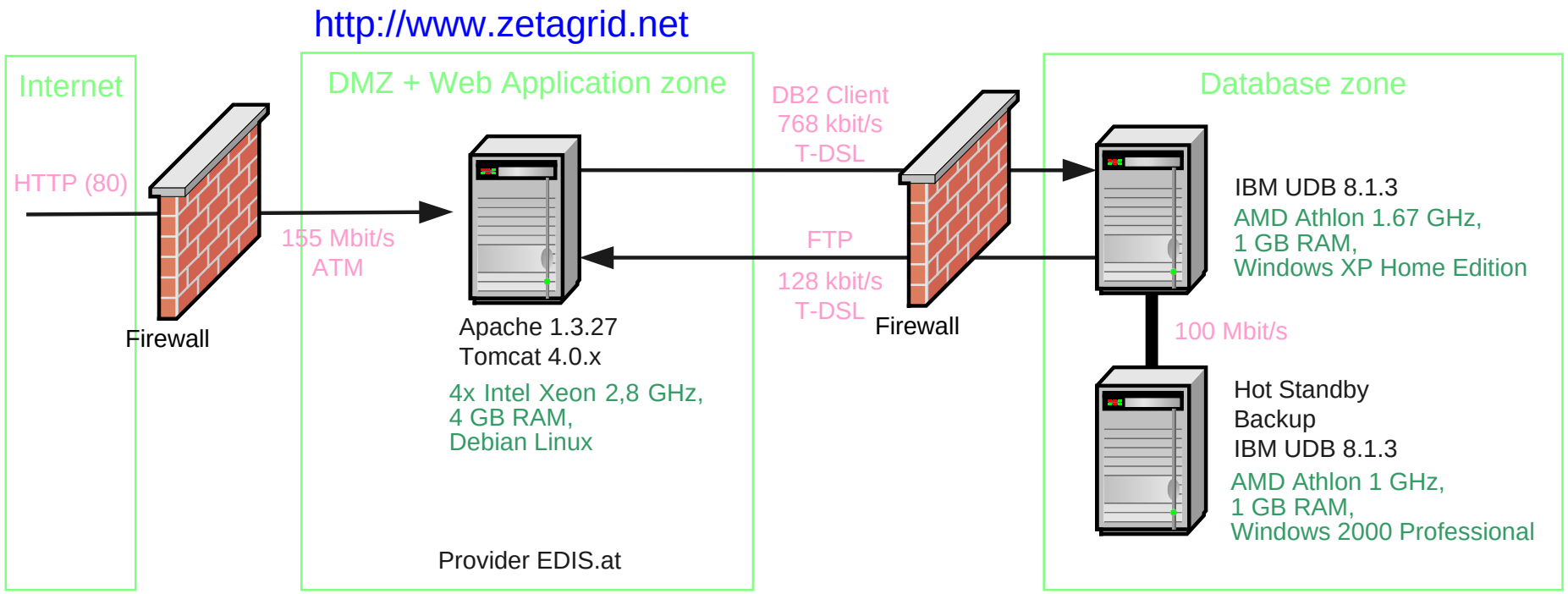
Operational model conceptual level

- Consists four tiers

E: Execution Deployment Unit
D: Persistence Deployment Unit
CN: Conceptual nodes represent logical nodes that host one or multiple deployment units

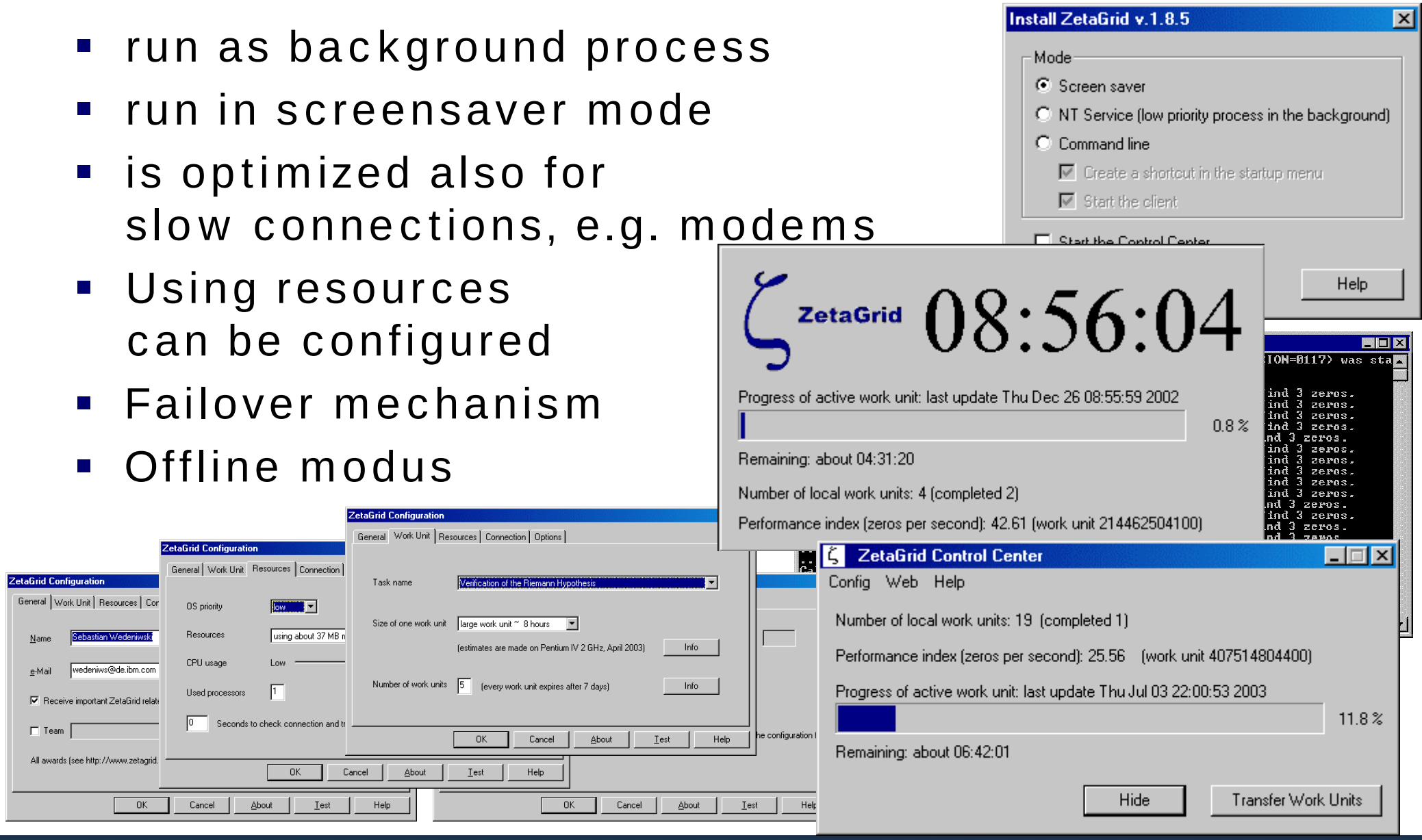


Operational model physical level



ZetaGrid client

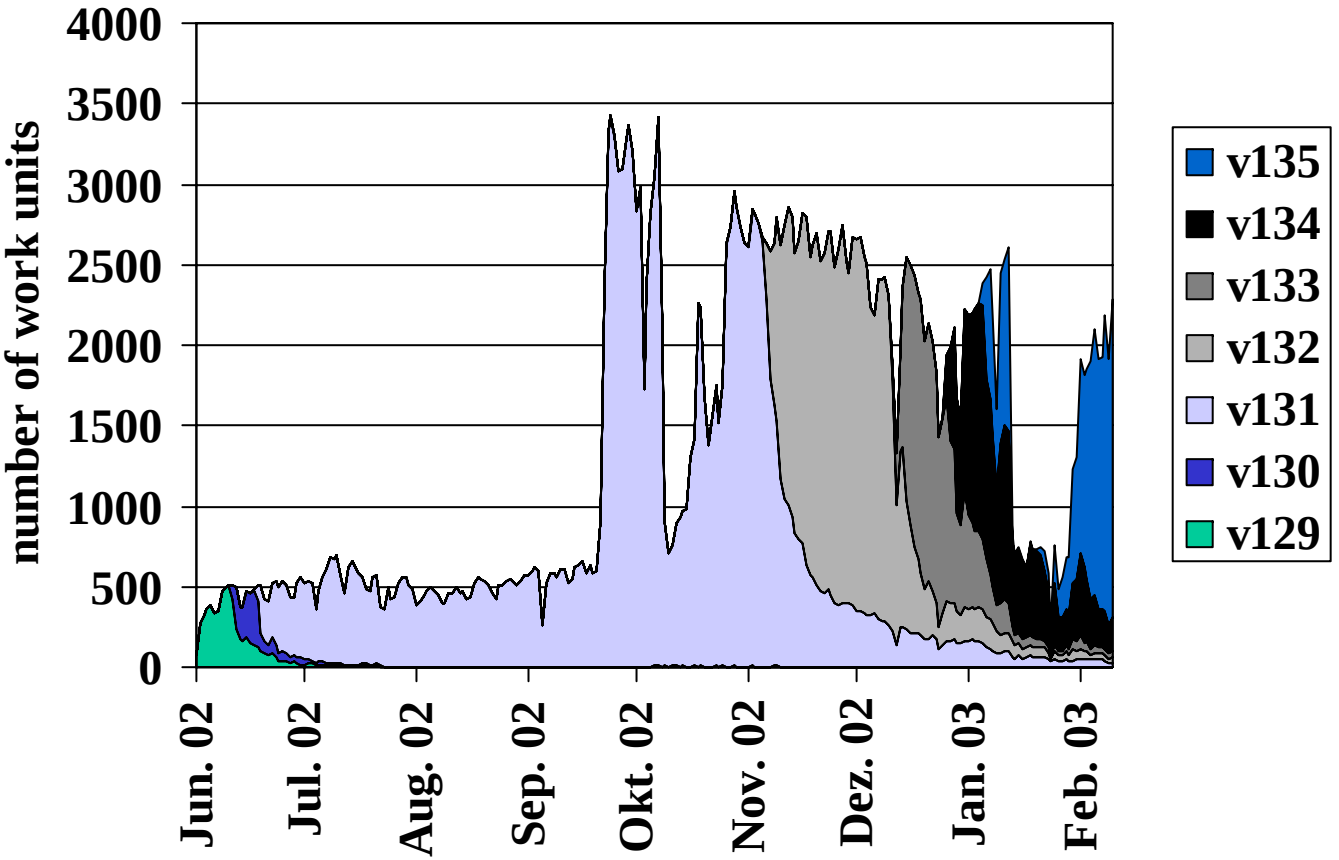
- run as background process
- run in screensaver mode
- is optimized also for slow connections, e.g. modems
- Using resources can be configured
- Failover mechanism
- Offline modus



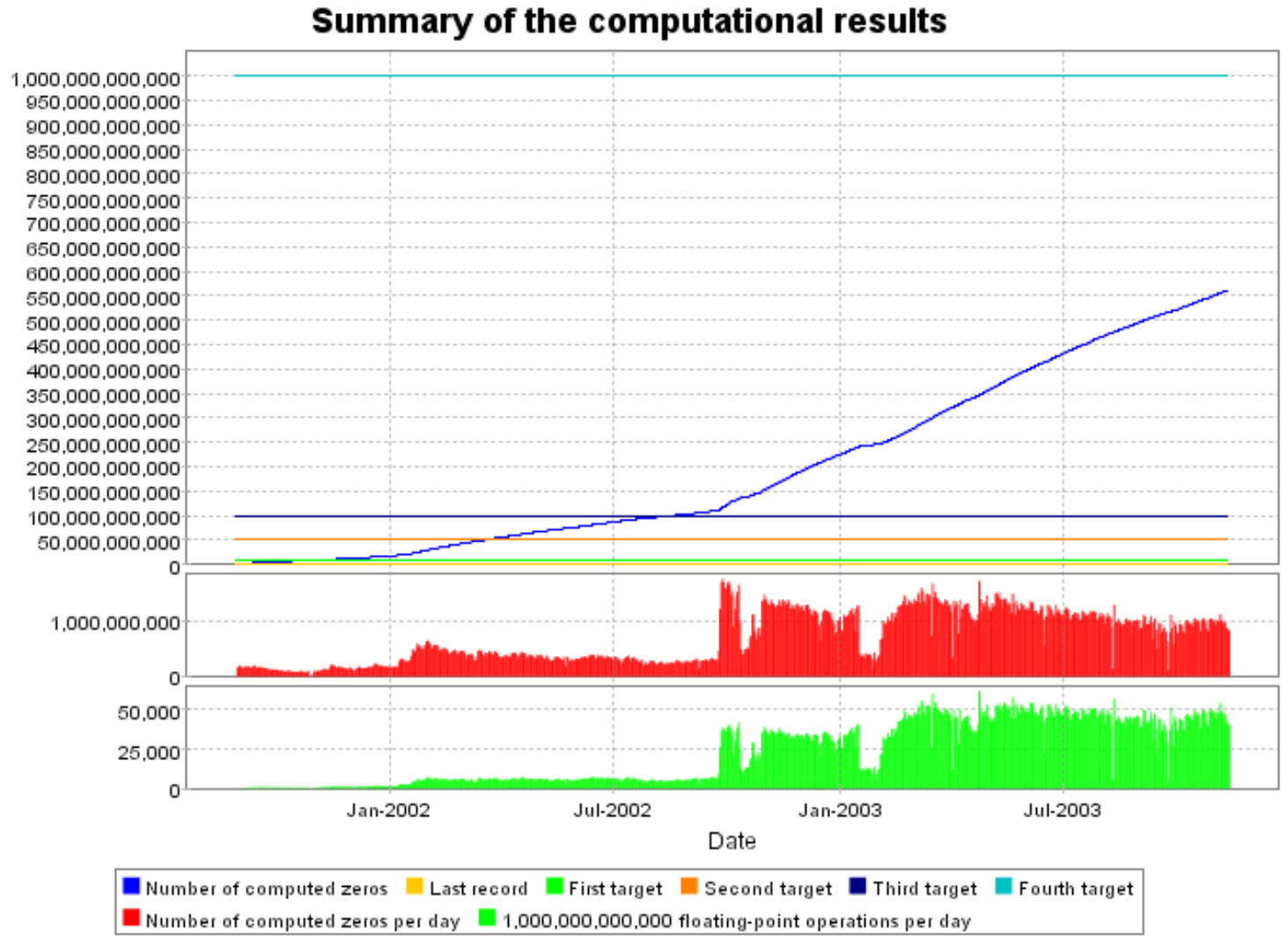
Task and work units

- A computational task can be split up into a configured number of independent work units.
- A task may depends on a specific hard- or software.
- Work units can be recomputed and redistributed.
- Work units must be traceable and monitored.
- Work units can have different sizes.
- Work units may have an overlap.
- A resource provider can request more than one work unit simultaneously (depends on his trust factor).

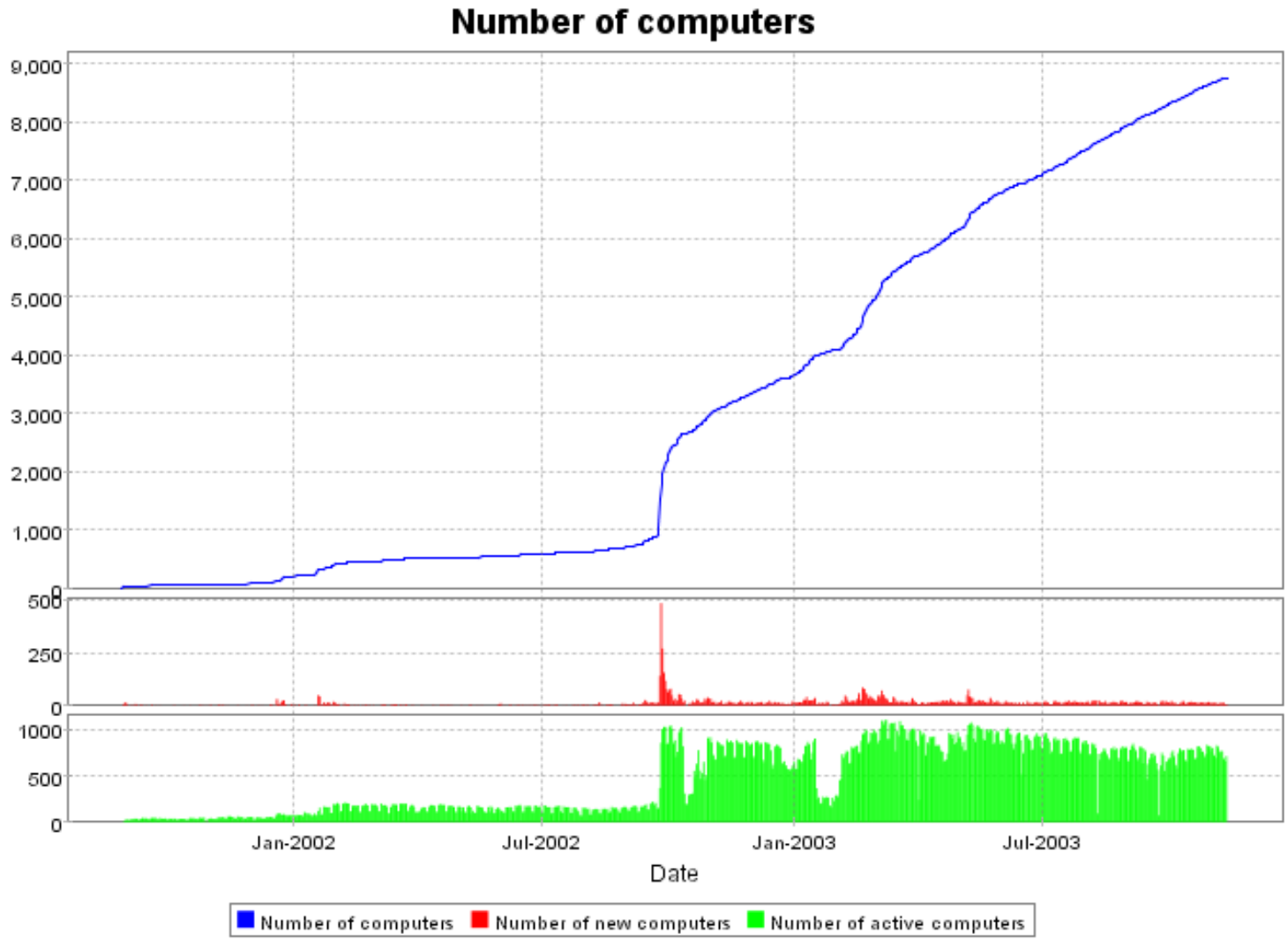
Version control



History of the computation

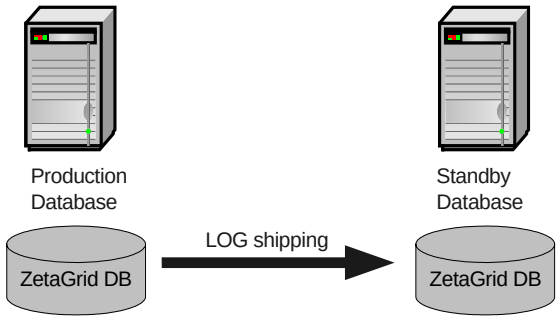


Number of computers



High availability of the back-end database

- Using log shipping to a standby database.

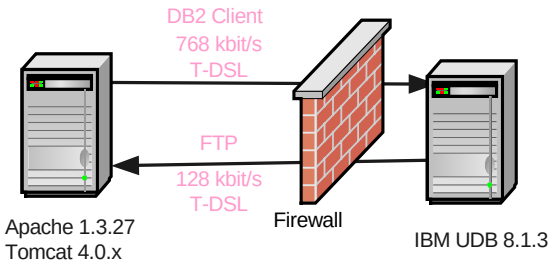


The standby database continuously rolls forward through the logs, ensuring that it is current up to the last successfully shipped log file.

- Daemon which checks and restarts the database process if specific communication errors occur.
- Daemon which kills and restarts the database process if “db2stop” hangs, e.g. UDB 8.1 FP3.
- Backup of the production database one time per day.

High availability of the DSL connection

- Using PPP over Ethernet dial-up connection, e.g. RASPPPOE.
- Daemon which stops, reconnects, sends the new IP address to the application server, and restart the database server every 23 hours.
  Availability: about 99.98%
- Daemon which pings specific addresses to keep alive the connection.



- Tool which simulates keystrokes to eliminate troubleshootings with dial-up connections, e.g. MCL.
- Daemon which kills the dial-up connection if it hangs.

High availability of Windows XP Home

- Disable automatic shutdown.
- Disable the “Indexing Service.”
- Disable the service “Messenger.”
- Log on automatically at system startup and restart all daemons if for example an electrical power outage occurred. Tools like “Tweak UI” can be used.
- Using automatically updating AntiVirus and Firewall tools.
- Install OS security patches manually.

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Security functions

- Authentication
- Access control / authorization
- Confidentiality
- Data integrity
- Privacy
- Nonrepudiation

Authentication

- Definition:
  Authentication is the process of verifying the identity of a participant to an operation or request.

- Solution in ZetaGrid:
  - Using the user name, e-mail address, and hostname for the client-server authentication.
  - Using hostname, IP address patterns, and encryption (448-bit key Blowfish).

Access control / authorization

- Definition:
  Authorization is the process through which it is determined whether a particular operation is allowed.

- Solution in ZetaGrid:
  - Proprietary solution (trust factor, active, etc.)
  - Database access control (user, administrator, monitor)

Confidentiality

- Definition:
  The degree to which the sensitive data have not been made available or disclosed to unauthorized individuals, processes, or other entities.

- Solution in ZetaGrid:
  - ElGamal public-key encryption; the keys have a length of 1024 Bits
  - Key establishment protocols (half-certified Diffie-Hellmann and ElGamal key agreement)

Data integrity

- Definition:
  The data integrity condition existing when data is unchanged from its source and has not been accidentally or maliciously modified, altered, or destroyed.

- Solution in ZetaGrid:
  - Digital signatures
  - ElGamal public-key encryption; the keys have a length of 1024 Bits

Privacy

- Definition:
  The protection given to prevent unauthorized disclosure of the information in the system.

- Solution in ZetaGrid:
  - The client is written in Java only so that Java2 Security concepts, i.e. the Java Sandbox
  - Open Source

Nonrepudiation

- Definition:
  A sender and a receiver should not be able to falsely deny later that he sent a message.

- Solution in ZetaGrid:
  - Access list of the web server
  - Logs of the application server
  - Only insert and select statements are permitted in the database (no delete or update)

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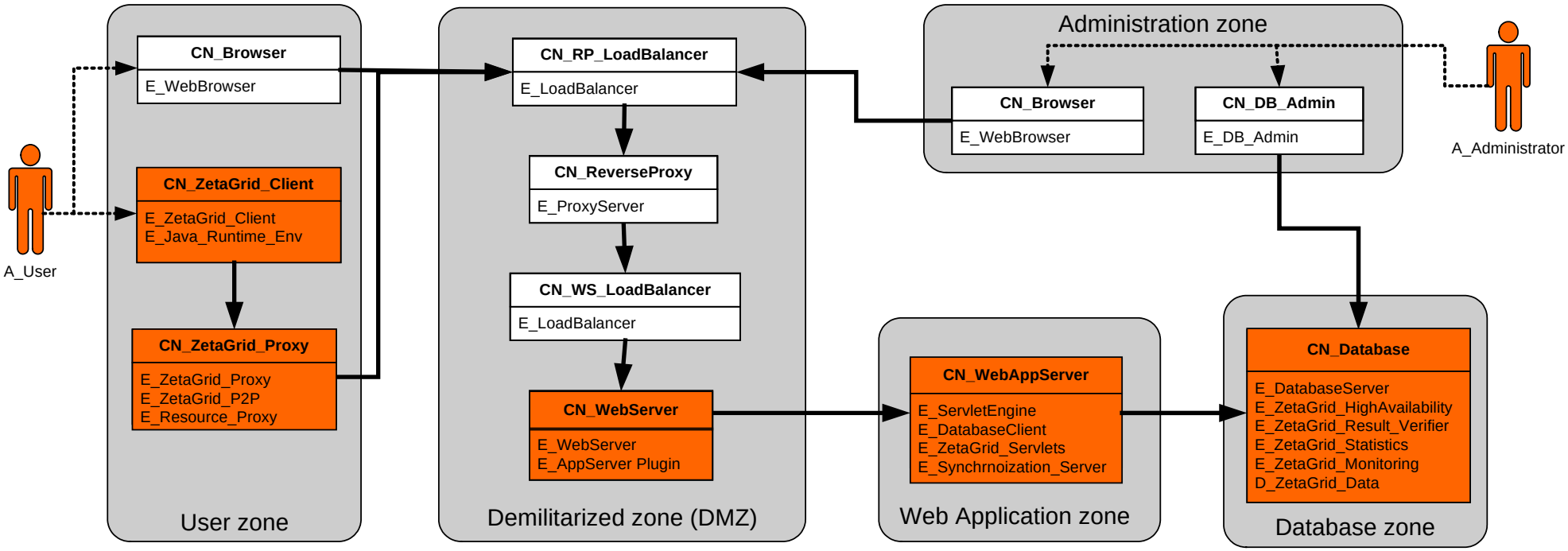
Operational model conceptual level

- OGSA
- Using forward proxies



Questions

Heterogeneity

operating system	processor	computers	percentage	zeros	percentage
AIX	ppc	434	6.50%	5,098,103,500	1.32%
Linux	alpha	6	0.09%	103,100,000	0.03%
Linux	i386	1,523	22.80%	64,756,490,000	16.78%
Linux	ppc	9	0.13%	42,800,000	0.01%
Linux	s390	4	0.06%	451,700,000	0.12%
Linux	sparc	5	0.07%	20,100,000	0.01%
Linux	x86	175	2.62%	24,790,297,900	6.42%
Mac OS X	ppc	30	0.45%	107,000,000	0.03%
SunOS	sparc	39	0.58%	624,400,000	0.16%
SunOS	sparcv9	1	0.01%	9,200,000	0.00%
Windows 2000	x86	2,529	37.86%	164,865,208,500	42.72%
Windows 95	x86	31	0.46%	247,900,000	0.06%
Windows 98	x86	262	3.92%	6,001,500,000	1.56%
Windows Me	x86	84	1.26%	1,941,300,000	0.50%
Windows NT	x86	472	7.07%	72,831,058,100	18.87%
Windows XP	x86	1,075	16.10%	44,016,774,000	11.41%
Σ 16		6,679		385,906,932,000	

Version control (2003/11/11)

version	starting	ending	#WU	%
0100	2001-08-28	2001-09-07	123	0.04
0101	2001-08-30	2001-09-18	1,092	0.12
0102	2001-09-02	2001-09-11	157	0.02
0103	2001-09-04	2001-09-30	3,454	0.32
0107	2001-09-14	2001-10-16	2,444	0.19
0108	2001-09-21	2001-11-19	2,309	0.14
0109	2001-09-25	2001-10-17	1,228	0.10
0110	2001-10-01	2001-12-11	2,374	0.21
0111	2001-10-15	2001-11-04	1,127	0.09
0112	2001-10-22	2001-11-12	703	0.05
0113	2001-10-26	2001-11-20	1,445	0.12
0114	2001-11-02	2001-11-16	1,715	0.14
0115	2001-11-11	2001-11-26	1,777	0.15
0116	2001-11-15	2001-11-21	879	0.07
0117	2001-11-18	2002-01-08	2,293	0.20
0118	2001-11-25	2001-12-16	1,558	0.13
0119	2001-11-30	2002-01-07	4,371	0.38
0120	2001-12-14	2002-02-01	8,433	0.73

version	starting	ending	#WU	%
0121	2001-12-30	2002-02-25	436	0.04
0122	2002-01-04	2002-02-08	6,781	0.57
0123	2002-01-17	2002-06-05	8,654	0.83
0124	2002-01-24	2002-07-24	5,560	0.49
0125	2002-01-26	2002-06-25	9,037	0.82
0126	2002-02-02	2002-08-05	24,916	2.34
0127	2002-02-13	2002-12-10	33,553	3.19
0128	2002-04-17	2002-11-22	32,089	2.96
0129	2002-06-03	2002-08-19	6,106	0.55
0130	2002-06-13	2002-11-29	3,173	0.30
0131	2002-06-18	2003-09-09	182,020	16.20
0132	2002-09-23	2003-10-17	81,614	6.91
0133	2002-12-13	2003-11-10	30,690	2.71
0134	2002-12-26	2003-11-11	36,300	3.38
0135	2002-12-14	2003-11-11	333,759	28.79
0136	2003-02-24	2003-11-11	272,376	25.91
0137	2003-05-05	2003-11-11	5,155	0.48
0138	2003-10-23	2003-11-11	1,836	0.14