

Development of the BSD Professional Lab Exam

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Abstract

Since its inception in 2005, the BSD Certification Group (BSDCG) has had a goal to design and implement a psychometrically valid “hands-on” lab exam as a component of the BSD Professional (BSDP) certification. Early proponents vigorously debated the type and content of the exam. As the BSDCG grew more familiar with the mechanics of certification exam creation, a way forward began to emerge. This paper describes the evolution of the lab exam through concept, design and development, implementation of the beta exams held at BSDCan in May of 2014 and 2015, and future directions.

Concept

By 2008 there was general agreement that the BSDP certification should consist of both a written test and an “hands-on” lab exam. As with the BSD Associate certification, what was needed was a Job Task Analysis (JTA) to determine the scope of knowledge of a practicing senior level BSD system administrator. In October, 2009, the BSDCG released a Job Task Analysis survey, which was publicly available on the Internet for approximately 2 months. Responders from over 30 countries completed the survey and the results were analyzed in detail. The final report “BSD Professional Certification Job Task Analysis Survey Results” was published in March, 2010.¹



Illustration 1: BSDP JTA Report

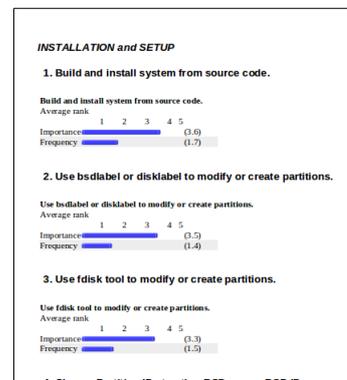


Illustration 2: JTA Item Analysis Detail

The results published in the JTA were used in the development of the “BSD Professional Certification Requirements”² document – the official exam objectives for the BSDP certification. The exam objectives document refined the important and frequent tasks a senior level BSD administrator would commonly be expected to know and organized them in several “Knowledge Domains” in the document. The percentage of each of the Knowledge Domains for the BSD Professional Exam (both written and “hands-on”) were developed by Dr. Sandra Dolan, the psychometrician working with the BSD Certification Group, and are shown in Table 1.

¹ www.bsdcertification.org/downloads/bsd-p-jta-report.pdf

² www.bsdcertification.org/downloads/certreq-bsd-p-en.pdf

Table 1: BSDP Knowledge Domains and Percentages

Domain	Pct of Exam
INSTALLATION and SETUP	5.00%
SECURITY	10.00%
FILESYSTEMS and FILES	8.00%
USERS	6.00%
GENERAL ADMINISTRATION	8.00%
COMMON SERVICES	7.00%
GENERAL NETWORKING	10.00%
BACKUP and RESTORE	16.00%
VIRTUALIZATION	8.00%
LOGGING and MONITORING	16.00%
HIGH AVAILABILITY HIGH PERFORMANCE	7.00%

Lab Exam Design and Development

The next set of tasks were to begin the design and development of the BSDP Exam. Previous work was reviewed during this stage. Hubert Feyrer, one of the founding members of the BSDCG, had developed a similar system (Virtual Unix Lab³) as his PhD thesis and some ideas were borrowed from that paper. Concepts were also borrowed from industry network professional exams, industry firewall exams, and other relevant material.

Developing the exam questions was the next step in the process. The results of the JTA were analyzed, and time estimates were applied. Since the exam was intended to be psychometrically valid, all knowledge domains should be included. A spreadsheet was used to organize all knowledge domains, and order tasks in each domain for importance and frequency. With a goal of having the exam last no more than 180 minutes, a selection of exam tasks that met these requirements was selected (example shown here does not reflect actual exam).

	A	B	C	D	E	F	G	H
1	Minutes	181.8	9		18		14.4	
2	Questions	27	2		4		1	
3			3.1 - Installation and Setup	t	3.2 - Security	t	3.3 - Filesystems and Files	t
4								
7			3.1.13 Compile a customized binary using ports or <u>pkgsrc</u> .	10	3.2.9 Download and apply security patches.	10	3.3.4 Resolve full <u>filesystem</u> issues.	10
8			3.1.9 Configure <u>sysctl</u> values to be loaded at system <u>startup</u> .	10	3.2.22 Utilize daily security checks to monitor system for common security threats.	15	3.3.2 Manually run file system checker and repair tool.	20
9			3.1.11 Configure system to mount remote network <u>filesystems</u> at boot.	15	3.2.17 Configure a firewall with custom packet filtering rules.	20	3.3.3 Restore system files from single user mode.	15

Illustration 3: Analysis of All Tasks in Each Domain

From a practical standpoint, not all tasks would be able to be done within the Lab Exam, so some tasks were assigned to the written test instead.

3 <http://www.feyrer.de/vulab/>

The next step was to determine – at a high level – how this could be accomplished. Eventually, a set of requirements emerged which has continually guided the development of the lab exam:

- 1 – Lab must match the exam objectives.
- 2 – Lab must be proctored.
- 3 – Lab must be “low cost” to BSDCG, candidates, and proctors.
- 4 – Lab must be simple to set up, take down, and administer. Minimal baggage.
- 5 – Lab must focus on “services” not “software products”.
- 6 – Lab must be reliable. No Single Point of Failure at test time.
- 7 – Lab must be secure- before, during and after the exam.
- 8 – Lab must be easy to score (i.e. scoring should be automated).
- 9 – Lab must be doable anywhere- Internet access must not be required.
- 10 – Lab must not be predictable. (Can't preload test results or services.)
- 11 – Lab must be as close to real world requirements as possible.

To deliver a Lab Exam, several ideas were rapidly discussed on the BSDCG mailing list – using an online “Virtual Lab” (proctored), owning or leasing BSDCG lab testing centers, creating an on-site 'single server / multiple X sessions' lab, providing special BSDCG laptops, using a live CD/DVD containing the exam, and several others. Each idea was considered in light of the above requirements. Of the many ideas described, those that relied on candidate hardware were rejected as insecure. Ideas that involved acquiring or renting large numbers of testing centers or expensive equipment were held to be beyond the resources of the BSDCG. That left only two main choices – renting PCs or delivering the exam on dedicated USB drives.

The actual design of the lab environment reflects the need to have separate exam environments for each candidate, but a common network. Design ideas were presented and discussed at BSDCan 2010, and the design was refined over several months in 2013. The beta launch of the BSDP Exam in 2014 used the design shown in Illustration 4:

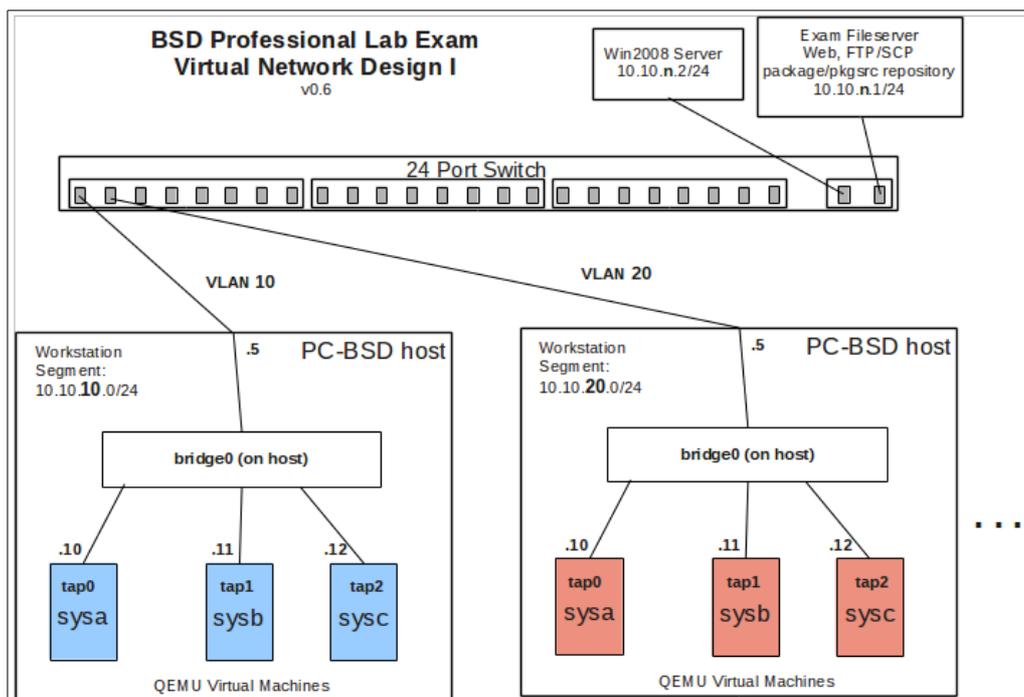


Illustration 4: BSDP Lab Exam Configuration at Beta Launch (BSDCan 2014)

In this instance, there were 10 computers, all configured with a customized version of PC-BSD. Qemu (and Aqemu) were used for virtualization. All computers and two servers were connected to a Cisco 24 port switch. Each machine was in its own VLAN. The servers had a virtual interface in each VLAN, but there was no IP forwarding (no routing between VLANs). No other connectivity, including connectivity to the Internet, was permitted.

Scoring Implementation

Scoring each task was then investigated – what is the best way to score the results in a reliable, repeatable manner? Declarative configuration systems such as Puppet, and cfengine were investigated to see if they could be used to match a required state to a configured state – i.e. have the candidate configure a system according to requirements and run the configuration system to check (test) the results. Such a scoring implementation was possible, but rejected as the configuration systems would have to be installed (either by the candidate, or by the test administrator), and this could potentially pollute or corrupt the system after the candidate completed the exam. Also, compatible versions of these systems were not available for all BSDs in scope for the exam.

An alternative was found in Net::OpenSSH⁴. This perl module allows the developer to write shell commands that are sent to a remote system and to receive command results from those systems. By suitably programming Net::OpenSSH scripts to login, and run tests on each configured virtual machine, the test would be repeatable and reliable across all BSDs. A side benefit is that the Net::OpenSSH scripts are installed on the Exam Fileserver, not on the candidate virtual machines. Illustration 5 shows the scoring design for the Lab Exam.

However, to be psychometrically valid, scoring the exam needed two different tracks. The individual candidate needs immediate results, but the psychometrician needs to have a large pool of results to analyze and maintain for psychometric analysis. A compromise was reached by providing two different scorings – a “provisional” score which is immediately available, and a psychometric report which goes to the psychometrician.

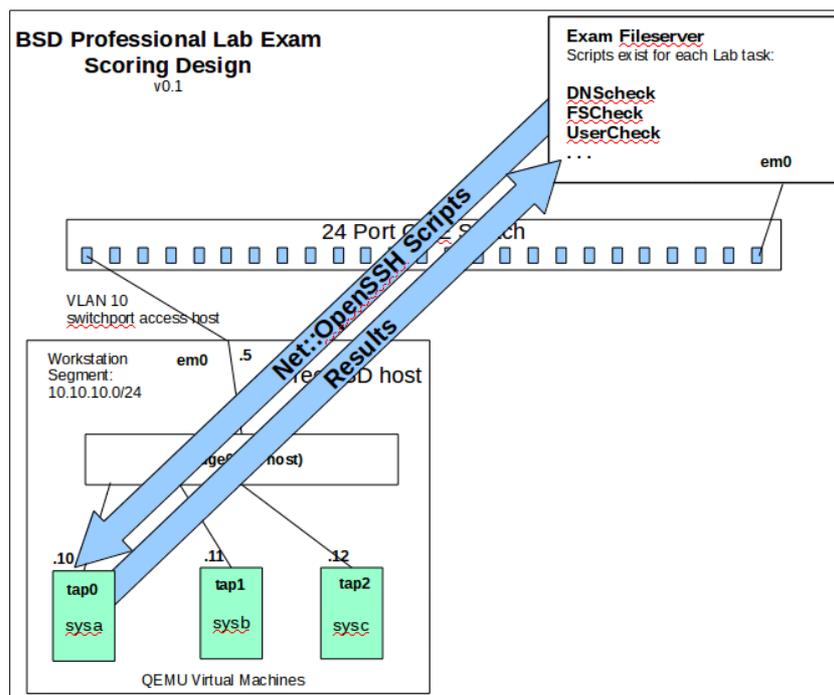


Illustration 5: BSDP Lab Exam Scoring Design

4 search.cpan.org/~salva/Net-OpenSSH-0.62/lib/Net/OpenSSH.pm

The provisional scoring results were dressed up with the perl TAP::Formatter::HTML⁵ module and customized for the Lab Exam (see Illustration 6).

Demo Version

A demonstration version was created for the NYCBUG BSDCon one-day conference held in New York, in February, 2014. The demo used a small set of 5 questions (not real exam questions) and was intended to get feedback from the BSD community prior to the launch of the beta version of the exam. The demo was taken by a number of attendees at the conference and changes were made to presentation and scoring. Illustration 6 shows results from the 2014 BSDCon Exam demo.

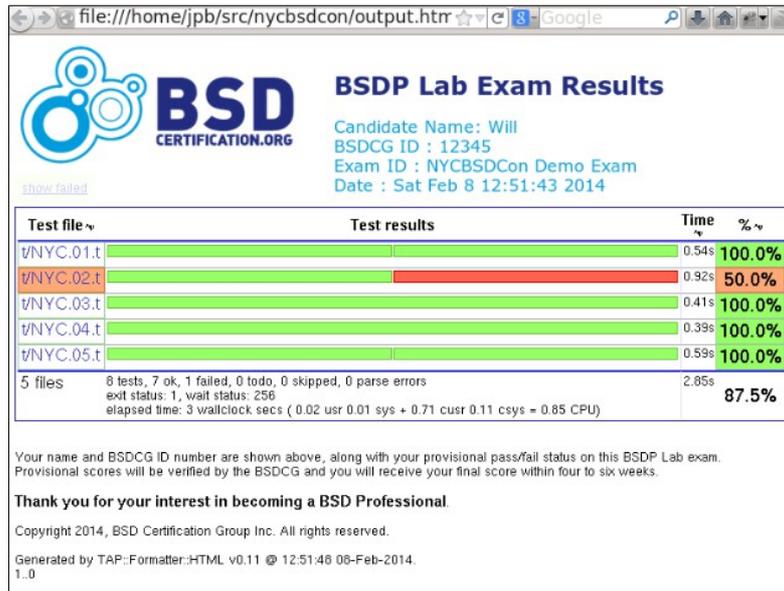


Illustration 6: Sample NYCBSDCon Demo Lab Exam Score Results

Implementation

By the end of February, 2014, all the pieces were designed, and a representative exam was ready to deliver. To get a beta exam ready, the BSDCG decided to combine two ideas – rent PCs, so the candidates would not be able to save results to a local hard disk, and use customized USB boot drives to deliver the desktop environment that included the lab exam. For virtualization, QEMU was chosen for licensing reasons and simplicity of operation.

The USB boot drives were developed around a custom install of PC-BSD. The minimum possible configuration was chosen with the LXDE window manager, and a small set of utilities (Conky, Firefox, and Aqemu). The desktop was set with individual icons for each BSD version supported on the exam, DragonFly BSD, FreeBSD, NetBSD, and OpenBSD.

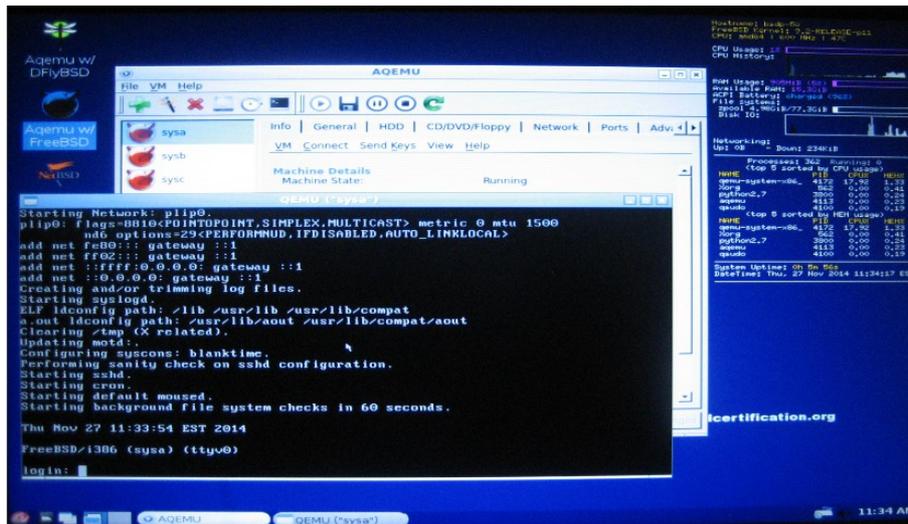


Illustration 7: Screenshot of Lab Exam Workstation

Because PC-BSD supports ZFS out of the box, an implementation goal was to take a snapshot immediately after initial installation, and a snapshot after the conclusion of the exam. The post-exam snapshot can be saved for future reference, while the system can be rolled back to the initial snapshot to be ready for the next exam. However, due to time pressures to get the exam workstations ready, these snapshots were not taken.

Beta Launch

Arrangements were made to launch the beta version of the exam at BSDCan 2014 in Ottawa, Canada. 10 attendees were recruited and agreed to participate. A collection of 10 computers (HP Elite 8400p, 16G RAM, hi-res display) was tested and rented. BIOS's were adjusted for booting from USB, and the displays were adjusted for use with the exam.

Exam books were printed and individually bagged in sealed envelopes to ensure exam security. The exam was completed by all attendees and the launch was successful. Exam booklets were always under the control of the proctor and were permanently secured after the exam.

Lessons Learned

- Several examinees noted that performance was not sufficient, even though the USB drives were rated as USB 3.0. This is under active investigation.
- Generally, there was enough time to get everything done on the exam.
- Some textual changes in the exam booklet were needed to make some questions clearer, particularly to non native English speaking candidates.
- Some scoring scripts did not take into account alternate ways of accomplishing a task.
- Each candidate needs space to spread out - ideally a half meter on either side.

Issues Yet to be Resolved

Within the four BSD projects supported by the exam, some previously common directions are now diverging such as OpenBSD announcing that they are dropping support for loadable kernel modules, and DragonFly BSD discontinuing support for 32 bit versions. Since the exam must match the exam requirements, some adjustments will have to be made to the exam content.

A related concern is the continual progress of all the BSD projects. While most exam requirements do not depend on advanced features, some of the advanced features in 2010 are more common today, such as boot environments, ZFS, and virtualization.

Presenting the exam at conferences does not scale well. BSDCG will have to partner with other BSD minded organizations to deliver the BSD Professional Exam to a wider audience.

More feedback from the BSD community is needed to maintain a high quality exam.

Future Considerations

Hardware improvements have been made – use of SSD disks will replace spindled USB disks. This should provide sufficient performance improvements. A side benefit is that the drives are less susceptible to vibration and jostling.

Aqemu is lagging support for new versions of Qemu and will not be used in future exams as it seems to be unmaintained at present. Replacement options for Aqemu are VirtualBox and VMWare. VMWare, while attractive, is not within the desired licensing framework for the BSDCG. Testing with VirtualBox was unsuccessful. More than 3 virtual machines under heavy load caused continual crashes.

Bhyve, the natively developed virtualization system on FreeBSD is not yet ready for use, but the BSDCG is tracking developments with Bhyve closely and expects that this hypervisor will be usable soon. There is already work being done in the Qemu community to incorporate Bhyve as another hypervisor backend.

The latest version of Qemu at the time of this publication (qemu-devel v2.2.0) will be used with SSD disk support. LXDE provides support for clickable activation of scripts and organizable folders. The latest version of the exam interface will feature clickable icons to start pre-configured instances of Qemu as shown in Illustration 8. Testing with multiple BSDs (3 of each project, shown in Illustration 9) under heavy workload has proven stable enough to use for the exam.

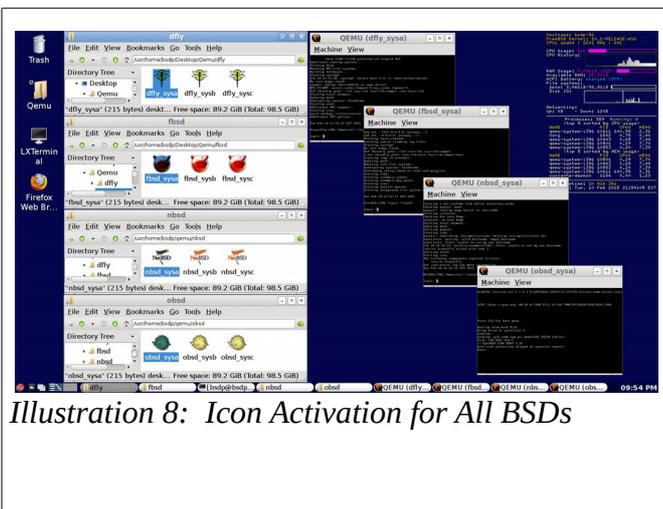


Illustration 8: Icon Activation for All BSDs

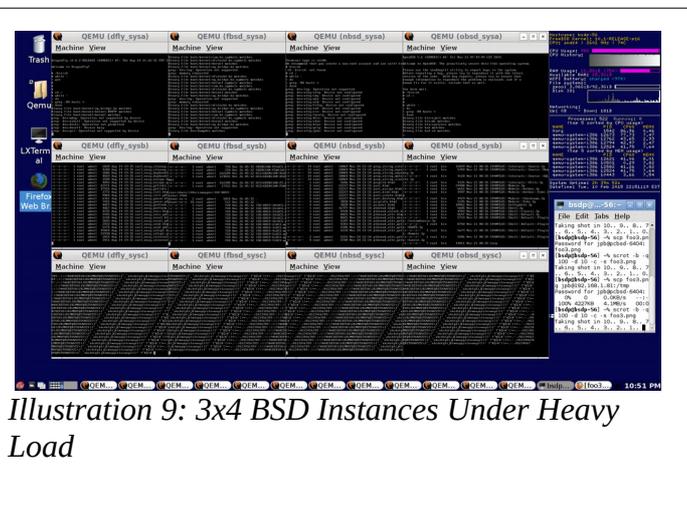


Illustration 9: 3x4 BSD Instances Under Heavy Load

Installation and setup instructions along with configuration information for each BSD will be posted online to enable community participation in delivering a high quality exam.