Dynamic web cache publishing for IaaS clouds using Shoal

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Abstract.

We have developed a highly scalable application, called Shoal, for tracking and utilizing a distributed set of HTTP web caches. Our application uses the Squid HTTP cache. Squid servers advertise their existence to the Shoal server via AMQP messaging by running Shoal Agent. The Shoal server provides a simple REST interface that allows clients to determine their closest Squid cache. Our goal is to dynamically instantiate Squid caches on IaaS clouds in response to client demand. Shoal provides the VMs on IaaS clouds with the location of the nearest dynamically instantiated Squid Cache.

1. Introduction

The CERN Virtual Machine File System (CVMFS) \cite{1} is widely adopted by the High Energy Physics (HEP) community for the distribution of project software. CVMFS is a read-only network file system that provides access to files from a CVMFS Server over HTTP. When CVMFS is used on a cluster of worker nodes, a HTTP web proxy can be used to cache the file system contents, so that all subsequent requests for that file will be delivered from the local HTTP proxy server. Typically, a HEP computing site has a local or regional Squid HTTP web proxy \cite{2}, with the central CVMFS servers located at a laboratory.

The use of IaaS cloud resources is becoming a realistic solution for HEP workloads \cite{3, 4}, and CVMFS is an effective means of providing the software to the virtual machines (VMs). Each VM has a list of the available Squid servers and, in most cases, the Squids are remote. The optimal Squid may be different depending on the location of the cloud. Further, one can imagine dynamically instantiating Squid servers in an opportunistic cloud environment to meet application demand. However, there is currently no mechanism for locating the optimal Squid server. As a result, we have developed Shoal as a new service that can dynamically publish and advertise the available Squid servers.

2. Design

Shoal is divided into three logical modules, a server, an agent, and a client. Each package is uploaded to the Python Package Index \cite{5}. Each component is designed to provide the
functionality of different parts of the system as follows:

**Shoal Server** - is responsible for the following key tasks:

(i) Maintaining a list of active Squid servers in volatile memory and handling AMQP messages sent from active Squid servers.

(ii) Providing a RESTful interface for Shoal Clients to retrieve a list of geographically closest Squid servers.

(iii) Providing basic support for Web Proxy Auto-Discovery Protocol (WPAD).

(iv) Providing a web user interface to easily view Squid servers being tracked.

**Shoal Agent** - is a daemon process run on Squid servers to send an Advanced Message Query Protocol (AMQP) message to Shoal Server on a set interval. Every Squid server wishing to publish its existence runs Shoal Agent on boot. Shoal Agent sends periodic heartbeat messages to the Shoal Server (typically every 30 seconds).

**Shoal Client** - is used by worker nodes to query Shoal Server to retrieve a list of geographically nearest Squid servers via the REST\(^1\) interface. Shoal Client is designed to be simple (less than 100 lines of Python) with no dependencies beyond a standard Python installation.

Figure 1 shows an overview of Shoal and the interaction between each module. Shoal Server runs at a centralized location with a public IP address. For agents (i.e. Squid servers), Shoal Server will consume the heartbeat messages sent and maintain an up-to-date list of active Squids. For clients, Shoal Server will return a list of Squids organized by geographical distance and load. For regular users of Shoal Server, a web server is provided. The web server generates dynamic web pages that display an overview of Shoal. All of the tracked Squid servers are displayed and updated periodically on Shoal Server's web user interface, and all client requests are available in the access logs.

AMQP forms the communications backbone of Shoal Server. All information exchanges between Shoal Agent (Squid Servers) and Shoal Server are done using this protocol, and all messages are routed through a RabbitMQ \[^7\] Server (see figure 2). The exchange will route the message according to a routing key that is set on the agent, and can be dynamic. The message will enter through the exchange and will then be delivered to a specific queue. Shoal Server creates this queue, and will receive all messages sent to the specific exchange. If Shoal Server is not running, all messages sent to the exchange will be discarded as there will be no queue for them to be routed to.

3. Results

Shoal was designed to handle large numbers of requests for the location of Squid caches and to receive continuous updates from many Squid caches. AMQP was selected for the method of communication between Shoal Agent and Shoal Server because of its robustness and the possibility of using message queues to scale system components horizontally.

In order to ensure that the AMQP messaging system would work effectively, a RabbitMQ server was configured on a VM running Scientific Linux 6.3 \[^8\] with 1GB of RAM and a single processing core. The server was sent 10000 Shoal Agent messages per minute and the load average \[^9\] was measured over a period of three minutes. This is equivalent to 5000 Squid Agents contacting the Server every 30 seconds. Figure 3 shows that the system load average during the test was consistently below 0.5, showing that RabbitMQ can handle a significant load with minimal resources.

In order to ensure that Shoal is able to function at the scale required, a number of benchmark tests were performed. The Shoal Server was set up on a 16 core x86_64 machine with 64 GB of

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\(^1\) Representational State Transfer (REST) is a style of software architecture for distributed systems such as the World Wide Web.
Figure 1. Interaction between Shoal modules. Shoal Agents will send regular interval AMQP messages to Shoal Server. Shoal Clients residing on IaaS clouds will query the REST interface on Shoal Server to retrieve a list of the geographically nearest Squid servers.

Figure 2. RabbitMQ message routing between Shoal Agents and Shoal Server. All AMQP [6] messages sent will be routed through the Exchange, and put into a queue. Shoal Server will then consume messages off this queue.
Figure 3. RabbitMQ server load average when it is receiving 10000 AMQP messages/minute. The load average is measured every 10 seconds over a 3 minute period.

Figure 4. The top plot shows the response time of the Shoal Server shown as a function of the number of Squid caches for 1, 100, 200 and 400 concurrent requests. The bottom plot shows the number of requests per second that the Shoal Server can sustain as a function of the number of Squid caches for 1, 100, 200 and 400 concurrent requests.

RAM. A RabbitMQ server was set up on the previously described Virtual Machine. A client machine with the Apache benchmarking tool `ab` [10] was set up to access the Shoal Server with a configurable number of parallel accesses, thus simulating the load from many worker nodes.
The top plot in figure 4 shows the response time of the Shoal Server as a function of the number of Squid servers. The test was conducted using 1, 100, 200, and 400 concurrent connections. We observed that the response times increased roughly linearly with the number of Squid caches, with an approximate slope of 10 ms per 1000 Squid caches.

The bottom plot of figure 4 shows the same benchmark with the data plotted as total number of requests which can be satisfied per second. We see that a single Shoal Server, tracking 800 squid servers, is able to respond to 1000 requests per second. This is equivalent to handling 1.8 million worker nodes requesting their nearest Squid Proxy every 30 minutes, demonstrating that Shoal has sufficient scalability for large-scale deployments.

4. Future Work
The algorithm for finding the nearest Squid server can be substantially improved if a temporary cache is used for different IP subnets. This would allow Shoal Server to use a hash table to store the nearest Squid servers, reducing the majority of RESTful API calls to complete in $O(1)$ time, whereas in its current implementation each web request requires $O(n \log(n))$ time, where $n$ is the number of tracked Squids.

Work is underway to authenticate the Squid Caches registering with the Shoal Server using Secure Socket Layer and X.509 [11] certificates. This measure is necessary to prevent malicious Squids from advertising themselves to the Shoal server. However, it is important to note that the CVMFS repositories are cryptographically signed, so malicious Squid caches pose a denial of service risk for CVMFS rather than a code injection risk.

5. Conclusion
We have developed a highly scalable application, called Shoal, for tracking and utilizing a distributed set of Squid HTTP web caches. We see that a single Shoal Server tracking 800 squid servers is able to respond to 1000 client requests per second. This is equivalent to handling over 1 million worker nodes requesting their nearest Squid Proxy every 30 minutes, demonstrating that Shoal can scale for massive deployments.

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