Monitoring Large-Scale Cloud Systems with Layered Gossip Protocols

Jonathan Stuart Ward
School of Computer Science
University of St Andrews, Scotland
jonathan.stuart.ward@st-andrews.ac.uk

Adam Barker
School of Computer Science
University of St Andrews, Scotland
adam.barker@st-andrews.ac.uk

ABSTRACT
In this paper we propose the development of a cloud monitoring suite to provide scalable and robust lookup, data collection and analysis services for large-scale cloud systems. We propose a multi-tier architecture using a layered gossip protocol to aggregate monitoring information and facilitate lookup, information collection and the identification of redundant capacity. This enables monitoring to be done in situ without the need for significant additional infrastructure to facilitate monitoring services.

1. INTRODUCTION
Cloud computing has become a common means for the deployment of large-scale scientific and enterprise applications. Elasticity is one of the key properties central to the appeal of cloud computing, allowing for large-scale systems to be rapidly provisioned and decommissioned on-demand within a short period of time. With the immense benefits of this paradigm comes a number of challenges, amongst these is the challenge of monitoring.

Monitoring large-scale distributed systems is challenging. It requires substantial engineering effort to identify pertinent information and to obtain, store and process that information in order for it to become useful. Despite the difficulty, monitoring is a crucial component of any large-scale systems deployment. Effective monitoring helps eliminate performance bottlenecks, security flaws and is instrumental in helping engineers make informed decisions about how to improve current systems and how to build new systems. Existing monitoring systems are predominantly intended for monitoring physical servers which are not usually prone to rapid change which occurs through elasticity 2.

Current monitoring systems commonly rely on a central server, or set of servers to pull data from a static pool of monitored servers. This design has two significant issues: (i) centralised data collection substantially increases in cost and decreases in speed as the size of the system increases and (ii) requires reconfiguration to add and remove individual servers. This approach is not ideal for monitoring large scale cloud based systems. Monitoring systems which are designed specifically for the cloud are provisioned as a service; such services typically achieve scalability by utilising conventional centralised tools supported by significant backend infrastructure.

In this paper we propose and evaluate an architecture for performing fully decentralised data collection, analysis and monitoring of cloud virtual machines (VMs). Our approach abandons the traditional monitoring concept in lieu of a decentralised approach based upon a hierarchical gossip algorithm. By leveraging this mechanism we propose an architecture which is highly scalable, and attempts to eliminate the need for additional, dedicated monitoring infrastructure. It is through this approach that we intend to meet the requirements imposed by rapid-elasticity 2 and provide a monitoring system suitable for cloud computing.

2. ARCHITECTURE
Gossip protocols operate analogous to the manner in which gossip spreads over a social network. Gossip style communication is highly responsive, lacks any single point of failure, exerts minimal load on individual processes and is extremely scalable when compared to other methods of group communication 1. Gossip communication has been used to great effect as a basis for broadcast and multicast, database replication, failure detection and aggregation. Here we propose the use of a gossip protocol to facilitate data collection and monitoring in large-scale cloud systems.

Our gossip protocol is layered in order to best exploit the topography of IaaS clouds and reduce the volume of communication overhead. There are three layers: clouds, groups and VMs. The rationale for this hierarchy is rooted in the differences between intra and inter cloud communication. Within clouds there is high bandwidth, low latency and the connection is unmetered. This environment lends itself to the use of rapid, UDP based information dissemination. Between cloud regions this is not as feasible, costs arising from latency and bandwidth metering force communication to be performed in a slower, more reliable fashion. This therefore requires a slower, reliable protocol to synchronise state between regions.

Groups are created based upon the software installed in each VM. Group allocation uses a feature vector to describe the primary applications which the VM operates. Groups are created based upon the proximity of VMs to one another within the feature space. This ensures that related VMs, e.g., all web servers or all Hadoop nodes are grouped together. This scheme is based upon the presupposition that monitoring data from a VM is most relevant to other VMs which are similar to the first.
Each VM maintains a set of peers belonging to the same group and a list of contacts for VMs in other groups in the same cloud region and different cloud regions. At every $T_{gossip}$ a VM selects a number of other VMs from the same group propotional the size of the group, preferentially selecting those with a lower communication latency. The VM will then gossip a message containing a representation of its resource usage including: CPU, memory, disk and network utilisation to each target. Each VM receiving the message selects additional targets and repeats this process. This mechanism attempts to ensure that the resource usage of each VM is aggregated to its group.

Figure 1: Monitoring architecture. Black lines denote frequent intra-group communication, green denotes fast, less frequent inter-group communication and blue lines denotes slow, infrequent inter-cloud communication. Large circles denotes groups, small circles VMs.

Periodically, at a rate proportional to intra-group gossip, the aggregated resource usage of a group is gossiped to every other group by an agreed upon VM. Proportional to this communication is inter-cloud communication whereby the aggregated resource usage of an entire region is gossiped to every other region. Figure 1 illustrates this communication hierarchy. This ensures that every VM is aware of system wide resource usage and serves as a basis for more complex monitoring. This design has significant merit over existing designs which rely upon significant dedicated infrastructure provided either by the user or by the cloud provider. When monitoring a heavily loaded system, self monitoring is not feasible and requires some additional infrastructure to fulfil all monitoring functions. Prior to this point, monitoring can be achieved without additional infrastructure by distributing monitoring functions throughout the monitored system.

3. USE CASE

Our tool is intended to provide monitoring services for large-scale systems hosted on an IaaS cloud such as Amazon EC2 or OpenStack without (or with a reduced) need for additional monitoring infrastructure. A typical use case based on EC2 would involve a web application and associated infrastructure deployed over hundreds of virtual machines amongst three AWS regions. Rather than paying for a monitoring service or deploying additional servers to perform monitoring, our architecture may be deployed over each VM to facilitate monitoring. The required software is installed either at runtime or built directly into the VM image. Once VMs are started, a gossip based overlay network will be constructed over the VM deployment and data collection and monitoring services will be provided through this overlay.

4. EVALUATION

In order to evaluate our architecture we compare our architecture to flat gossip scheme and to a centralised data collection architecture analogous to that used by a number of open source monitoring systems, e.g., Nagios and Ganglia. We evaluate our architecture against other common architectures by way of software based simulation. Figure 2 shows the message rates of each communication scheme. The centralised scheme employed by current monitoring systems is by far the most conservative due to its reliance on unicast. This ensures that messages are kept to a minimum at the cost of the required computation to perform all monitoring functions in a single location. Of the two gossip strategies, the layered gossip method utilised in our architecture has significantly lower message rates due to the grouping method. While having still significantly higher messages rates than that of centralised monitoring systems, our architecture attempts to exploit a tolerable middle ground where increased message rates are an acceptable trade-off in order to achieve decentralised monitoring. While up to 74% more messages are sent using our architecture than conventional centralised tools, in a cloud setting such communication is entirely feasible given the presence of high bandwidth, low latency connections.

5. CONCLUSION AND FUTURE RESEARCH

We have presented a framework for performing self-monitoring in a fully distributed fashion. This architecture has significant merits over existing systems which extensively rely on additional infrastructure to performing monitoring. Future research will investigate the functions which be be built upon the gossip infrastructure and how a full, feature complete monitoring service can be provisioned.

6. REFERENCES

[1] Ken Birman. The Promise, and Limitations, of Gossip Protocols. SIGOPS Oper. Syst. Rev., 41(5):8–13, October 2007.

[2] Jonathan Stuart Ward and Adam Barker. Semantic Based Data Collection for Large Scale Cloud Systems. In Proceedings of the fifth international workshop on Data-Intensive Distributed Computing, DIDC ’12, pages 13–22, New York, NY, USA, 2012. ACM.