Prophasis - An IT Infrastructure Monitoring Solution

Cameron Gray

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School of Informatics

University of Edinburgh

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Abstract

Prophasis is an IT infrastructure monitoring system that is designed to suit small to medium size businesses where a system needs to be intuitive to manage. Management of the entire system can therefore be handled from a single, responsive web interface. It is also suitable as a one-stop tool with support for both time series monitoring in addition to real time alerting. Traditionally two different tools would be needed to gain this level of monitoring.

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Chapter 1

Introduction

1.1 Background

In recent years, almost all businesses have been expanding their IT infrastructure to handle the modern demand for IT systems. As these systems grow and become increasingly important for business operation it is crucial that they are sufficiently monitored to prevent faults and periods of downtime going unnoticed. There is already a large market of tools for monitoring IT systems however they are designed for use on massive scale networks managed by teams of specialised systems administrators. They are therefore complicated to set up and manage and multiple tools are often required to gain a suitable level of monitoring.

For example, tools generally either fall into the category of real time alerting (i.e. telling someone when something breaks) and time series monitoring (i.e. capturing data about the performance of systems and presenting graphs and statistics based on it), there is a large gap in the market for tools that provide both of these in one package. This reduces the time required to manage the system as it eliminates the need to set up and configure two completely separate tools.

These tools are also generally managed and configured through various configuration files split across different machines on the network. This means that in order to efficiently use these tools a configuration management system such as Puppet must be used. In a small business with limited IT resources, a completely self contained system is often preferable.

1.2 Current Landscape

This section will review current IT infrastructure monitoring systems and evaluate them on several points as follows:

- Support for timeseries monitoring and real time alerting
- How they can be configured to monitor custom metrics
- How are alert thresholds defined
- How configuration and custom code is delivered to nodes (if required)
- How the user configures the system
- How dependencies are handled

1.2.1 Nagios

Timeseries monitoring and real time alerting Nagios is primarily focused at real time alerting and therefore has very little in the way of timeseries monitoring. Additional plugins are available which can be used to graph metrics over time but these cannot be used to make decisions on the status of a given system or service. All that is supported in terms of alerting on historical data is to refrain from alerting until a given condition has been observed in the previous n checks, there is no support for alerting based on trends in historical data. Supports basic display of changes in state of hosts/services over time but not individual metrics.

Support for custom metrics Nagios has support for custom metrics through the NRPE (Nagios Remote Plugin Executor) plugin. These plugins can be any sort of executable which prints out a message to represent the data read as well as a specific exit code which defines the status, for example ”OK”, ”Critical” .etc

Alert threshold definition Thresholds for NRPE agents must be set on the remote server itself. These thresholds are passed into the remote plugin as an argument when it is executed and are used internally by the script to output the appropriate alert level.

Code/Config delivery to nodes Nagios does not have any in built functionality to distribute configuration files or plugin code to remote nodes. In order to automate this, additional software such as Puppet would be required.

How the user configures the system Configuration for Nagios is primarily managed through text files stored on disk. Third party configuration tools are available to allow the system to be configured through a web interface. Configuration lives on both the Nagios server as well as on the machines being monitored.

How dependencies are handled Rigid tree - No way to define that a service/host is dependent on a given host OR another host being available. This reduces its usefulness in modern networks where redundancy and failover is commonplace. These are defined in config files that live on the Nagios server.

1.2.2 Icinga 2

Timeseries monitoring and real time alerting Like Nagios, Icinga's primary focus is around real time alerting however it has now introduced support for graphing performance metrics. No support for alerting based on trends in historical data beyond Nagios's idea of a state change changing to HARD once it has been observed n times.

Support for Custom Metrics Custom metrics can be written as scripts in any language as long as they echo a message to describe the status of what they are checkign and use a certain exit code to define the status e.g. ”OK”, ”CRITICAL”, ”WARNING”.etc.

Alert threshold definition Thresholds are passed into the check commands as command line arguments. Therefore they are defined on the machines being monitored individually.

Code/Config delivery to nodes Icinga 2 does not have any built-in mechanism to distribute code and config files to remote hosts. In order for this to be achieved, additional software such as Puppet would be required.

How the user configures the system Configuration is managed through configuration files stored on disk. Configuration files exist both on the Icinga server as well as the nodes being monitored.

How dependencies are handled Same as Nagios with a rigid tree. No way to define a host/service as being dependent on one of several different machines as is common in modern environments with redundancy/failover systems.

1.2.3 Munin

Timeseries monitoring and real time alerting Munin is targeted primarily as a timeseries monitoring tool. It therefore has good functionality for graphing data over time. However, it does not have much power in the way of alerting other than some very basic functionality where plugins must manually send out emails/syslog alerts. This is not really sufficient for any sort of production use and it instead recommended to use a tool such as Nagios and push the data from Munin into it.

Support for custom metrics Munin has a simple interface for custom plugins where a plugin is a simple script that prints out the name and value of the data being collected. This is then served by the Munin node which the Munin server contacts over the network to fetch values from the nodes.

Alert threshold definition Nothing built in, plugins however can create thresholds internally and use them for alerting (as detailed above) although this isn't really the intended use of Munin.

Code/Config delivery to nodes Nothing built in, code and config must be distributed manually or automatically through the use of additional software such as Puppet.

How the user configures the system Configuration is handled through text files stored on disk. These are stored on both the Munin server as well as machines being monitored.

How dependencies are handled No dependency functionality.

1.3 Improvements

Prophasis is designed for use in a small to medium business with limited IT resources. They may have a small IT team with limited resources or may not even have a dedicated IT team at all, instead relying on one or two employees in other roles who manage the business's IT systems on the side of their regular jobs. Therefore the system needs to be quick to deploy and manage with a shallow learning curve. In order to use the system efficiently there should be no requirement for additional tooling to be deployed across the company.

1.3.1 Configuration Management

It should be possible to manage the configuration of the system from a single location. Prophasis therefore provides a responsive web interface where every aspect of the system's operation can be configured, Prophasis then handles distributing this configuration to all other machines in the system in the background. Custom code for plugins is handled in the same way; it is uploaded to the single management machine and is then automatically distributed to the appropriate remote machines when it is required.

1.3.2 Time Series Monitoring & Real Time Alerting

Prophasis provides both the ability to alert administrators in real time when a fault is discovered with the system alongside functionality to collect performance metrics over time and use this data to generate statistics about how the system has been performing. This time series data can be used to both investigate the cause of a failure in post-mortem investigations in addition to being able to be used to predict future failures by looking at trends in the collected data.

1.3.3 Expandability

It is important that a monitoring tool can be expanded to support the monitoring of custom hardware and software. An example of this would be hardware RAID cards. Getting the drive health from these types of devices can range from probing for SMART data all the way to communicating with the card over a serial port. It is therefore crucial that Prophasis can be easily expanded to support custom functionality such as this. Therefore Prophasis supports a system of custom ”plugins” which can be written and uploaded to the monitoring server where they can then be configured to monitor machines. These plugins are designed to be self contained and to follow a well defined and documented structure. This provides scope for a plugin ”marketplace” therefore eliminating the need for every user to implement custom monitoring code for the systems they are using.

Chapter 2

Design

2.1 Technology Choice

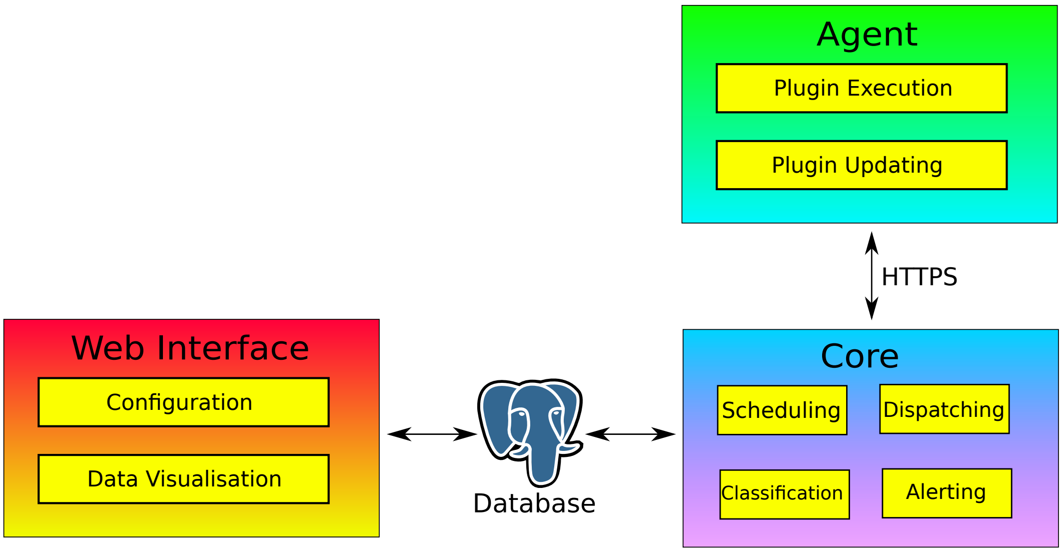
2.1.1 Why Python?

2.1.2 Why HTTPS?

2.2 System Structure

The system is split up into three separate components; Web, Core and Agent. Web and core both share the same relational database allowing data to be shared between them. Figure 2.1 shows the individual components of the system and how they all interact.

Figure 2.1: Diagram showing the layout of the components of the system



2.2.1 Agent

The agent runs on every machine that is being monitored and provides an API for communication with the monitoring server. It listens on port 4048 (by default) and exposes an HTTPS API. This API includes methods to check the version of a plugin currently installed on the agent, a method to push updated plugins to the agent and another method to execute a plugin and to retrieve the value and message produced by it.

The agent's API is authenticated using a long, pre-shared key of which a salted hash is stored on the agent in a configuration file. Being hashed prevents users who may have access to read the configuration file (possibly through misconfiguration) from getting the key to be able to communicate with the agent.

2.2.2 Core

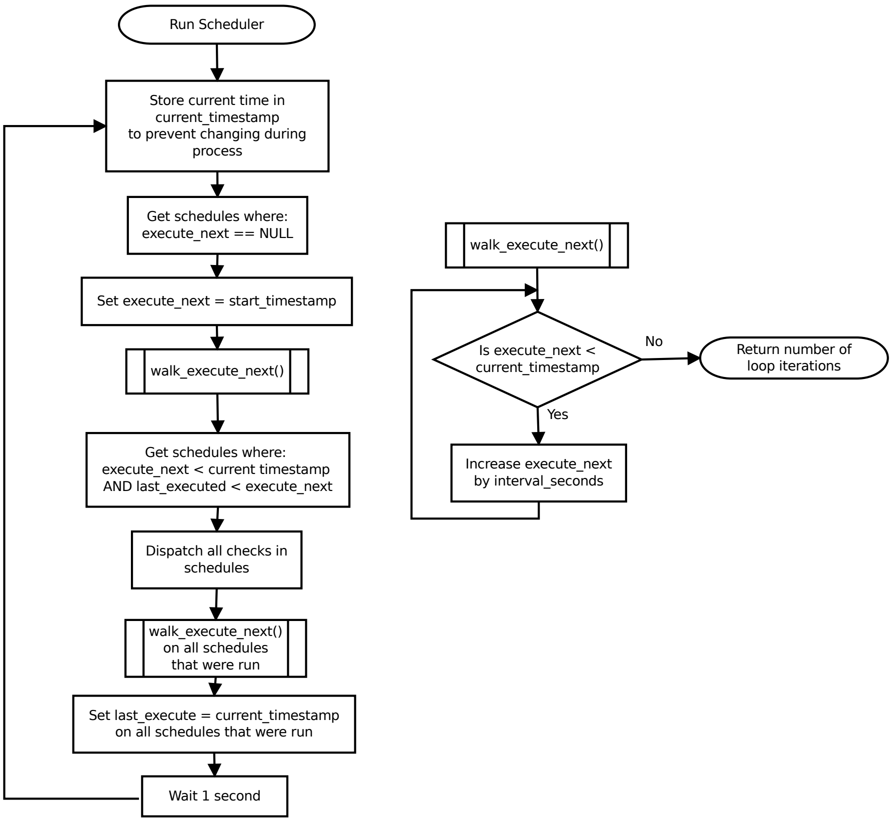
The core runs on the machine that is performing the monitoring, it has several different roles; scheduling, dispatching, classification and alerting.

2.2.2.1 Scheduling

The core is responsible for looking at the schedules stored in the database and executing the appropriate checks on the correct hosts at the correct time. There is a configuration value for "maximum lateness" that defines how late after its defined time slot a check can be executed. The core repeatedly checks the database looking at the intervals for each schedule along with the time at which a given schedule was last executed. If it decides that a schedule is due to be executed it passes this onto the dispatcher.

Figure 2.2 describes how the scheduler operates. Each schedule has a `start_timestamp` which is defined by the user when the schedule is created, an `interval` which is how often the schedule executes and a value for `execute_next` which is the timestamp that the schedule is next to be executed. When the scheduler starts up it first gets all schedules that do not have an `execute_next` value - These are schedules that have never run. It then calls `walk_execute_next` which is a simple algorithm that "fast forwards" the `execute_next` value until it reaches a timestamp that is in the future. It then retrieves any schedules that are due to be executed (`execute_next` is in the past) and executes them, it then calls `walk_execute_next` on each of these to set the `execute_next` value to the time that the schedule should be run again. The algorithm will then wait for 1 second before executing the process again.

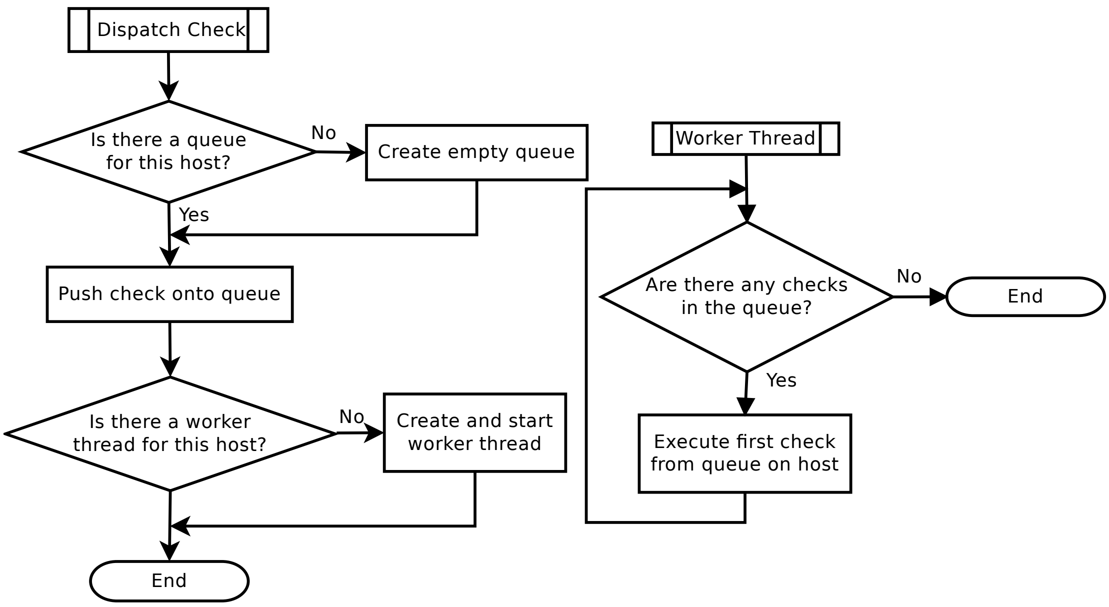
Figure 2.2: Flowchart describing the operation of the scheduler



2.2.2.2 Dispatching

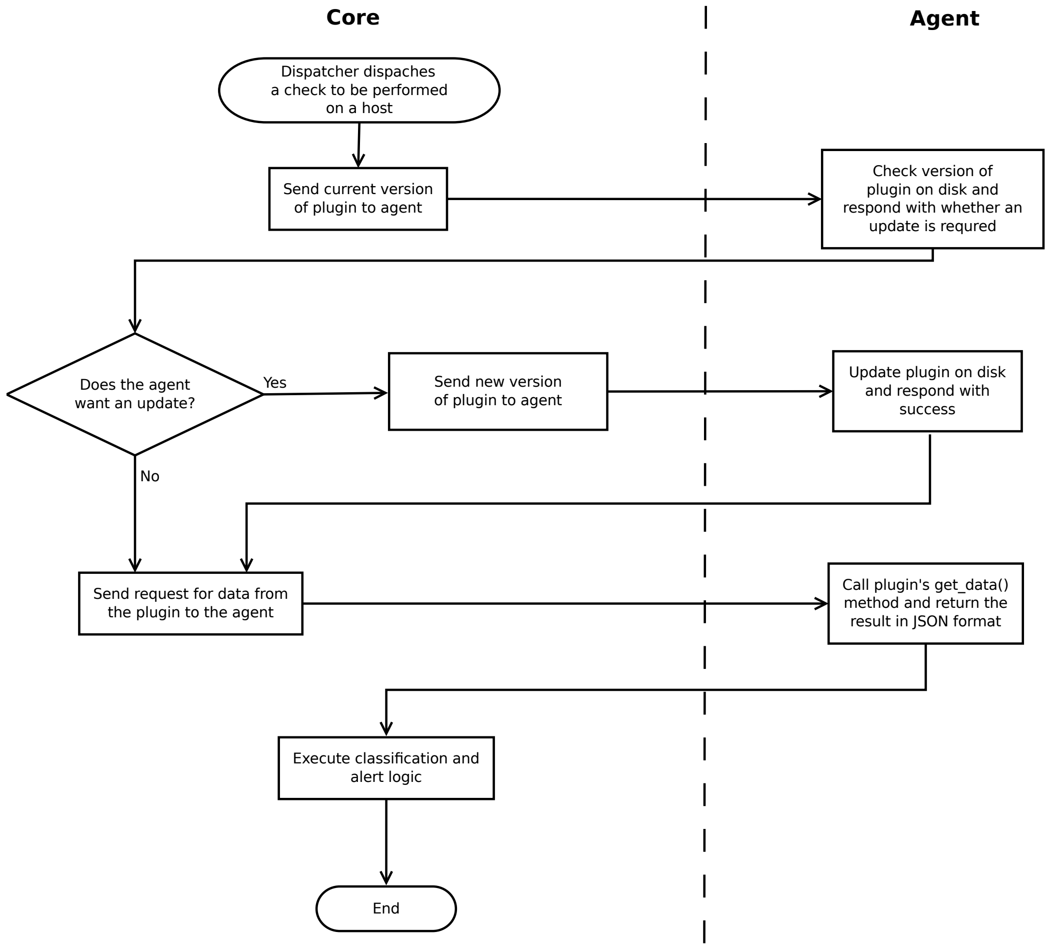
The dispatcher component of the core is responsible for issuing checks to agents when they are due to be run (as decided by the scheduler). Checks may take some time to execute so executing these all in series would all be impractical. The solution for this was for the dispatcher to spawn a process for each agent that it is currently executing checks for. Each process maintains a queue of plugins that are due to be executed and issues them to the agent in the order that they were dispatched. This way only one plugin can be executing on a given agent at any moment in time. This both prevents agents from becoming overwhelmed and means that plugin developers do not need to be concerned about other plugins interfering with their plugin. Figure 2.3 shows the operation of the dispatcher.

Figure 2.3: Flowchart describing the operation of the dispatcher



Communication Between Core and Agent When a check is dispatched, the core and agent communicate to first of all establish if the agent already has the correct version of the plugin due to be executed installed. If it does not then an update will be sent to the agent. Once this is done the core will then request the agent to execute the plugin and the data will be returned for classification. Figure 2.4 describes the communication between the core and the agent.

Figure 2.4: Flowchart describing the communication between the core and the agent when a check is dispatched



2.2.2.3 Classification

When data is collected from an agent, it needs to be classified as ”ok”, ”major”, ”minor”, ”critical” or ”unknown”. Classification is performed by lua code that is stored alongside each plugin. When the core finishes collecting a from an agent it will retrieve the classification code for the plugin and execute it in a sandboxed lua runtime environment. The result of the classification is then stored in the database. The use of Lua code provides total flexibility, classifications can be as simple as comparing values to a threshold or could go as far as looking at previous historical values and classifying based on a trend in the data. Plugins define how many previous historical values they want to classify on (n), the plugin's classifier code is then executed with two Lua tables, one containing the previous n ”values” stored and the other containing the previous n ”messages”.

2.2.2.4 Alerting

Once the core has classified a piece of data, the core now needs to work out whether it needs to send an alert or not. To do this it looks at the previous state for the plugin and host along with the current state. It then looks through the database for alerts that match that state transition and are applicable to the host/plugin combination. If any alerts match it will call the alert module to send the alert out to inform the necessary people about the state change.

2.2.3 Web Interface

Prophasis provides a web interface for both configuring the system and viewing collected data. The interface is designed to be clear and easy to understand for users. It is also built to be fully responsive so will work correctly on mobile device without any loss of functionality. Designing it to be responsive was the aim from the outset as servers often fail when the administrator may not currently be in easy reach of a computer so will need to use a mobile device to investigate the issue.

The web interface will connect to the same database as the core, the web interface will update the configuration data stored in this database and will retrieve the data about hosts.

The web interface provides dashboards for visualisation of data collected from plugins. The collected data can then be displayed using graphs, tables, lists of messages or any other way that suits the type of data collected.

2.3 Monitoring Methodology

2.3.1 Host Management

In Prophasis, a ”host” refers to a single machine that is being monitored. To aid management and organisation, it is possible to organise hosts into ”Host Groups.” These can be comprised of hosts or other groups and can be used in place of hosts when defining services and checks. Hosts can be grouped in various ways such as their role (Webserver, VM Host), hardware configuration (Hardware RAID, Contains GPU), location (Edinburgh Office, Datacenter) or any other way that makes sense given the specific implementation.

2.3.2 Plugins

A ”plugin” is a package that checks a single attribute of a system. For example a plugin could check the CPU load of a given machine or be used to check the health of all the hard drives in a system. Plugins are implemented as Python modules that implement a specific API, they can return both a ”value” (a numerical representation of the data they collected) and/or a ”message” (a string representation of the collected data). Plugins are then packaged in a .tar.gz archive along with a manifest JSON file which contains information about the plugin for use when it is installed.

Plugins are automatically distributed from the core to remote machines and when executed by the agent the value and message are returned to the core for classification and storage in the database.

2.3.3 Checks

A ”check” is a named set of hosts/host groups and a set of plugins to be executed on them. When a check is executed, all of the plugins specified in the check will be executed across all of the hosts specified in the check.

Checks allow logical grouping of various plugins. For example you may have a check for ”Webserver Resource Usage” which will execute plugins to check the CPU load and memory across all hosts in the ”Webservers” host group.

2.3.4 Schedules

A schedule defines when one or more checks are to be executed. Each schedule can contain multiple ”intervals” which define when the check is run. An interval has a start date/time and a time delta that defines how regularly it is to be implemented.

2.3.5 Services

Services can be used to define a more fine grained representation of how the availability of a host affects the performance of the system overall. A service is defined in terms of ”dependencies” and ”redundancy groups”. Each dependency represents a host that must be operational for the service to work. A redundancy group can contain multiple hosts where at least one must be operational for the service to work.

As an example, you may have a ”Website” service that has a dependency on the single router but has a redundancy group containing multiple webservers. Therefore, if the router fails then the website will be marked as failed however if one of the webservers fails but at least one other webserver is still operational, the website service will only be marked as degraded.

The use of services provides a clearer view of the impact of a given failure on the functionality of the network. It also allows alerts to be set up so that they are only triggered when the service functionality is severely impacted and prevents alerts from being sent out for host failures that do not have a severe impact.

2.3.6 Alerts

In Prophasis, alerts are set up to communicate with a specific person/group of people in a certain situation. Alerts are defined in terms of to/from stage changes where an alert will be sent if the state of a host/service changes from one state to another (e.g. ”ok” to ”critical”). These can then be restricted to certain hosts, host groups, services, plugins and checks.

The system supports ”alert modules” - Python modules that are used to send alerts using various methods. Examples of alert modules could be email, SMS or telephone call.

Multiple alerts can be set up to handle different severities of issues. For example, if a redundant service becomes degraded, a SMS or email message may be sufficient but if a service becomes critical it may be desirable to use a telephone call to gain quicker attention.

Chapter 3

Implementation

3.1 Technologies

The vast majority of the system is implemented in Python 3. This allows for a large variety of modules to be used during development. Python is also widely available on UNIX systems and is easy to install on machines where it is not included.

The Python ”Virtual Environment” (Virtualenv) system is also extremely useful in this system. It allows all dependencies to be kept totally separate from the rest of the system, this is particularly important for the agent as it ensures that the agent cannot interfere with the Python environment of the systems it is running on.

3.1.1 Flask Web Framework

The agent and web interface are both built using the Flask web framework which handles routing URLs to the correct Python functions as well as handling request data and building the correct HTTP responses. The agent purely uses the routing and request/response functionality provided by Flask whereas the web interface also uses Flask's bundled templating engine, Jinja2, to render the HTML pages that are displayed to the user. The web interface also uses the Flask-Login package to provide login and user session management functionality.

3.1.2 Tornado HTTP Server

While Flask does provide a built in webserver, it is only designed for development use. In order to provide a production suitable web server for the agent. Tornado uses the uWSGI interface provided by Flask. Tornado was chosen as it can easily be integrated directly into the Flask application and therefore does not require any sort of external webserver to be installed/configured on the system.

3.1.3 SQLAlchemy ORM

All database functionality in Prophasis is handled through the SQLAlchemy ORM which abstracts the database into a set of Python classes (known as models). This not only reduces development time, it also reduces the likelihood of errors as all of the database queries are generated by the library rather than being handwritten. The SQLAlchemy models file can also be shared between both the web interface and the core preventing duplication of database query logic.

3.1.4 Lupa

Lupa provides an interface between the system's Lua runtime and Python. It is used by Prophasis to execute the user provided Lua code that is used to classify the results of checks. A sandboxed Lua environment is configured to prevent this user provided code from performing undesired operations. Sandboxing is covered further in section 3.5.2.1.

3.1.5 PostgreSQL Database

Prophasis has been officially developed to support PostgreSQL databases, however through the use of an ORM it is possible to easily move to different database platforms such as MySQL or Oracle. SQLAlchemy transparently handles the difference between different database platforms when generating its queries.

3.1.6 File path thingy

3.2 Plugin Interface

- Explain structure of a plugin
- UML Diagram?
- Why Lua for classification logic?

3.3 Database Design

3.4 Web Interface

- Go into detail about web structure WRT templates, assets.etc

3.5 Core

3.5.1 Dispatcher

The dispatcher is the system which sends off requests to the agent and waits for the responses back which are then classified and then stored in the database. Due to the time it may take to execute some checks it would be impractical to execute them in series, therefore the dispatcher is multi-threaded.

The Prophasis dispatcher uses Python's built in "multiprocessing" library. This provides various methods to manage processes as well as thread-safe data structures for communicating between them. The dispatcher uses `multithreading.Process` to spawn worker processes and uses `multiprocessing.Queue` to define thread safe queues for passing data into these worker processes.

Fork vs Spawn The multiprocessing library supports three different ways to start a process. By default on UNIX systems it uses `os.fork()` to fork the existing process. This is unsuitable in this situation as the process creates a copy of the already open database connection - this causes conflicts when the workers try to write to the database. The solution to this is to tell the multiprocessing library to use the "spawn" context (the default on Windows) which will create a fresh Python interpreter process, this prevents open handles from being carried over into the child process. Using spawn is comparatively slower than forking the process but since we are only creating schedules are called (which is on a real world timescale), this difference will not be noticeable.

3.5.2 Classification

When data is collected from the agent it needs to be "classified" to determine whether it is "ok", "major", "critical".etc. Classification is done by Lua code that is bundled with the plugin and can also be modified by the user through the web interface. The Lua classification code is stored in the database for ease of modification. The ”lupa” Python library is used to integrate the Lua runtimes into the Python code.

3.5.2.1 Sandboxing

Classification code is executed directly on the machine under the same user as the core. Since this classification code can be changed through the Prophasis web interface it is critical that this code cannot perform malicious operations on the system. In order to resolve this, a Lua sandbox is created. This is done by creating a Lua table with only specific, trusted functions such as `math` and `ipairs` added to it. Lua’s `setfenv` (set function environment) function is then called to ensure that all user provided code is executed inside this sandbox and can therefore not access more risky operating system functions such as file handling.

3.5.2.2 Functions

In order to make developing classification code easier, several predefined functions are provided to handle common operations such as `arrayMax(array)` which will return the maximum value in an array and `arrayContains(array, value)` which returns a boolean defining whether the given value is in the array or not. These functions are stored in a separate Lua file and are included before the user provided classification code before it is executed.

3.5.2.3 Handling Errors

When dealing with user defined code, there is always the potential for errors to occur when the classification code is executed. In this situation the system will automatically fall back and classify the result as ”unknown”. The error will also be logged within Prophasis and can be easily viewed by the user in the web interface’s ”System Logs” area.

- Scheduling
- Multi-threaded dispatcher

3.6 Agent

The agent is implemented using the Flask web framework to expose a HTTPS API that the core communicates with. Requests are sent to the agent using regular HTTP GET and POST requests with information passed using URL parameters or HTTP form data respectively. Responses are formatted as JSON. The Tornado HTTP server is used to handle incoming HTTP connections and communicates with Flask through using uWSGI.

Authentication In order to prevent unauthorised actions being performed on the agent, the core must authenticate with every request. The agent stores a hash of a long authentication key in its configuration file. This key is generated on agent installation and is different for every agent. This ensures that if the key for one agent is obtained, an attacker cannot access every other agent on the network. Storing a hash means that if someone was able to read the agent configuration file they cannot obtain the authentication key which could have allowed them to execute code as the agent's user which may have higher privileges than their user. HTTP's basic access authentication is used which allows a username and password to be easily sent along with an HTTP request, in this situation the username is "core" and the password is the authentication key. A Python decorator (`@requires_auth`) is applied to functions that require authentication which will verify the authentication token and only allow the function to execute if the token is correct, otherwise it will respond with HTTP error 401 (Unauthorised). Using a decorator dad

- Communication
- Authentication

Chapter 4

Testing

- Unit testing
- Use within Tardis & Lynchpin

Chapter 5

Evaluation

Chapter 6

Conclusion