GDP Discovery Service (GDPDS)

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Abstract

The GDP Discovery Service (GDPDS) provides secure discovery and advertisement to clients using the Global Data Plane (GDP). GDPDS servers advertise themselves on local networks, allowing clients to connect to them and advertise their capabilities to other clients connected to the GDP. This allows querying clients to identify clients which they have permission to interact with and which possess specific capabilities. GDPDS is designed to be used by lightweight and mobile clients while still providing the option of client authentication.

Introduction

The Global Data Plane (GDP) provides a flat name space through which clients can communicate using logs. However, without a discovery service, GDP log names and client GUIDs must be obtained out of band. GDPDS provides a system through which clients can identify the log names and GUIDs of other clients which they can communicate with via GDP logs.

Many IoT devices using the GDP may have limited computation and communication capabilities. This presents a requirement that GDPDS be designed to minimize data traffic and client-side computation. At odds with this requirement; however, is the importance of authenticating devices. In order to verify clients' identities as they register with the discovery service, the clients must be capable of using RSA. In order to strike a balance between these competing requirements, the GDPDS is designed to minimize communication with the discovery service. Clients must still use RSA algorithms in order to authenticate themselves, though this is made optional so low-power devices still have the potential to use the service.

Overview of GDPDS

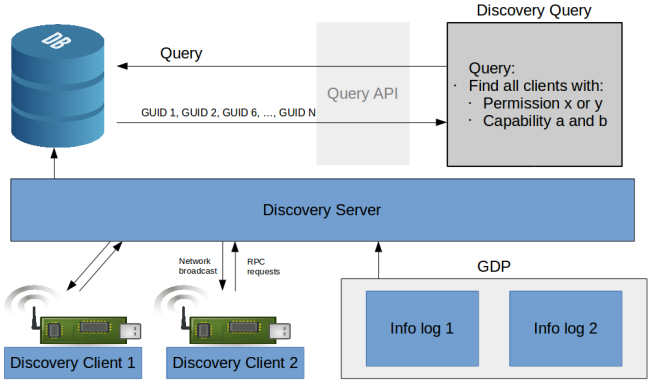
In order to accommodate as wide of a variety of client devices as possible, GDPDS is designed to minimize data transmission over networks and client-side computation.

Clients' information is stored permanently within an “info log” in the GDP so clients need only communicate log names and their GUID to discovery servers rather than needing to send them potentially lengthy lists of their capabilities and allowable permissions. The discovery server then reads the client's corresponding info log and stores its information within a MySQL database. This database can be queried by other clients to identify clients which they wish to communicate with.

GDPDS has also been designed with the consideration that the discovery service needs to verify that the clients which are advertising themselves to GDPDS servers are the clients they claim to be and possess the capabilities they claim to have. This requirement has been achieved using RSA authentication, linking clients to info logs and the ability to verify the validity of info logs by verifying the chain of trust within the certificate each info log has.

The primary contents of the discovery package are the “server” and “client” modules. To ease the process of preparing info logs and querying discovery databases for client information, “client_setup” and “query” modules have also been included within the discovery package. The purpose of each of these modules is summarized below:

- **server:**
  The server module advertises its presence on a local network using Avahi. It accepts client registration requests, reads clients' “info logs,” and logs their information within a MySQL database.
- **client:**
  The client module searches for discovery servers which are broadcasting their presence on a network and sends them a connection request. Once registered with a local discovery server, the client sends periodic renewals to avoid timing out with the discovery service.
- **client_setup:**
  The client_setup module writes a set of capabilities, permissions, and a certificate to an info log. It also generates a client key pair, writing the public key to the info log. Since info logs can describe multiple clients with the same allowable permissions and capabilities, this module can generate multiple client key pairs for a given info log.
- **query:**
  The query module provides an interface for applications to query a discovery database for clients based on their capabilities and allowable permissions.



Implementation

Each client using the GDPDS must have an info log which describes it, and optionally may have an output log and input log which can be used to communicate with other clients via the GDP. When advertising itself to a discovery server, the client must communicate each of its corresponding log names using the GDPDS RPC interface. The discovery server can then read the client's info log, authenticate the client and its info log, and log the client's information in its database.

Data Storage

GDPDS is designed around the idea that clients can best be identified by their GUID, capabilities and allowable permissions. Capabilities, represented as strings, allow for the GDPDS to be used with any ontology. While GUIDs and capabilities are relatively straight forward, the concept of permissions requires more explanation. If clients were queried based solely on capabilities, the query could return many clients which the querier does not have the ability to communicate with because it does not have keys to decrypt information in the queried clients' output logs or does not have the ability to write to clients' input logs. Permissions provide a way for queried clients to pruned based on whether or not a querier has permission to interact with them. Therefore, info logs contain a list of permissions, which, like capabilities, can be any string. A querier can specify which permission strings returned clients must have in order to ensure that the the querier has the ability to interact with the returned clients.

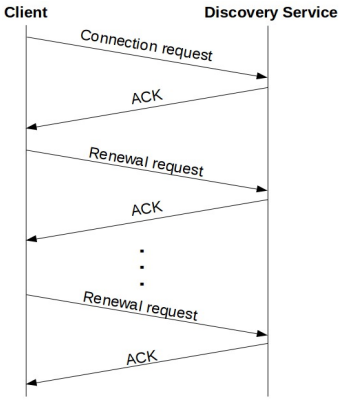
Discovery databases are designed to be ephemeral, storing only the data of clients currently connected to them. Databases can be started and stopped, requiring only a new connection signal from clients to re-log them in their databases. Discovery databases store client information in three MySQL tables:

- **clients:**
  Each entry contains a client's guid, IP address, info log name, input log name, output log name, authentication status and certification status
- **capabilities:**
  Each entry contains a 1 to 1 mapping of a client GUID and a capability
- **permissions:**
  Each entry contains a 1 to 1 mapping of a client GUID and a permission

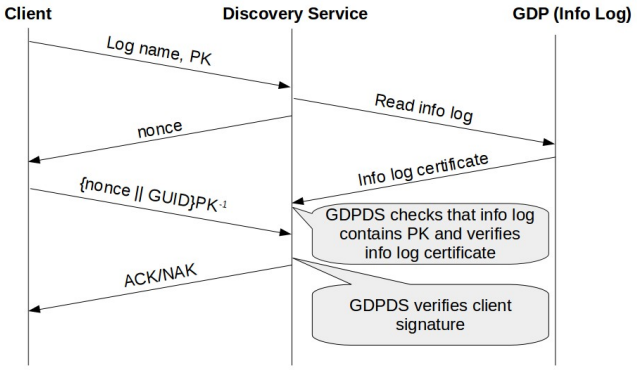
RPC interface

The RPC interface used by the GDPDS is both general and lightweight. Each RPC request contains a field specifying the length of the request name, the type of RPC message (request, ACK or NAK) and the payload length. The first field of the payload must be the request name, allowing the discovery server to dispatch the request to the proper handler.

Since many clients may be mobile, a renewal request must be sent to the discovery service at least once ever 30 seconds. If a renewal is not sent within that time period, the discovery server will delete the client from its database and a new connection request must be sent for the client to re-register.



Security



To prevent attacks where clients impersonate other clients or deceive querying clients into thinking the attacker has capabilities or permissions it does not, GDPDS provides the option for the clients to authenticate themselves and their info logs.

Client authentication creates a verifiable one-to-many mapping between an info log and one or more clients. Since the info log contains the public key of each of the clients it represents, and each client contains its own private key, the discovery server can verify that (a) the client's public key is in the info log and (b) the client possesses the corresponding private key. Client_setup currently uses 2048-bit RSA keys.

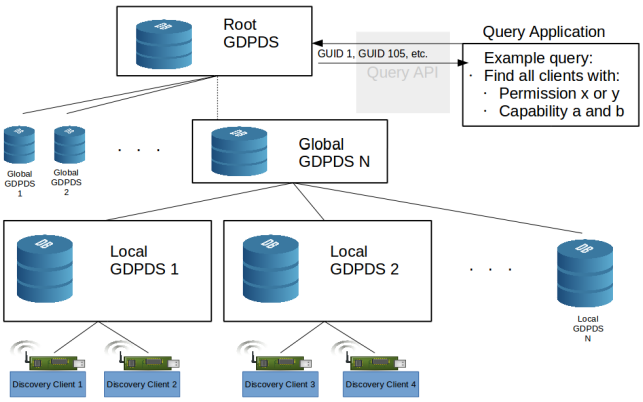
A certificate embedded in an info log creates a chain of trust which verifies the validity of an info log's contents. Info log certificates are X509 certificates which are signed using SHA-256 by a certificate authority during initial info log setup.

While client authentication and info log certificates are optional, the discovery database stores whether or not clients are authenticated and/or certified, so querying clients can prune results which are potentially not authentic. Client authentication and certificates were made optional so low power devices do not have to support RSA computation and to reduce the setup complexity created by the need for certificate authorities.

Future Work

Some of the potential extensions of GDPDS are described below:

- **Global discovery:**
  Currently GDPDS allows for discovery only on local networks. In the future, this could be extended to allow queries to reveal clients anywhere in the GDP. One implementation is a DNS style hierarchy where queries can recursively be processed by discovery servers.



- **Improved query API:**
  Currently the query API provides only a single, basic method for querying client GUIDs based on capabilities and permissions alone. This API could be expanded to allow queries based on IP address, authentication status and certification status. Additionally, the API could be expanded to return other information about clients.
- **Lighter weight client module:**
  The client module could be implemented in C to allow it to run more efficiently on devices with limited resources.
- **Caching of client data**:
  Discovery servers could be augmented to include a cache, which stores info log contents so re-connecting clients would not have to wait for the discovery server to read its info log each time it wishes to advertise itself.
- **Language-independent API:**
  Use of GDPDS currently requires python function calls or command line calls. A language-independent API could be implemented to expand GDPDS's usability.
- **Ontology:**
  GDPDS is a platform which can use any ontology; however, choosing one and layering it on top of GDPDS could improve its usability.

Conclusions

GDPDS uses a novel system of info logs to store information about clients in a way which is ontology-independent allows for easy queries. This system shows how large amounts of information about devices can be obtained without devices needing to communicate it themselves.

Additionally, GDPDS utilizes an authentication system uniquely suited for IoT applications where it is important to verify device identity and capabilities. A major downside of this system; however, is the requirement that devices be capable of using RSA.