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L. Daigle
T. Eklof

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Architecture for Integrated Directory Services - Result from TISDAG

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Abstract

A single, unified, global whitepages directory service remains elusive. Nonetheless, there is increasing call for participation of widely-dispersed directory servers (i.e., across multiple organizations) in large-scale directory services. These services range from national whitepages services, to multi-national indexes of WWW resources, and beyond. Drawing from experiences with the TISDAG (Technical Infrastructure for Swedish Directory Access Gateways) ([TISDAG]) project, this document outlines an approach to providing the necessary infrastructure for integrating such widely-scattered servers into a single service, rather than attempting to mandate a single protocol and schema set for all participating servers to use.

1. Introduction

The TISDAG project addressed the issue of providing centralized access to distributed information for whitepages information on a national scale. The specification of the eventual system is presented in [TISDAG], and [DAGEXP] outlines some of the practical experience already gained in implementing a system of this scale and nature. [DAG-Mesh] considers the issues and possibilities of networking multiple DAG services. Following on from those, this document attempts to describe some of the architectural underpinnings of the system, and propose directions in which the approach can be generalized, within the bounds of applicability.

The proposed architecture inserts a coordinated set of modules between the client access software and participating servers. While the client software interacts with the service at a single entry point, the remaining modules are called upon (behind the scenes) to provide the necessary application support. This may come in the form of modules that provide query proxying, schema translation, lookups, referrals, security infrastructure, etc.

Part of this architecture is an "internal protocol" -- called the "DAG/IP" in the TISDAG project. This document also outlines the perceived requirements for this protocol in the extended DAG.

2.0 Some terminology

Terms used in this document are compliant with those set out in [ALVE]. For the purposes of this document, important distinctions and relationships are defined between applications, services, servers and systems. These are defined as follows:

Application: this is meant in the general sense, as a solution to a particular (set of) user need(s). That is, the definition is not tied to a particular piece of software (as in "application program").

The definition of an application includes the type(s) of information to be exchanged, expected behavior, etc. Thus, a whitepages (search) application may expect to receive a name as input to a query engine, and will return all information associated with the name. By contrast, a specific security application might use the same input name to verify access controls.

Service: an operational system providing (controlled) access to fulfill a particular application’s needs.

One service may be changed by configuring location, access controls, etc. Changing application means changing the service.

Server: a single component offering access through a dedicated protocol, without regard to a specific service (or services) it may be supporting in a given configuration. Typically programmed for a particular application.

System: a set of components with established interconnections.

Thus, a service can be split between several servers. A collection of services (independently, or interrelated through specified agreements) act as an implementation of an application. A system is composed of one or more servers and services.

A "system architecture" identifies specific software components, their behavior, communication channels and messages needed to fulfill a particular service's needs. The TISDAG specification [TISDAG] includes just such a description, defining a software system that will meet the needs of a national whitepages directory service. Here, we outline some of the general principles which lead to that specific system architecture and discuss ways in which the principles can be applied in other contexts.

Looking at this bigger picture, we present a "service architecture", or a framework for assembling components into systems that meet the needs of a wider variety of services. This is not a question of developing one or more new protocols for services, but rather to examine a useful framework of interoperating components. The goal is to reduce the overall number of (specialized) protocols that are developed requiring incorporation of some very general concepts that are common to all protocols.

3.0 TISDAG -- a first implementation, and some generalizations

The Swedish TISDAG project (described in detail in [TISDAG], with some experiences reported in [DAGEXP]) was designed to fulfill the requirements of a particular national directory service. The experience of developing component-based system for providing a directory service through a uniform interface (client access point) provided valuable insight into the possibilities of extending the system architecture so that services with different base requirements can benefit from many of the same advantages.

3.1 Deconstructing the TISDAG architecture

In retrospect, we can describe the TISDAG system architecture in terms of 3 key requirements and 4 basic design principles:

R1. The service had to function with (several) existing client and server software for the white pages application.

R2. It had to be possible to extend the service to accommodate new client and server protocols if and when they became relevant.

R3. The service had to be easily reconfigurable -- to accommodate more machines (load-sharing), etc.

D1. As a design principle, it was important to consider the possibility that queries and information templates (schema) other than the originally-defined set might eventually be supported.

D2. As the architecture was already modular and geared towards extensibility, it seemed important to keep in mind that the same (or a similar) system could be applied to other (non-white pages) applications.

D3. There is an "inside" and an "outside" to the service -- distinguishing between components that are accessible to the world at large and those that are open only to other components of the system.

D4. Internally, there is a single protocol framework for all communications -- this facilitates service support functions (e.g., security of transmission), ensures distributability, and provides the base mechanism for allowing/ascertaining interoperability of components.

The resulting system architecture featured modular component (types) to fulfill a small number of functional roles, interconnected by a generic query-response language. The functional roles were defined as:

CAPs -- "client access points" -- responsible for accepting and responding to incoming requests through programmed and configured behavior -- to translate the incoming query into some set of DAG-internal actions (queries) and dealing with the responses, filtering and recombining them in such a way as to fulfill the client request within the scope of the service. In the TISDAG system, all CAPs are responsible for handling whitepages queries, but the CAPs are distinguished by the application protocol in which they will receive queries (e.g., LDAPv2, LDAPv3, HTTP, etc). To the client software, the TISDAG system appears as a server of that particular protocol. In the more general case, CAPs may be configured to handle different aspects of a service (e.g., authenticated vs. non-authenticated access). While the TISDAG CAPs all had a simple control structure, the more general case would also see CAPs drawing on different subsets of DAG (internal) servers in order to handle different query types. (See the "Operator Service" example, in section 5.2 below).

SAPs -- "service access points" -- responsible for proxying DAG-internal queries to specified services. These are resources drawn upon by other components within the system. Through programmed and configured behavior, they translate queries in the internal protocol into actions against (typically external) servers, taking care of any necessary overhead or differences in interaction style, and converting the responses back into the internal protocol. In the TISDAG system, all SAPs are responsible for handling whitepages queries, but they are distinguished by the

application protocol in which they will access remote services. Further distinctions could be made based on the (remote service's) schema mappings they handle, and other service differentiators.

Internal Servers respond to queries in the internal protocol and provide specific types of information. In the TISDAG system, there is one internal server which provides referral information in response to queries.

Note that all these components are defined by the functional roles they play in the system, not the particular protocols they handle, or even the aspect of the service they are meant to support. That is, a client access point is responsible for handling client traffic, whether its for searching, establishing security credentials, or some other task.

3.2 Some generalizations

The Requirements and Design principles outlined above are not particular to a national whitepages service. They are equally applicable in any application based on a query-response model, in services where multiple protocols need to be supported, and/or when the service requires specialized behavior "behind the scenes". In the TISDAG project, this last was inherent in the way the service first looks for referrals, then makes queries as appropriate. For protocols that don't handle the referral concept natively, the TISDAG system proxies the queries.

Because of its particular application to query-response situations, the term "Directory Access Gateway", or "DAG" still fits as a label for this type of system architecture.

Internet applications are evolving, and require more sophisticated features (e.g., security mechanisms, accounting mechanisms, integration of historical session data). Continuing to develop a dedicated protocol per application type results in encumbered and unwieldy protocols, as each must implement coverage of all of these common aspects. But creating a single multi-application protocol seems unlikely at best. The implicit proposal here is that, rather than overloading protocols to support multiple aspects of a service, those aspects can be managed by breaking the service into multiple supporting components to carry out the specialized tasks of authentication, etc.

3.3 A Word on DAG/IP

In the TISDAG project, the choice was made to use a single "internal protocol" (DAG/IP). The particular protocol used is not relevant to the architecture, but the principle is important. By selecting a single query-response transaction protocol, the needs of the particular application could be mapped onto it in terms of queries and data particular to the application. This makes the internal communications more flexible for configuration to other environments (services, applications).

It is common today to select an existing, widely deployed protocol for transferring commands and data between client and server -- e.g., HTTP. However, apart from any issues of the appropriateness (or inappropriateness) of extending HTTP to this use, the work would have remained to define all the transaction types and data types over that protocol -- the specification of the interaction semantics and syntax.

3.4 Perceived benefits

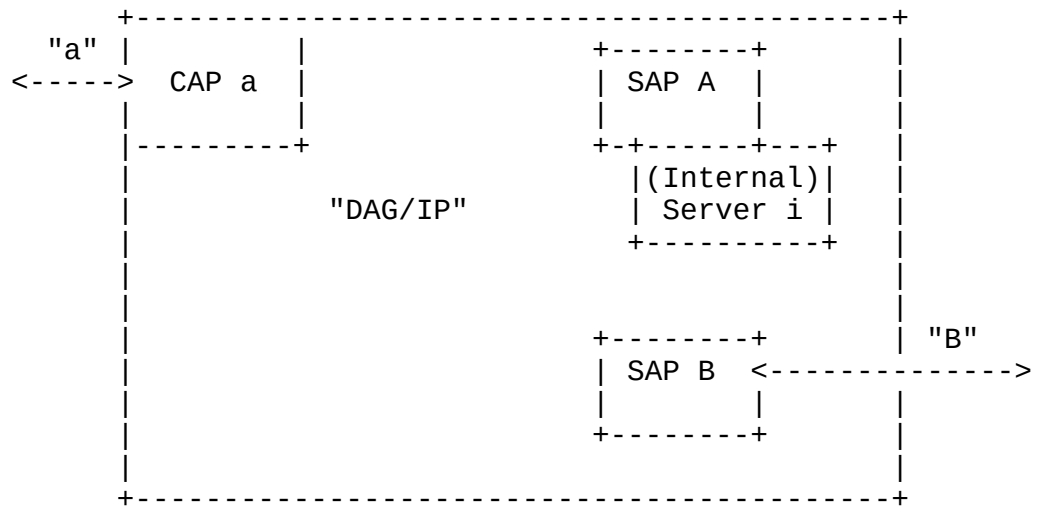
Apart from the potential to divide and conquer service aspects, as described above, this approach has many perceived benefits:

- For multi-protocol environments, it requires on the order of N+M inter-protocol mappings, not NxM.
- distribution of development
- distribution of operation
- eventual possibilities of hooking together different systems (of different backgrounds)
- separation of
    - architectural principles
    - implementation to a specific application
    - configuration for a given service

It is not the goal to say that a standardized system architecture can be made so that single components can be built for all possible applications. However, this approach in general permits the decoupling of access protocols from specific applications, and facilitates the integration of necessary infrastructure independently of access protocol (e.g., referrals, security, lookup services, distribution etc).

4.0 Proposed service architecture

Pictorially, the DAG architecture is as follows:



Note that the bounding box is conceptual -- all components may or may not reside on one server, or a set of servers governed by the provider of the service.

As we saw in the TISDAG project, the provider of this DAG-based service may be only loosely affiliated with the remote services that are used (Whitepages Directory Service Providers (WDSPs) in this case).

4.1 Using the architecture

Building a service on this architecture requires:

Service implementation:

1. definition of the overall application to be supported by the system -- whitepages, web resource indexing, medical information
2. requirements
3. expected behavior

System architecture:

1. nature of deployment -- distributed, security requirements, etc.
2. identification of necessary CAPs -- in terms of access protocols to be supported, different service levels to be provided (e.g., secure and unsecure connections)

3. identification of necessary services -- e.g., proxying to remote information search services, lookup services, "AAA[A]" (Authentication, Authorization, Accounting, [and Access]) servers, etc
4. definition of the transaction process for the service: insofar as the CAPs represent the service to client software, CAP modules manage the necessary transactions with other service modules

Data architecture:

1. selection of schemas to be used (in each protocol)
2. definition of schema and protocol mappings -- into and out of some DAG/IP representation

5.0 Illustrations

5.1 Existing TISDAG Project

Consider the TISDAG project in the light of the above definitions.

Service implementation:

1. A national-scale subset of Whitepages lookups, with specific query types supported: only certain schema attributes were permitted in queries, and the expected behavior was limited in scope.
2. Requirements: the service had to support multiple query protocols (from clients and for servers), and be capable of searching the entire space of data without centralizing the storage of records.
3. Given a query of accepted type, provide referrals to whitepages servers that might have information to fulfill the query; if necessary, proxy the referrals (chain) to retrieve the information for the client.

System architecture:

1. distributable components
2. publicly accessible CAPs in HTTP, SMTP, Whois++, LDAPv2, and LDAPv3
3. referral proxies to Whois++, LDAPv2 and LDAPv3 WDSPs, as well as a referral query service
4. the basic transaction process, uniform across all CAPs, is:
   - query the RI for relevant referrals
   - where necessary, chain referrals through SAPs of appropriate protocol return, in the native protocol, all remaining referrals and data

Data architecture: see the spec.

In the TISDAG project, the above diagram could be mapped as follows:

CAP a	LDAPv2 CAP
SAP A	the Referral Index (RI) interface
Server i	the Referral Index (RI)
SAP B	LDAPv3 SAP

Note that, in the TISDAG project specification, the designation SAP referred exclusively to proxy components designed to deal with external servers. The Referral Index was considered an entity in its own right. However, generalizing the concepts of the TISDAG experience lead to the proposal of regarding all DAG/IP-supporting service components as SAPs, each designed to carry out a particular type of service functionality, and whether the server is managed internally to the DAG system or not is immaterial.

5.2 Operator service

Consider the case of "number portability" -- wherein it is necessary to determine the current service provider of a specific phone number. The basic assumption is that phone numbers are assigned to be globally unique, but are not in any way tied to a specific service provider. Therefore, it is necessary to determine the current service provider for the given number before being able to retrieve current information. For the sake of our illustration, let us assume that the management of numbers is two-tiered -- suppose the system stores (internally) the mapping between these random digit strings and the country in which each was originally activated, but relies on external (country-specific) services to manage the updated information about which service provider currently manages a given number. Then, the service data need only be updated when new numbers are assigned, or national services change their access points.

We can look at a grossly-simplified version of the problem as an illustration of some of the concepts proposed in this service architecture. We couple it with the "name search" facet of the TISDAG example, to underscore that a single service ("operator") may in fact be supported by several disjunct underlying activities.

Service implementation:

1. Retrieving service information for a particular (unstructured) phone number digit sequence, or searching for numbers associated with a particular name (or fragment thereof).
2. Requirements: support IP-telephony through HTTP-based requests, wireless device requests through WAP [WAP].

3. Expected behavior: given a name (fragment), return a list of names and numbers to match the fragment; given a phone number, return appropriately-structured information re. the current service mapping for that number.

System architecture:

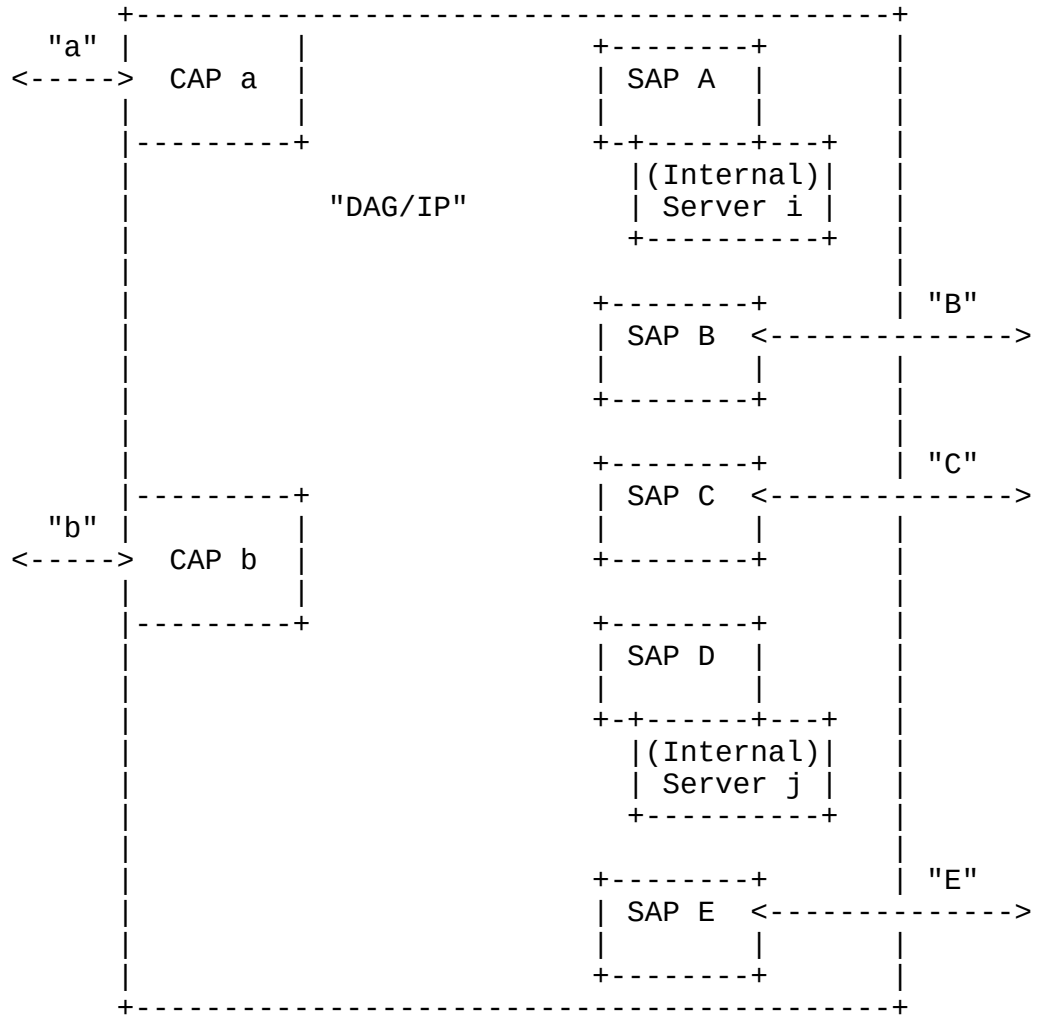
1. Publicly accessible through CAPs; components widely distributed.
2. Need one CAP for HTTP, one for WAP.
3. Support services include: an internal service for lookup of number strings (to identify nation of origin of the number), a proxy to access national services for registration of numbers and service providers, and a proxy for remote service provider for retrieval of detailed information regarding numbers. For the name searching, we also need a referral index over the names, and a proxy to whatever remote servers are managing the whitepages directories.
4. Now, 2 different types of transaction are possible: search for name, or look-up a number. In the name search case, the CAP receives a name or name fragment, looks it up in the internal referral index, and finds associated numbers through external whitepages services (WDSPs). To look-up a number, the CAP first uses the internal look-up service to determine the country of origin of the number, and then uses a SAP to access that nation’s number-service provider directory, and finally uses a different SAP to access the current service provider to determine the information required to make the call.

Data architecture:

[Out of scope for the purposes of this illustration]

Note that some elements of the system architecture are deliberately vague. Per the requirements, no structure is expected in the number string, and therefore the lookup server must maintain an index of number-to-country mappings and relies on an external number-to-service mapping service (in each country). However, were there any structure to the numbers, the lookup server could make use of that structure in the indexing, or in distribution of the index itself. This would have no effect on the CAPs, which have no inherent reliance on how the lookup server performs its task.

Pictorially, the example can be rendered as follows:



where

CAP a	HTTP CAP
CAP b	WAP CAP
SAP A	the number-nation lookup interface
Server i	number-nation lookup server (what country)
SAP B	nation-service lookup SAP (what service provider)
SAP C	service-number information lookup SAP (current service details)
SAP D	referral index interface
Server j	referral index service
SAP E	proxy for chaining queries to remote WDSPs

5.3 Medical application

The service architecture is useful for applications outside the scope of "telecoms". In another hypothetical illustration, consider the case of medical information -- records about patients that may be created and stored at a variety of institutions which they visit. It is not unusual to need to access all information concerning a patient, whether or not the person can recollect (or communicate) conditions that were treated, procedures that were performed, or medical institutions visited. The data may include everything from prescriptions, to X-rays and other images, to incident reports and other elements of medical history, etc. Typically, the information is stored where it is collected (or by an agency authorized by that institution) -- not in a central repository. Any service that looks to provide complete answers to queries must deal with these realities, and clearly must function with a strong security model.

Service implementation:

1. Retrieving all medical information for a particular person.
2. Requirements: must retrieve, or at least locate, all available information, regardless of its storage location; cannot require central repository of information; must implement authorization and access controls. Must support a proprietary protocol for secure connections within hospitals, wireless access for personnel in emergency vehicles (not considered secure access).
3. Expected behavior: given a patient’s national ID, and authorized access by medical personnel in secure locations, determine what kinds of records are available, and where; given a request for a specific type of record, retrieve the record. Given a patient’s national ID, and authorized access from a wireless device, provide information re. any known medical flags (e.g., medicine allergies, conditions, etc).

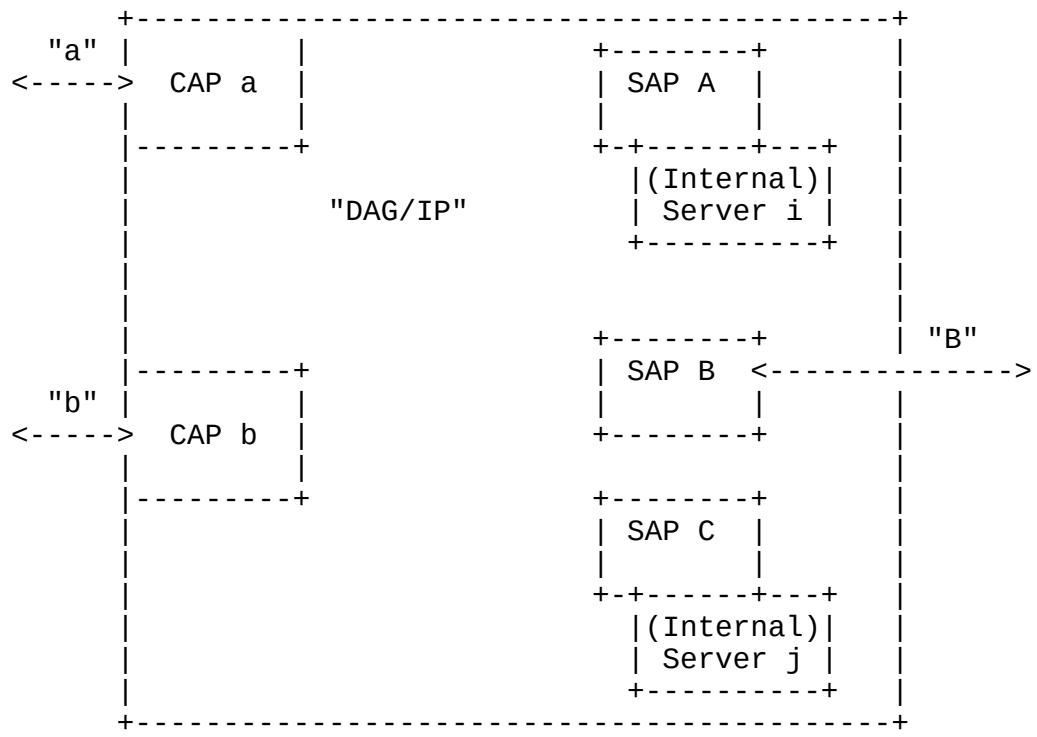
System architecture:

1. Only 2 CAP types are needed, but instances of these will be established at major medical institutions.
2. Need one CAP to support the proprietary protocol, one to support wireless access.
3. Support services include: an internal server to support security authentication and access control determination; an internal server to act as referral index for finding information pertinent to a particular patient, and one or more proxies for accessing remote data storage servers.
4. The basic transaction requires that the first step be to authenticate the end-user and determine access privileges. In the case of wireless access, this last will not involve

a specific lookup, but rather will be set to allow the user to see the list of publicized medical conditions. Depending on the query type, the next step will be to contact the referral index to determine what records exist, and then track down information at the remote sources.

Data architecture:
[Out of scope for the purposes of this illustration]

Pictorially, the example can be rendered as follows:



where

CAP a	CAP for proprietary protocol, secure clients
CAP b	WAP CAP, for roaming access
SAP A	authentication and ACL lookup interface
Server i	authentication and ACL lookup server
SAP B	remote service SAP -- probably LDAPv3
SAP C	Referral Index interface
Server j	Referral Index

6. Requirements for the future DAG/IP

The role of the DAG/IP is less as a query protocol, and more as a framework or structure for carrying basic query-response transactions of different (configurable) types.

Whatever the syntax or grammar, the basic requirements for the DAG/IP include that it be:

- lightweight; CAPs, SAPs should be able to be quite small
- flexible enough to carry queries of different paradigms, results of different types
- able to support authentication, authorization, accounting and audit mechanisms -- not necessarily native to the protocol
- able to support encryption and end-to-end security within the DAG system
- sophisticated enough to allow negotiation of capabilities -- querying & identifying application type supported (e.g., whitepages vs. service location vs. URN resolution), query types supported, results types supported

This also means:

Better support for query-passing/other query semantics (need to balance that against the fact that you don’t want DAG-CAPs/SAPs to have to know a multiplicity of semantic possibilities.

Security infrastructure -- ability to establish security credentials, maintain a secure transaction, and propagate the security information forward in the transaction (don’t want to reinvent the wheel, just want to be able to use it!).

Ability to do lookups, instead of searches -- might mean connecting to different services than the RI and/or presenting things in a slightly different light -- e.g., lookup <blat> in the <foo> space, as opposed to search for all things concerning <blat>.

Ability to access other services -- e.g., Norwegian Directory of Directories [NDD] -- beyond just for specific characteristics of the service (e.g., security).

In short, the model that seems to stand out from these requirements one of a protocol framework that looks after establishing secure and authenticated (authorized, accountable, auditable...) connections, with transaction negotiation facilities. Within that framework, it must be possible to identify transaction types, provide suitable input information (negotiation?) for those transactions, and accept transaction result objects back.

7. Revisiting TISDAG -- for the future

In the light of the above proposals, we can revisit the way the TISDAG CAPs would be defined.

The whitepages-application service known as TISDAG could have SAPs that supported 2 types of query, and 2 types of result sets:

query types:
- token-based
- phrase-based

result types:
- result data
- referrals

The Whois++ CAP would be configured to contact LDAPv2 and LDAPv3 SAPs because they are identified as providing that kind of service (i.e., if referral protocol == LDAPv2 connect to a particular service). The query paradigm will be phrase-oriented -- NOT because the Whois++ CAP understands LDAP, but because that is one of the defined query types.

8. Applicability Limitations

As it stands, this type of service architecture is limited to query-response type transactions. This does account for a broad range of applications and services, although it would be interesting to consider broadening the concept to make it applicable to tunneling other protocols (e.g., to connect a call through a SAP, in the number portability example above).

9. Security Considerations

This document takes a high-level perspective on service architecture, and as such it neither introduces nor addresses security concerns at an implementation level.

A distributed service built following this approach must address issues of authentication of users, authorization for access to material/components of the system, and encryption of links between them, as befits the nature of the information and service provided.

10. Acknowledgements

In discussing this perspective on the evolution of DAG/IP, it seemed to us that the requirements for DAG/IP are falling into line with the proposed text-based directory access protocol that has variously been discussed. Whether it survives in a recognizable form or not :-) some of the above has been drawn from discussions of that protocol with Michael Mealling and Patrik Faltstrom.

The work described in this document was carried out as part of an on-going project of Ericsson. For further information regarding that project, contact:

Bjorn Larsson
bjorn.x.larsson@era.ericsson.se

11. Authors' Addresses

Leslie L. Daigle
Thinking Cat Enterprises

EMail: leslie@thinkingcat.com

Thommy Eklof
Hotsip AB

EMail: thommy.eklof@hotsip.com

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13. Full Copyright Statement

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