

Network Working Group
Request for Comments: 1588
Category: Informational

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ISI
February 1994

WHITE PAGES MEETING REPORT

STATUS OF THIS MEMO

This memo provides information for the Internet community. This memo does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

INTRODUCTION

This report describes the results of a meeting held at the November IETF (Internet Engineering Task Force) in Houston, TX, on November 2, 1993, to discuss the future of and approaches to a white pages directory services for the Internet.

As proposed to the National Science Foundation (NSF), USC/Information Sciences Institute (ISI) conducted the meeting to discuss the viability of the X.500 directory as a practical approach to providing white pages service for the Internet in the near future and to identify and discuss any alternatives.

An electronic mail mailing list was organized and discussions were held via email for two weeks prior to the meeting.

1. EXECUTIVE SUMMARY

This report is organized around four questions:

1) What functions should a white pages directory perform?

There are two functions the white pages service must provide: searching and retrieving.

Searching is the ability to find people given some fuzzy information about them. Such as "Find the Postel in southern California". Searches may often return a list of matches.

While the idea of indexing has been around for some time, such as the IN-ADDR tree in the Domain Name System (DNS), a new acknowledgment of its importance has emerged from these

discussions. Users want fast searching across the distributed database on attributes different from the database structure. Pre-computed indices satisfy this desire, though only for specified searches.

Retrieval is obtaining additional information associated with a person, such as an address, telephone number, email mailbox, or security certificate.

Security certificates (a type of information associated with an individual) are essential for the use of end-to-end authentication, integrity, and privacy in Internet applications. The development of secure applications in the Internet is dependent on a directory system for retrieving the security certificate associated with an individual. For example, the privacy enhanced electronic mail (PEM) system has been developed and is ready to go into service, and is now hindered by the lack of an easily used directory of security certificates. An open question is whether or not such a directory needs to be internally secure.

2) What approaches will provide us with a white pages directory?

It is evident that there are and will be several technologies in use. In order to provide a white pages directory service that accommodates multiple technologies, we should promote interoperation and work toward a specification of the simplest common communication form that is powerful enough to provide the necessary functionality. This "common ground" approach aims to provide the ubiquitous WPS (White Pages Service) with a high functionality and a low entry cost.

3) What are the problems to be overcome?

It must be much easier to be part of the Internet white pages than to bring up a X.500 DSA (Directory Service Agent), yet we must make good use of the already deployed X.500 DSAs. Simpler white pages services (such as Whois++) must be defined to promote multiple implementations. To promote reliable operation, there must be some central management of the X.500 system. A common naming scheme must be identified and documented. A set of index-servers, and indexing techniques, must be developed. The storage and retrieval of security certificates must be provided.

4) What should the deployment strategy be?

Some central management must be provided, and easy to use user interfaces (such as the Gopher "gateway"), must be widely deployed. The selection of a naming scheme must be documented. We should capitalize on the existing infrastructure of already deployed X.500 DSAs. The "common ground" model should be adopted. A specification of the simplest common communication form must be developed. Information about how to set up a new server (of whatever kind) in "cookbook" form should be made available.

RECOMMENDATIONS

1. Adopt the common ground approach. Encourage multiple client and server types, and the standardization of an interoperation protocol between them. The clients may be simple clients, front-ends, "gateways", or embedded in other information access clients, such as Gopher or WWW (World Wide Web) client programs. The interoperation protocol will define message types, message sequences, and data fields. An element of this protocol should be the use of Universal Record Locators (URLs).
2. Promote the development of index-servers. The index-servers should use several different methods both for gathering data for their indices, and for searching their indices.
3. Support a central management for the X.500 system. To get the best advantage of the effort already invested in the X.500 directory system it is essential to provide the relatively small amount of central management necessary to keep the system functioning.
4. Support the development of security certificate storage and retrieval from the white pages service. One practical approach is initially to focus on getting support from the existing X.500 directory infrastructure. This effort should also include design and development of the storage and retrieval of security certificates for other white pages services, such as Whois++.

2. HISTORY

In February 1989, a meeting on Internet white pages service was initiated by the FRICC (Federal Research Internet Coordinating Committee) and the ensuing discussions resulted in RFC 1107 [1] that offered some technical conclusions. Widespread deployment was to have taken place by mid-1992.

RFC 1107: K. Sollins, "Plan for Internet Directory Services", [1].

Several other RFCs have been written suggesting deployment strategies and plans for an X.500 Directory Service.

They are:

RFC 1275: S. Hardcastle-Kille, "Replication Requirements to provide an Internet Directory using X.500", [2].

RFC 1308: C. Weider, J. Reynolds, "Executive Introduction to Directory Services Using the X.500 Protocol", [3].

RFC 1309: C. Weider, J. Reynolds, S. Heker, "Technical Overview of Directory Services Using the X.500 Protocol", [4].

RFC 1430: S. Hardcastle-Kille, E. Huizer, V. Cerf, R. Hobby & S. Kent, "A Strategic Plan for Deploying an Internet X.500 Directory Service", [5].

Also, a current working draft submitted by A. Jurg of SURFnet entitled, "Introduction to White pages services based on X.500", describes why we need a global white pages service and why X.500 is the answer [6].

The North America Directory Forum (NADF) also has done some useful work setting conventions for commercial providers of X.500 directory service. Their series of memos is relevant to this discussion. (See RFC 1417 for an overview of this note series [7].) In particular, NADF standing document 5 (SD-5) "An X.500 Naming Scheme for National DIT Subtrees and its Application for c=CA and c=US" is of interest for its model of naming based on civil naming authorities [8].

Deployment of a X.500 directory service including that under the PSI (Performance Systems International) White Pages Pilot Project and the PARADISE Project is significant, and continues to grow, albeit at a slower rate than the Internet.

3. QUESTIONS

Four questions were posed to the discussion list:

- 1) What functions should a white pages directory perform?
- 2) What approaches will provide us with a white pages directory?
- 3) What are the problems to be overcome?
- 4) What should the deployment strategy be?

3.A. WHAT FUNCTIONS SHOULD A WHITE PAGES DIRECTORY PERFORM?

The basic function of a white pages service is to find people and information about people.

In finding people, the service should work fast when searching for people by name, even if the information regarding location or organization is vague. In finding information about people, the service should retrieve information associated with people, such as a phone number, a postal or email address, or even a certificate for security applications (authentication, integrity, and privacy). Sometimes additional information associated with people is provided by a directory service, such as a list of publications, a description of current projects, or a current travel itinerary.

Back in 1989, RFC 1107 detailed 8 requirements of a white pages service: (1) functionality, (2) correctness of information, (3) size, (4) usage and query rate, (5) response time, (6) partitioned authority, (7) access control, (8) multiple transport protocol support; and 4 additional features that would make it more useful: (1) descriptive naming that could support a yellow pages service, (2) accountability, (3) multiple interfaces, and (4) multiple clients.

Since the writing of RFC 1107, many additional functions have been identified. A White Pages Functionality List is attached as Appendix 1. The problem is harder now, the Internet is much bigger, and there are many more options available (Whois++, Netfind, LDAP (Lightweight Direct Access Protocol), different versions of X.500 implementations, etc.)

A white pages directory should be flexible, should have low resource requirements, and should fit into other systems that may be currently in use; it should not cost a lot, so that future transitions are not too costly; there should be the ability to migrate to something else, if a better solution becomes available; there should be a way to share local directory information with the Internet in a seamless

fashion and with little extra effort; the query responses should be reliable enough and consistent enough that automated tools could be used.

3.B. WHAT APPROACHES WILL PROVIDE US WITH A WHITE PAGES DIRECTORY?

People have different needs, tastes, etc. Consequently, a large part of the ultimate solution will include bridging among these various solutions. Already we see a Gopher to X.500 gateway, a Whois++ to X.500 gateway, and the beginnings of a WWW to X.500 gateway. Gopher can talk to CSO (a phonebook service developed by University of Illinois), WAIS (Wide Area Information Server), etc. WWW can talk to everything. Netfind knows about several other protocols.

Gopher and WAIS "achieved orbit" simply by providing means for people to export and to access useful information; neither system had to provide ubiquitous service. For white pages, if the service doesn't provide answers to specific user queries some reasonable proportion of the time, users view it as a failure. One way to achieve a high hit rate in an exponentially growing Internet is to use a proactive data gathering architecture (e.g., as realized byarchie and Netfind). Important as they are, replication, authentication, etc., are irrelevant if no one uses the service.

There are pluses and minuses to a proactive data gathering method. On the plus side, one can build a large database quickly. On the minus side, one can get garbage in the database. One possibility is to use a proactive approach to (a) acquire data for administrative review before being added to the database, and/or (b) to check the data for consistency with the real world. Additionally, there is some question about the legality of proactive methods in some countries.

One solution is to combine existing technology and infrastructure to provide a good white pages service, based on a X.500 core plus a set of additional index/references servers. DNS can be used to "refer" to the appropriate zone in the X.500 name space, using WAIS or Whois++, to build up indexes to the X.500 server which will be able to process a given request. These can be index-servers or centroids or something new.

Some X.500 purists might feel this approach muddles the connecting fabric among X.500 servers, since the site index, DNS records, and customization gateways are all outside of X.500. On the other hand, making X.500 reachable from a common front-end would provide added incentive for sites to install X.500 servers. Plus, it provides an immediate (if interim) solution to the need for a global site index in X.500. Since the goal is to have a good white pages service,

X.500 purity is not essential.

It may be that there are parts of the white pages problem that cannot be addressed without "complex technology". A solution that allows the user to progress up the ladder of complexity, according to taste, perceived need, and available resources may be a much healthier approach. However, experience to date with simpler solutions (Whois++, Netfind, archie) indicates that a good percentage of the problem of finding information can be addressed with simpler approaches. Users know this and will resist attempts to make them pay the full price for the full solution when it is not needed. Whereas managers and funders may be concerned with the complexity of the technology, users are generally more concerned with the quality and ease of use of the service. A danger in supporting a mix of technologies is that the service may become so variable that the loose constraints of weak service in some places lead users to see the whole system as too loose and weak.

Some organizations will not operate services that they cannot get for free or they cannot try cheaply before investing time and money. Some people prefer a bare-bones, no support solution that only gives them 85 percent of what they want. Paying for the service would not be a problem for many sites, once the value of the service has been proven. Although there is no requirement to provide free software for everybody, we do need viable funding and support mechanisms. A solution can not be simply dictated with any expectation that it will stick.

Finally, are there viable alternative technologies to X.500 now or do we need to design something new? What kind of time frame are we talking about for development and deployment? And will the new technology be extensible enough to provide for the as yet unimagined uses that will be required of directory services 5 years from now? And will this directory service ultimately provide more capabilities than just white pages?

3.C. WHAT ARE THE PROBLEMS TO BE OVERCOME?

There are two classes of problems to be examined; technology issues and infrastructure.

TECHNOLOGY:

How do we populate the database and make software easily available?

Many people suggest that a public domain version of X.500 is necessary before a wide spread X.500 service is operational. The current public domain version is said to be difficult to install and

to bring into operation, but many organizations have successfully installed it and have had their systems up and running for some time. Note that the current public domain program, quipu, is not quite standard X.500, and is more suited to research than production service. Many people who tried earlier versions of quipu abandoned X.500 due to its costly start up time, and inherent complexity.

The ISODE (ISO Development Environment) Consortium is currently developing newer features and is addressing most of the major problems. However, there is the perception that the companies in the consortium have yet to turn these improvements into actual products, though the consortium says the companies have commercial off-the-shelf (COTS) products available now. The improved products are certainly needed now, since if they are too late in being deployed, other solutions will be implemented in lieu of X.500.

The remaining problem with an X.500 White Pages is having a high quality public domain DSA. The ISODE Consortium will make its version available for no charge to Universities (or any non-profit or government organization whose primary purpose is research) but if that leaves a sizeable group using the old quipu implementation, then there is a significant problem. In such a case, an answer may be for some funding to upgrade the public version of quipu.

In addition, the quipu DSA should be simplified so that it is easy to use. Tim Howes' new disk-based quipu DSA solves many of the memory problems in DSA resource utilization. If one fixes the DSA resource utilization problem, makes it fairly easy to install, makes it freely available, and publishes a popular press book about it, X.500 may have a better chance of success.

The client side of X.500 needs more work. Many people would rather not expend the extra effort to get X.500 up. X.500 takes a sharp learning curve. There is a perception that the client side also needs a complex Directory User Interface (DUI) built on ISODE. Yet there are alternative DUIs, such as those based on LDAP. Another aspect of the client side is that access to the directory should be built into other applications like gopher and email (especially, accessing PEM X.509 certificates).

We also need data conversion tools to make the transition between different systems possible. For example, NASA had more than one system to convert.

Searching abilities for X.500 need to be improved. LDAP is great help, but the following capabilities are still needed:

- commercial grade easily maintainable servers with back-end database support.
- clients that can do exhaustive search and/or cache useful information and use heuristics to narrow the search space in case of ill-formed queries.
- index servers that store index information on a "few" key attributes that DUIs can consult in narrowing the search space. How about index attributes at various levels in the tree that capture the information in the corresponding subtree?

Work still needs to be done with Whois++ to see if it will scale to the level of X.500.

An extended Netfind is attractive because it would work without any additional infrastructure changes (naming, common schema, etc.), or even the addition of any new protocols.

INFRASTRUCTURE:

The key issues are central management and naming rules.

X.500 is not run as a service in the U.S., and therefore those using X.500 in the U.S. are not assured of the reliability of root servers. X.500 cannot be taken seriously until there is some central management and coordinated administration support in place. Someone has to be responsible for maintaining the root; this effort is comparable to maintaining the root of the DNS. PSI provided this service until the end of the FOX project [9]; should they receive funding to continue this? Should this be a commercial enterprise? Or should this function be added to the duties of the InterNIC?

New sites need assistance in getting their servers up and linked to a central server.

There are two dimensions along which to consider the infrastructure: 1) general purpose vs. specific, and 2) tight vs. loose information framework.

General purpose leads to more complex protocols - the generality is an overhead, but gives the potential to provide a framework for a wide variety of services. Special purpose protocols are simpler, but may lead to duplication or restricted scope.

Tight information framework costs effort to coerce existing data and to build structures. Once in place, it gives better managability and more uniform access. The tight information framework can be

subdivided further into: 1) the naming approach, and 2) the object and attribute extensibility.

Examples of systems placed in this space are: a) X.500 is a general purpose and tight information framework, b) DNS is a specific and tight information framework, c) there are various research efforts in the general purpose and loose information framework, and d) Whois++ employs a specific and loose information framework.

We need to look at which parts of this spectrum we need to provide services. This may lead to concluding that several services are desirable.

3.D. WHAT SHOULD THE DEPLOYMENT STRATEGY BE?

No solution will arise simply by providing technical specifications. The solution must fit the way the Internet adopts information technology. The information systems that have gained real momentum in the Internet (WAIS, Gopher, etc.) followed the model:

- A small group goes off and builds a piece of software that supplies badly needed functionality at feasible effort to providers and users.
- The community rapidly adopts the system as a de facto standard.
- Many people join the developers in improving the system and standardizing the protocols.

What can this report do to help make this happen for Internet white pages?

Deployment Issues.

- A strict hierarchical layout is not suitable for all directory applications and hence we should not force fit it.
- A typical organization's hierarchical information itself is often proprietary; they may not want to divulge it to the outside world.

It will always be true that Institutions (not just commercial) will always have some information that they do not wish to display to the public in any directory. This is especially true for Institutions that want to protect themselves from headhunters, and sales personnel.

-- There is the problem of multiple directory service providers, but see NADF work on "Naming Links" and their "CAN/KAN" technology [7].

A more general approach such as using a knowledge server (or a set of servers) might be better. The knowledge servers would have to know about which server to contact for a given query and thus may refer to either service provider servers or directly to institution-operated servers. The key problem is how to collect the knowledge and keep it up to date. There are some questions about the viability of "naming links" without a protocol modification.

-- Guidelines are needed for methods of searching and using directory information.

-- A registration authority is needed to register names at various levels of the hierarchy to ensure uniqueness or adoption of the civil naming structure as delineated by the NADF.

It is true that deployment of X.500 has not seen exponential growth as have other popular services on the Internet. But rather than abandoning X.500 now, these efforts, which are attempting to address some of the causes, should continue to move forward. Certainly installation complexity and performance problems with the quipu implementation need solutions. These problems are being worked on.

One concern with the X.500 service has been the lack of ubiquitous user agents. Very few hosts run the ISODE package. The use of LDAP improves this situation. The X.500-gopher gateway has had the greatest impact on providing wide-spread access to the X.500 service. Since adding X.500 as a service on the ESnet Gopher, the use of the ESnet DSA has risen dramatically.

Another serious problem affecting the deployment of X.500, at least in the U.S., is the minimal support given to building and maintaining the necessary infrastructure since the demise of the Fox Project [9]. Without funding for this effort, X.500 may not stand a chance in the United States.

4. REVIEW OF TECHNOLOGIES

There are now many systems for finding information, some of these are oriented to white pages, some include white pages, and others currently ignore white pages. In any case, it makes sense to review these systems to see how they might fit into the provision of an Internet white pages service.

4.A. X.500

Several arguments in X.500's favor are its flexibility, distributed architecture, security, superiority to paper directories, and that it can be used by applications as well as by humans. X.500 is designed to provide a uniform database facility with replication, modification, and authorization. Because it is distributed, it is particularly suited for a large global White Pages directory. In principle, it has good searching capabilities, allowing searches at any level or in any subtree of the DIT (Directory Information Tree). There are DUIs available for all types of workstations and X.500 is an international standard. In theory, X.500 can provide vastly better directory service than other systems, however, in practice, X.500 is difficult, too complicated, and inconvenient to use. It should provide a better service. X.500 is a technology that may be used to provide a white pages service, although some features of X.500 may not be needed to provide just a white pages service.

There are three reasons X.500 deployment has been slow, and these are largely the same reasons people don't like it:

- 1) The available X.500 implementations (mostly quipu based on the ISODE) are very large and complicated software packages that are hard to work with. This is partly because they solve the general X.500 problem, rather than the subset needed to provide an Internet white pages directory. In practice, this means that a portion of the code/complexity is effectively unused.

The LDAP work has virtually eliminated this concern on the client side of things, as LDAP is both simple and lightweight. Yet, the complexity problem still exists on the server side of things, so people continue to have trouble bringing up data for simple clients to access.

It has been suggested that the complexity in X.500 is due to the protocol stack and the ISODE base. If this is true, then LDAP may be simple because it uses TCP directly without the ISODE base. A version of X.500 server that took the same approach might also be "simple" or at least simpler. Furthermore, the difficulty in getting an X.500 server up may be related to finding the data to

put in the server, and so may be a general data management problem rather than an X.500 specific problem.

There is some evidence that eventually a large percentage of the use of directory services may be from applications rather than direct user queries. For example, mail-user-agents exist that are X.500 capable with an integrated DUA (Directory User Agent).

- 2) You have to "know a lot" to get a directory service up and running with X.500. You have to know about object classes and attributes to get your data into X.500. You have to get a distinguished name for your organization and come up with an internal tree structure. You have to contact someone before you can "come online" in the pilot. It's not like gopher where you type "make", tell a few friends, and you're up and running.

Note that a gopher server is not a white pages service, and as noted elsewhere in this report, there are a number of issues that apply to white pages service that are not addressed by gopher.

Some of these problems could be alleviated by putting in place better procedures. It should not any be harder to get connected to X.500 than it is to get connected to the DNS, for example. However, there is a certain amount of complexity that may be inherent in directory services. Just compare Whois++ and X.500. X.500 has object classes. Whois++ has templates. X.500 has attributes. Whois++ has fields. X.500 has distinguished names. Whois++ has handles.

- 3) Getting data to populate the directory, converting it into the proper form, and keeping it up-to-date turns out to be a hard problem. Often this means talking to the administrative computing department at your organization.

This problem exists regardless of the protocol used. It should be easy to access this data through the protocol you're using, but that says more about implementations than it does about the protocol. Of course, if the only X.500 implementation you have makes it really hard to do, and the Whois++ implementation you have makes it easy, it's hard for that not to reflect on the protocols.

The fact that there are sites like University of Michigan, University of Minnesota, Rutgers University, NASA, LBL, etc. running X.500 in serious production mode shows that the problem has more to do with the current state of X.500 software procedures. It takes a lot of effort to get it going. The level of effort required to keep it going is relatively very small.

The yellow pages problem is not really a problem. If you look at it in the traditional phonebook-style yellow pages way, then X.500 can do the job just like the phone book does. Just organize the directory based on different (i.e., non-geographical) criteria. If you want to "search everything", then you need to prune the search space. To do this you can use the Whois++ centroids idea, or something similar. But this idea is as applicable to X.500 as it is to Whois++. Maybe X.500 can use the centroids idea most effectively.

Additionally, it should be noted that there is not one single Yellow Pages service, but that according to the type of query there could be several such as querying by role, by location, by email address.

No one is failing to run X.500 because they perceive it fails to solve the yellow pages problem. The reasons are more likely one or more of the three above.

X.500's extra complexity is paying off for University of Michigan. University of Michigan started with just people information in their tree. Once that infrastructure was in place, it was easy for them to add more things to handle mailing lists/email groups, yellow pages applications like a documentation index, directory of images, etc.

The ESnet community is using X.500 right now to provide a White Pages service; users succeed everyday in searching for information about colleagues given only a name and an organizational affiliation; and yes, they do load data into X.500 from an Oracle database.

LBL finds X.500 very useful. They can lookup DNS information, find what Zone a Macintosh is in, lookup departmental information, view the current weather satellite image, and lookup people information.

LDAP should remove many of the complaints about X.500. Implementing a number of LDAP clients is very easy and has all the functionality needed. Perhaps DAP should be scrapped.

Another approach is the interfacing of X.500 servers to WWW (the interface is sometimes called XWI). Using the mosaic program from the NCSA, one can access X.500 data.

INTERNET X.500

The ISO/ITU may not make progress on improving X.500 in the time frame required for an Internet white pages service. One approach is to have the Internet community (e.g., the IETF) take responsibility for developing a subset or profile of that part of X.500 it will use, and developing solutions for the ambiguous and undefined parts of X.500 that are necessary to provide a complete service.

Tasks this approach might include are:

1. Internet (IETF) control of the base of the core service white pages infrastructure and standard.
2. Base the standard on the 1993 specification, especially replication and access control.
3. For early deployment choose which parts of the replication protocol are really urgently needed. It may be possible to define a subset and to make it mandatory for the Internet.
4. Define an easy and stable API (Application Program Interface) for key access protocols (DAP, LDAP).
5. Use a standard knowledge model.
6. Make sure that high performance implementations will exist for the most important servers, roles principally for the upper layers of the DSA tree.
7. Make sure that servers will exist that will be able to efficiently get the objects (or better the attributes) from existing traditional databases for use at the leaves of the DSA tree.

4.B. WHOIS++

The very first discussions of this protocol started in July 1992. In less than 15 months there were 3 working public domain implementations, at least 3 more are on the way, and a Whois++ front-end to X.500. In addition, the developers who are working on the resource location system infrastructure (URL/URI) have committed to implementing it on top of Whois++ because of its superior search capabilities.

Some of the main problems with getting a White Pages directory going have been: (1) search, (2) lack of public domain versions, (3) implementations are too large, (4) high start up cost, and (5) the implementations don't make a lot of sense for a local directory, particularly for small organizations. Whois++ can and does address all these problems very nicely.

Search is built into Whois++, and there is a strong commitment from the developers to keep this a high priority.

The protocols are simple enough that someone can write a server in 3 days. And people have done it. If the protocols stay simple, it will always be easy for someone to whip out a new public domain server. In this respect, Whois++ is much like WAIS or Gopher.

The typical Whois++ implementation is about 10 megabytes, including the WAIS source code that provides the data engine. Even assuming a rough doubling of the code as additional necessary functionality is built in, that's still quite reasonable, and compares favorably with the available implementations of X.500. In addition, WAIS is disk-based from the start, and is optimized for local searching. Thus, this requires only disk storage for the data and the indexes. In a recent test, Chris Weider used a 5 megabyte source data file with the Whois++ code. The indices came to about another 7 megabytes, and the code was under 10 megabytes. The total is 22 megabytes for a Whois++ server.

The available Whois++ implementations take about 25 minutes to compile on a Sun SPARCstation IPC. Indexing a 5 megabyte data file takes about another 20 minutes on an IPC. Installation is very easy. In addition, since the Whois++ server protocol is designed to be only a front-end, organizations can keep their data in any form they want.

Whois++ makes sense as a local directory service. The implementations are small, install quickly, and the raw query language is very simple. The simplicity of the interaction between the client and the server make it easy to experiment with and to write clients for, something that wasn't true of X.500 until LDAP. In addition, Whois++ can be run strictly as a local service, with integration into the global infrastructure done at any time.

It is true that Whois++ is not yet a fully functional White Pages service. It requires a lot of work before it will be so. However, X.500 is not that much closer to the goal than Whois++ is.

Work needs to be done on replication and authentication of data. The current Whois++ system does not lend itself to delegation. Research is still needed to improve the system and see if it scales well.

4.C. NETFIND

Right now, the white pages service with the most coverage in the Internet is Mike Schwartz' Netfind. Netfind works in two stages: 1) find out where to ask, and 2) start asking.

The first stage is based on a database of netnews articles, UUCP maps, NIC WHOIS databases, and DNS traversals, which then maps organizations and localities to domain names. The second stage consists of finger queries, Whois queries, smtp expns and vrfys, and DNS lookups.

The key feature of Netfind is that it is proactive. It doesn't require that the system administrator bring up a new server, populate it with all kinds of information, keep the information in sync, worry about update, etc. It just works.

A suggestion was made that Netfind could be used as a way to populate the X.500 directory. A tool might do a series of Netfind queries, making the corresponding X.500 entries as it progresses. Essentially, X.500 entries would be "discovered" as people look for them using Netfind. Others do not believe this is feasible.

Another perhaps less interesting merger of Netfind and X.500 is to have Netfind add X.500 as one of the places it looks to find organizations (and people).

A search can lead you to where a person has an account (e.g., law.xxx.edu) only to find a problem with the DNS services for that domain, or the finger service is unavailable, or the machines are not be running Unix (there are lots of VMS machines and IBM mainframes still out there). In addition, there are security gateways. The trends in computing are towards the use of powerful portables and mobile computing and hence Netfind's approach may not work. However, Netfind proves to be an excellent yellow-pages service for domain information in DNS servers - given a set of keywords it lists a set of possible domain names.

Suppose we store a pointer in DNS to a white-pages server for a domain. We can use Netfind to come up with a list of servers to search, query these servers, then combine the responses. However, we need a formal method of gathering white-pages data and informal methods will not work and may even get into legal problems.

The user search phase of Netfind is a short-term solution to providing an Internet white pages. For the longer term, the applicability of the site discovery part of Netfind is more relevant, and more work has been put into that part of the system over the past 2 years than into the user search phase.

Given Netfind's "installed customer base" (25k queries per day, users in 4875 domains in 54 countries), one approach that might make sense is to use Netfind as a migration path to a better directory, and gradually phase Netfind's user search scheme out of existence. The idea of putting a record in the DNS to point to the directory service to search at a site is a good start.

One idea for further development is to have the DNS record point to a "customization" server that a site can install to tailor the way Netfind (or whatever replaces Netfind) searches their site. This would provide sites a choice of degrees of effort and levels of service. The least common denominator is what Netfind presently does: DNS/SMTP/finger. A site could upgrade by installing a customization server that points to the best hosts to finger, or that says "we don't want Netfind to search here" (if people are sufficiently concerned about the legal/privacy issues, the default could be changed so that searches must be explicitly enabled). The next step up is to use the customization server as a gateway to a local Whois, CSO, X.500, or home grown white pages server. In the long run, if X.500 (or Whois++, etc.) really catches on, it could subsume the site indexing part of Netfind and use the above approach as an evolution path to full X.500 deployment. However, other approaches may be more productive. One key to Netfind's success has been not relying on organizations to do anything to support Netfind, however the customization server breaks this model.

Netfind is very useful. Users don't have to do anything to wherever they store their people data to have it "included" in Netfind. But just like archie, it would be more useful if there were a more common structure to the information it gives you, and therefore to the information contained in the databases it accesses. It's this common structure that we should be encouraging people to move toward.

As a result of suggestions made at the November meeting, Netfind has been extended to make use of URL information stored in DNS records. Based on this mechanism, Netfind can now interoperate with X.500, WHOIS, and PH, and can also allow sites to tune which hosts Netfind uses for SMTP or Finger, or restrict Netfind from searching their site entirely.

4.D. ARCHIE

Archie is a success because it is a directory of files that are accessible over the network. Every FTP site makes a "conscious" decision to make the files available for anonymous FTP over the network. The mechanism that archie uses to gather the data is the same as that used to transfer the files. Thus, the success rate is near 100%. In a similar vein, if Internet sites make a "conscious" decision to make white-pages data available over the network, it is possible to link these servers to create a world-wide directory, such as X.500, or build an index that helps to isolate the servers to be searched, Whois++. Users don't have to do anything to their FTP archives to have them included in archie. But everybody recognizes that it could be more useful if only there were some more common structure to the information, and to the information contained in the archives. Archie came after the anonymous FTP sites were in wide-spread use. Unfortunately for white-pages, we are building tools, but there is no data.

4.E. FINGER

The Finger program that allows one to get either information about an individual with an account, or a list of currently logged in users, from a host running the server, can be used to check a suggestion that a particular individual has an account on a particular host. This does not provide an efficient method to search for an individual.

4.F. GOPHER

A "gateway" between Gopher and X.500 has been created so that one can examine X.500 data from a Gopher client. Similar "gateways" are needed for other white pages systems.

4.G. WWW

One extension to WWW would be an attribute type for the WWW URI/URL with the possibility for any client to request from the X.500 server (1) either the locator (thus the client would decide to access or not the actual data), or (2) for client not capable of accessing this data, the data itself (packed) in the ASN.1 encoded result.

This would give access to potentially any piece of information available on the network through X.500, and in the white pages case to photos or voice messages for persons.

This solution is preferable to one consisting of storing this multimedia information directly in the directory, because it allows WWW capable DUIS to access directly any piece of data no matter how large. This work on URIs is not WWW-specific.

5. ISSUES

5.A. DATA PROTECTION

Outside of the U.S., nearly all developed countries have rather strict data protection acts (to ensure privacy mostly) that governs any database on personal data.

It is mandatory for the people in charge of such white pages databases to have full control over the information that can be stored and retrieved in such a database, and to provide access controls over the information that is made available.

If modification is allowed, then authentication is required. The database manager must be able to prevent users from making available unallowed information.

When we are dealing with personal records the issues are a little more involved than exporting files. We can not allow trawling of data and we need access-controls so that several applications can use the directory and hence we need authentication.

X.500 might have developed faster if security issues were not part of the implementation. There is tension between quick lightweight implementations and the attempt to operate in a larger environment with business issues incorporated. The initial belief was that data is owned by the people who put the data into the system, however, most data protection laws appoint the organizations holding the data responsible for the quality of the data of their individuals. Experience also shows that the people most affected by inaccurate data are the people who are trying to access the data. These problems apply to all technologies.

5.B. STANDARDS

Several types of standards are needed: (1) standards for interoperation between different white pages systems (e.g., X.500 and Whois++), (2) standards for naming conventions, and (3) standards within the structured data of each system (what fields or attributes are required and optional, and what are their data types).

The standards for interoperation may be developed from the work now in progress on URLs, with some additional protocol developed to govern the types of messages and message sequences.

Both the naming of the systems and the naming of individuals would benefit from consistent naming conventions. The use of the NADF naming scheme should be considered.

When structured data is exchanged, standards are needed for the data types and the structural organization. In X.500, much effort has gone into the definition of various structures or schemas, and yet few standard schemas have emerged.

There is a general consensus that a "cookbook" for Administrators would make X.500 implementation easier and more attractive. These are essential for getting X.500 in wider use. It is also essential that other technologies such as Whois++, Netfind, and archie also have complete user guides available.

5.C. SEARCHING AND RETRIEVING

The main complaint, especially from those who enjoyed using a centralized database (such as the InterNIC Whois service), is the need to search for all the John Doe's in the world. Given that the directory needs to be distributed, there is no way of answering this question without incurring additional cost.

This is a problem with any distributed directory - you just can't search every leaf in the tree in any reasonable amount of time. You need to provide some mechanism to limit the number of servers that need to be contacted. The traditional way to handle this is with hierarchy. This requires the searcher to have some idea of the structure of the directory. It also comes up against one of the standard problems with hierarchical databases - if you need to search based on a characteristic that is NOT part of the hierarchy, you are back to searching every node in the tree, or you can search an index (see below).

In general:

- the larger the directory the more need for a distributed solution (for upkeep and managability).
- once you are distributed, the search space for any given search MUST be limited.
- this makes it necessary to provide more information as part of the query (and thus makes the directory harder to use).

Any directory system can be used in a manner that makes searching less than easy. With a User Friendly Name (UFN) query, a user can usually find an entry (presuming it exists) without a lot of trouble. Using additional listings (as per NADF SD-5) helps to hide geographic or civil naming infrastructure knowledge requirements.

Search power is a function of DSA design in X.500, not a function of Distinguished Naming. Search can be aided by addition in X.500 of non-distinguishing attributes, and by using the NADF Naming Scheme it is possible to lodge an entry anywhere in the DIT that you believe is where it will be looked for.

One approach to the distributed search problem is to create another less distributed database to search, such as an index. This is done by doing a (non-interactive) pre-search, and collecting the results in an index. When a user wants to do a real time search, one first searches the index to find pointers to the appropriate data records in the distributed database. One example of this is the building of centroids that contain index information. There may be a class of servers that hold indices, called "index-servers".

5.D. INDEXING

The suggestion for how to do fast searching is to do indexing. That is to pre-compute an index of people from across the distributed database and hold that index in an index server. When a user wants to search for someone, he first contacts the index-server. The index-server searches its index data and returns a pointer (or a few pointers) to specific databases that hold data on people that match the search criteria. Other systems which do something comparable to this arearchie (for FTP file archives), WAIS, and Netfind.

5.E. COLLECTION AND MAINTENANCE

The information must be "live" - that is, it must be used. Often one way to ensure this is to use the data (perhaps locally) for something other than white pages. If it isn't, most people won't bother to keep the information up to date. The white pages in the phone book have the advantage that the local phone company is in contact with the listee monthly (through the billing system), and if the address is not up to date, bills don't get delivered, and there is feedback that the address is wrong. There is even better contact for the phone number, since the local phone company must know that for their basic service to work properly. It is this aspect of directory functionality that leads towards a distributed directory system for the Internet.

One approach is to use existing databases to supply the white pages data. It then would be helpful to define a particular use of SQL (Structured Query Language) as a standard interface language between the databases and the X.500 DSA or other white pages server. Then one needs either to have the directory service access the existing database using an interface language it already knows (e.g., SQL), or to have tools that periodically update the directory database from the existing database. Some sort of "standard" query format (and protocol) for directory queries, with "standard" field names will be needed to make this work in general. In a way, both X.500 and Whois++ provide this. This approach implies customization at every existing database to interface to the "standard" query format.

Some strongly believe that the white pages service needs to be created from the bottom up with each organization supplying and maintaining its own information, and that such information has to be the same -- or a portion of the same -- information the organization uses locally. Otherwise the global information will be stale and incomplete.

One way to make this work is to distribute software that:

- is useful locally,
- fits into the global scheme,
- is available free, and
- works on most Unix systems.

With respect to privacy, it would be good for the local software to have controls that make it possible to put company sensitive information into the locally maintained directory and have only a portion of it exported for outsiders.

5.F. NAMING STRUCTURE

We need a clear naming scheme capable of associating a name with attributes, without any possible ambiguities, that is stable over time, but also capable of coping with changes. This scheme should have a clear idea of naming authorities and be able to store information required by authentication mechanisms (e.g., PEM or X.509 certificates).

The NADF is working to establish a National Public Directory Service, based on the use of existing Civil Naming Authorities to register entry owners' names, and to deal with the shared-entry problem with a shared public DIT supported by competing commercial service

providers. At this point, we do not have any sense at the moment as to how [un]successful the NADF may be in accomplishing this.

The NADF eventually concluded that the directory should be organized so entries can be found where people (or other entities) will look for them, not where civil naming authorities would place their archival name registration records.

There are some incompatibilities between use of the NADF Naming Scheme, the White Pages Pilot Naming Scheme, and the PARADISE Naming Scheme. This should be resolved.

5.G. CLAYMAN PROPOSAL

RFC 1107 offered a "strawman" proposal for an Internet Directory Service. The next step after strawman is sometimes called "clayman", and here a clayman proposal is presented.

We assume only white pages service is to be provided, and we let sites run whatever access technologies they want to (with whatever access controls they feel comfortable).

Then the architecture can be that the discovery process leads to a set of URLs. A URL is like an address, but it is a typed address with identifiers, access method, not a protocol. The client sorts the URLs and may discard some that it cannot deal with. The client talks to "meaningful URLs" (such as Whois, Finger, X.500).

This approach results in low entry cost for the servers that want to make information available, a Darwinian selection of access technologies, coalescence in the Internet marketplace, and a white pages service will tend toward homogeneity and ubiquity.

Some issues for further study are what discovery technology to use (Netfind together with Whois++ including centroids?), how to handle non-standard URLs (one possible solution is to put server on top of these (non-standard URLs) which reevaluates the pointer and acts as a front-end to a database), which data model to use (Finger or X.500), and how to utilize a common discovery technology (e.g., centroids) in a multiprotocol communication architecture.

The rationale for this meta-WPS approach is that it builds on current practices, while striving to provide a ubiquitous directory service. Since there are various efforts going on to develop WPS based on various different protocols, one can envisage a future with a meta-WPS that uses a combination of an intelligent user agent and a distributed indexing service to access the requested data from any available WPS. The user perceived functionality of such a meta-WPS

will necessarily be restricted to the lowest common denominator. One will hope that through "market" forces, the number of protocols used will decrease (or converge), and that the functionality will increase.

The degree to which proactive data gathering is permitted may be limited by national laws. It may be appropriate to gather data about which hosts have databases, but not about the data in those databases.

6. CONCLUSIONS

We now revisit the questions we set out to answer and briefly describe the key conclusions.

6.A. WHAT FUNCTIONS SHOULD A WHITE PAGES DIRECTORY PERFORM?

After all the discussion we come to the conclusion that there are two functions the white pages service must provide: searching and retrieving.

Searching is the ability to find people given some fuzzy information about them. Such as "Find the Postel in southern California". Searches may often return a list of matches.

The recognition of the importance of indexing in searching is a major conclusion of these discussions. It is clear that users want fast searching across the distributed database on attributes different from the database structure. It is possible that pre-computed indices can satisfy this desire.

Retrieval is obtaining additional information associated with a person, such as address, telephone number, email mailbox, and security certificate.

This last, security certificates, is a type of information associated with an individual that is essential for the use of end-to-end authentication, integrity, and privacy, in Internet applications. The development of secure application in the Internet is dependent on a directory system for retrieving the security certificate associated with an individual. The PEM system has been developed and is ready to go into service, but is now held back by the lack of an easily used directory of security certificates.

PEM security certificates are part of the X.509 standard. If X.500 is going to be set aside, then other alternatives need to be explored. If X.500 distinguished naming is scrapped, some other structure will need to come into existence to replace it.

6.B. WHAT APPROACHES WILL PROVIDE US WITH A WHITE PAGES DIRECTORY?

It is clear that there will be several technologies in use. The approach must be to promote the interoperation of the multiple technologies. This is traditionally done by having conventions or standards for the interfaces and communication forms between the different systems. The need is for a specification of the simplest common communication form that is powerful enough to provide the necessary functionality. This allows a variety of user interfaces on any number of client systems communicating with different types of servers. The IETF working group (WG) method of developing standards seems well suited to this problem.

This "common ground" approach aims to provide the ubiquitous WPS with a high functionality and a low entry cost. This may be done by singling out issues that are common for various competing WPS and coordinate work on these in specific and dedicated IETF WGs (e.g., data model coordination). The IETF will continue development of X.500 and Whois++ as two separate entities. The work on these two protocols will be broken down in various small and focussed WGs that address specific technical issues, using ideas from both X.500 and Whois++. The goal being to produce common standards for information formats, data model and access protocols. Where possible the results of such a WG will be used in both Whois++ and X.500, although it is envisaged that several WGs may work on issues that remain specific to one of the protocols. The IDS (Integrated Directory Services) WG continues to work on non-protocol specific issues. To achieve coordination that leads to convergence rather than divergence, the applications area directorate will provide guidance to the Application Area Directors as well as to the various WGs, and the User Services Area Council (USAC) will provide the necessary user perspective.

6.C. WHAT ARE THE PROBLEMS TO BE OVERCOME?

There are several problems that can be solved to make progress towards a white pages service more rapid. We need:

To make it much easier to be part of the Internet white pages than bringing up a X.500 DSA, yet making good use of the already deployed X.500 DSAs.

To define new simpler white pages services (such as Whois++) such that numerous people can create implementations.

To provide some central management of the X.500 system to promote good operation.

To select a naming scheme.

To develop a set of index-servers, and indexing techniques, to provide for fast searching.

To provide for the storage and retrieval of security certificates.

6.D. WHAT SHOULD THE DEPLOYMENT STRATEGY BE?

We should capitalize on the existing infrastructure of already deployed X.500 DSAs. This means that some central management must be provided, and easy to use user interfaces (such as the Gopher "gateway"), must be widely deployed.

- Document the selection of a naming scheme (e.g., the NADF scheme).
- Adopt the "common ground" model. Encourage the development of several different services, with a goal of interworking between them.
- Develop a specification of the simplest common communication form that is powerful enough to provide the necessary functionality. The IETF working group method of developing standards seems well suited to this problem.
- Make available information about how to set up new servers (of what ever kind) in "cookbook" form.

7. SUMMARY

While many issues have been raised, there are just a few where we recommend the action be taken to support specific elements of the overall white pages system.

RECOMMENDATIONS

1. Adopt the common ground approach - give all protocols equal access to all data. That is, encourage multiple client and server types, and the standardization of an interoperation protocol between them. The clients may be simple clients, front-ends, "gateways", or embedded in other information access clients, such as Gopher or WWW client programs. The interoperation protocol will define some message types, message sequences, and data fields. An element of this protocol should be the use of URLs.
2. Promote the development of index-servers. The index-servers should use several different methods of gathering data for their indices, and several different methods for searching their indices.
3. Support a central management for the X.500 system. To get the best advantage of the effort already invested in the X.500 directory system it is essential to provide the relatively small amount of central management necessary to keep the system functioning.
4. Support the development of security certificate storage and retrieval from the white pages service. The most practical approach is to initially focus on getting this supported by the existing X.500 directory infrastructure. It should also include design and development of the storage and retrieval of security certificates in other white pages services, such as Whois++.

8. REFERENCES

- [1] Sollins, K., "Plan for Internet Directory Services", RFC 1107, M.I.T. Laboratory for Computer Science, July 1989.
- [2] Hardcastle-Kille, S., "Replication Requirements to provide an Internet Directory using X.500, RFC 1275, University College London, November 1991.
- [3] Weider, C., and J. Reynolds, "Executive Introduction to Directory Services Using the X.500 Protocol", FYI 13, RFC 1308, ANS, USC/Information Sciences Institute, March 1992.
- [4] Weider, C., Reynolds, J., and S. Heker, "Technical Overview of Directory Services Using the X.500 Protocol", FYI 14, RFC 1309, ANS, USC/Information Sciences Institute,, JvNC, March 1992.
- [5] Hardcastle-Kille, S., Huizer, E., Cerf, V., Hobby, R., and S. Kent, "A Strategic Plan for Deploying an Internet X.500 Directory Service", RFC 1430, ISODE Consortium, SURFnet bv, Corporation for National Research Initiatives, University of California, Davis, Bolt, Beranek, and Newman, February 1993.
- [6] Jurg, A., "Introduction to White pages services based on X.500", Work in Progress, October 1993.
- [7] The North American Directory Forum, "NADF Standing Documents: A Brief Overview", RFC 1417, The North American Directory Forum", NADF, February 1993.
- [8] NADF, "An X.500 Naming Scheme for National DIT Subtrees and its Application for c=CA and c=US", Standing Document 5 (SD-5).
- [9] Garcia-Luna, J., Knopper, M., Lang, R., Schoffstall, M., Schraeder, W., Weider, C., Yeong, W, Anderson, C., (ed.), and J. Postel (ed.), "Research in Directory Services: Fielding Operational X.500 (FOX)", Fox Project Final Report, January 1992.

9. GLOSSARY

API - Application Program Interface
COTS - commercial off the shelf
CSO - a phonebook service developed by University of Illinois
DAP - Direct Access Protocol
DIT - Directory Information Tree
DNS - Domain Name System
DUI - Directory User Interface
DUA - Directory User Agent
DSA - Directory Service Agent
FOX - Fielding Operational X.500 project
FRICC - Federal Research Internet Coordinating Committee
IETF - Internet Engineering Task Force
ISODE - ISO Development Environment
LDAP - Lightweight Direct Access Protocol
NADF - North American Directory Forum
PEM - Privacy Enhanced Mail
PSI - Performance Systems International
SQL - Structured Query Language
QUIPU - an X.500 DSA which is a component of the ISODE package
UFN - User Friendly Name
URI - Uniform Resource Identifier
URL - Uniform Resource Locator
WAIS - Wide Area Information Server
WPS - White Pages Service
WWW - World Wide Web

9. ACKNOWLEDGMENTS

This report is assembled from the words of the following participants in the email discussion and the meeting. The authors are responsible for selecting and combining the material. Credit for all the good ideas goes to the participants. Any bad ideas are the responsibility of the authors.

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10. SECURITY CONSIDERATIONS

While there are comments in this memo about privacy and security, there is no serious analysis of security considerations for a white pages or directory service in this memo.

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APPENDIX 1

The following White Pages Functionality List was developed by Chris Weider and amended by participants in the current discussion of an Internet white pages service.

Functionality list for a White Pages / Directory services

Serving information on People only

1.1 Protocol Requirements

- a) Distributability
- b) Security
- c) Searchability and easy navigation
- d) Reliability (in particular, replication)
- e) Ability to serve the information desired (in particular, multi-media information)
- f) Obvious benefits to encourage installation
- g) Protocol support for maintenance of data and 'knowledge'
- h) Ability to support machine use of the data
- i) Must be based on Open Standards and respond rapidly to correct deficiencies
- j) Serve new types of information (not initially planned) only upon request
- k) Allow different operation modes

1.2 Implementation Requirements

- a) Searchability and easy navigation
- b) An obvious and fairly painless upgrade path for organizations
- c) Obvious benefits to encourage installation
- d) Ubiquitous clients
- e) Clients that can do exhaustive search and/or cache useful information and use heuristics to narrow the search space in case of ill-formed queries
- f) Ability to support machine use of the data
- g) Stable APIs

1.3 Sociological Requirements

- a) Shallow learning curve for novice users (both client and server)
- b) Public domain servers and clients to encourage experimentation
- c) Easy techniques for maintaining data, to encourage users to keep their data up-to-date
- d) (particularly for organizations) The ability to hide an organization's internal structure while making the data public.

- e) Widely recognized authorities to guarantee unique naming during registrations (This is specifically X.500 centric)
- f) The ability to support the privacy / legal requirements of all participants while still being able to achieve good coverage.
- g) Supportable infrastructure (Perhaps an identification of what infrastructure support requires and how that will be maintained)

Although the original focus of this discussion was on White Pages, many participants believe that a Yellow Pages service should be built into a White Pages scheme.

Functionality List for Yellow Pages service

Yellow pages services, with data primarily on people

2.1 Protocol Requirements

- a) all listed in 1.1
- b) Very good searching, perhaps with semantic support OR
- b2) Protocol support for easy selection of proper keywords to allow searching
- c) Ways to easily update and maintain the information required by the Yellow Pages services
- d) Ability to set up specific servers for specific applications or a family of applications while still working with the WP information bases

2.2 Implementation Requirements

- a) All listed in 1.2
- b) Server or client support for relevance feedback

2.3 Sociological Requirements

- a) all listed in 1.3

Advanced directory services for resource location (not just people data)

3.1 Protocol Requirements

- a) All listed in 2.1
- b) Ability to track very rapidly changing data
- c) Extremely good and rapid search techniques

3.2 Implementation Requirements

- a) All listed in 2.2
- b) Ability to integrate well with retrieval systems
- c) Speed, Speed, Speed

3.3 Sociological Requirements

- a) All listed in 1.3
- b) Protocol support for 'explain' functions: 'Why didn't this query work?'