

Discovering Devices and Services In Home Networks

Useful systems from information appliances

An IBM White Paper

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Executive Summary

The emergence of information appliances and new types of connectivity is spurring a new form of networking: unmanaged, dynamic networks of consumer devices that spontaneously and unpredictably join and leave the network. Consumers will expect these ad hoc, peer to peer networks to automatically form within the home, in very small businesses and in networked vehicles.

Home networking, or systems of information appliances, have some unique requirements beyond traditional local area networking. For this technology to be accepted by consumers, it must be very easy to use. A key aspect of making these networks easy to use is making them self-configuring, rendering them virtually transparent to the consumer.

This white paper discusses:

- the unique requirements for successful home networking, in particular, the ease of use requirement;
- the role of self-configuration to address the ease of use requirement;
- how service discovery and service discovery protocols enable self configuration;
- the challenges presented by the growing number of service discovery protocols in the industry and interoperability solutions that overcome these challenges.

Over the course of the next five years, multiple discovery protocols will exist. These protocols must interoperate to meet the needs of the marketplace. IBM is working on technology and solutions to enable interoperability of devices and services that participate in heterogeneous service discovery protocols.

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Bluetooth

Bluetooth Special Interest Group

HAVi

Member companies of the HAVi consortium

Java

Sun Microsystems, Inc.

Jini

Sun Microsystems, Inc.

Salutation

Salutation Consortium

Universal Plug and Play

Microsoft Corp

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Introduction

A wide range of phenomena is driving the emergence of home networks. Among these phenomena are:

1. New forms of connectivity within the home
 - Phone line networking technology like Home Phoneline Networking Alliance¹
 - Wireless radio frequency-based technologies like HomeRF² and Bluetooth³
 - Power line networking technology, such as Intellon⁴'s recently-announced high-speed power line networking technology
 - Messaging and interoperability standards such as CEBus⁵
 - Structured wiring⁶ in new construction
2. More multiple PC households
 - Second (or third) desktop systems, driven by the emergence of \$599-\$999 systems
 - Notebook computers that are brought home from the office each night

This trend is described in a CNNFN⁷ article dated February 23, 1999:
 "A survey published earlier this year by Boston-based market research firm Yankee Group showed that 30.5 percent of U.S. households with PCs are interested in a way to connect electronic devices in their homes. Dataquest projects 350,000 U.S. households with more than one PC will be networked this year. The firm expects that number to jump to 1 million households by 2000 and 3.3 million in 2001."

 - These PCs need to share resources such as printers and Internet access.
3. The continuing emergence of *smart* consumer devices
 - home controllers
 - network printers
 - PDAs and other information appliances
 - Networked vehicles or *smart cars*
 - *WebCams* (surveillance cameras with built-in Web servers)
 - in general, whole new generation of network-enabled consumer electronics available or under development, like home security systems, home entertainment systems, and smart appliances

The Rise of Information Appliances

Computer chips are being embedded into the next generation of everyday devices. Our cars have had them for years -- now our children's toys, our kitchen appliances, and our living room entertainment systems have computing power that rivals previous desktop computers.

In addition, the emergence of *no new wires* networking technology has allowed these computer-enabled devices to become network connected. The result is very powerful and useful systems of these devices cooperating to simplify everyday activities and provide new functionality.

Donald Norman⁸ lists three critical design principles for the viability of information appliances:

- Simplicity
- Versatility
- Pleasurability.

¹ <http://www.homepna.org>

² <http://www.homerf.org>

³ <http://www.bluetooth.com>

⁴ <http://www.intellon.com>

⁵ <http://www.cebus.org>

⁶ For example, see <http://www.ibm.com/homedirector>

⁷ http://cnnfn.com/digitaljam/9902/23/feature_networking/index.htm

⁸ The Invisible Computer, Donald A. Norman, ©1998 Donald A Norman

The systems of information appliances we build for the home must be suitable for the non-technical user. The beneficiaries of these systems are you, your parents, your children, your spouse, and your neighbors; not all of these people will have the skills or desire to manage and maintain complex computing systems.

The viability of these products relies on how simple they are to set up, use and modify; how versatile they are, allowing new combinations of devices and services; and how pleasurable they are to own. If these networks are

- complex, or even *appear* to be complex,
- limited to a small fraction of devices which are compatible, or
- are frustrating to use,

then they will be relegated to the small niche of technology enthusiasts and early adopters.

This white paper speaks to one aspect of these systems that fosters simplicity, versatility and pleurability: self-configuration. Security and privacy are also important home networking issues but are beyond the scope and focus of this paper.

A scenario that illustrates the trends in home networking, especially in the area of self-configuration, is included in the Appendix.

Towards Self-Configuration

To achieve the goals of simplicity, versatility and pleurability, the appliances and the network(s) they join must *just work right out of the box*. By *just work* we mean that the participants on the network must simply *self configure*. By *self configure* we mean that these network devices and services simply discover each other, negotiate what they need to do and which devices need to collaborate ***without any manual intervention***. The system must work right out of the box, without any setup wizards or on-line settings to configure, and without any manuals to read. The utility to the human being must appear automatically and transparently, almost like magic.

Systems that can self-configure have the ability to bridge the chasm⁹ among early adopters/technophiles and the mainstream consumers in the marketplace.

Discovery Protocols

Service Discovery is a term used to describe the protocols and mechanisms by which a network connected device or software service becomes aware of the network to which it is connected and discovers which network services are available. For example, a PDA needs to *discover* the home network, and *find* a service that will provide PDA to PC synchronization capabilities and use that synchronization service.

Service discovery can be all pre-configured. This is the solution that techniques such as DHCP, DNS and LDAP provide for enterprise networks. For a relatively static system with infrequent addition of new devices or software services, this may be a viable approach. The configuration step can be done once during system installation, and manually maintained, usually by a skilled system administrator. For relatively static networks where central administration is needed or desirable, this sort of pre-configured service discovery may be appropriate.

However, within the networked home, new information appliances will be purchased and added to the network with some frequency. Mobile devices, such as cellular phones and PDAs, can enter and leave a home network quite frequently. Closed systems violate the axiom of versatility, as they are not amenable to easily adding new functionality. In these situations, it is difficult to rely on manual configuration of the network services without violating the axioms of simplicity, versatility and pleurability.

So, we need *service discovery* in the home, mobile, and similar environments to be *self-configuring*.

⁹ To borrow a term from G.A. Moore's *Crossing the Chasm: Marketing and Selling High-Tech Goods to Mainstream Customers* ©1991, Harper Business.

There are many existing service discovery protocols that have varying degrees of self-configuration, and more are being announced all the time. For the most part, these protocols are incompatible, providing a challenge for the axiom of versatility. This is natural because the *art* has not yet achieved maturity. If different device and network service manufacturers adopt different service discovery protocols (and it is likely that they will), then it will be difficult for devices built for one protocol to work with services provided by devices built to different protocols.

Let's examine some of the more important service discovery protocols, and afterwards we will describe a mechanism that addresses the axiom of versatility.

Important Service Discovery Protocols

Salutation

Salutation is an architecture for looking up, discovering, and accessing services and information. The Salutation architecture defines abstractions for devices, applications, and services; a capabilities exchange protocol; a service request protocol; "personalities" (standardized protocols for common services); and APIs for information access and session management. Its heritage has been (and most implementations to date have focused on) enabling access to office equipment (FAX, printers, scanners, and so on). However, the architecture also supports other information appliances such as telephones and PDAs through definitions for telephony, scheduling, and address book. Details on Salutation can be found at www.salutation.org.

SLP

Service Location Protocol (SLP)¹⁰ is a standard developed by a working group of the Internet Engineering Task Force (IETF). SLP addresses the problem of self-configuring service discovery by applying existing Internet standards to the problem. SLP is designed to be a lightweight, decentralized protocol with minimal administration requirements. Many companies, including IBM, have implemented SLP in products.

Jini

Sun Microsystems developed its Jini technology to address service discovery needs for networks of Java-enabled devices¹¹. Jini addresses the axioms of simplicity and versatility directly. Leveraging the Java platform, Jini uses very simple techniques to solve the hard problem of distributed service discovery. Jini is described at www.sun.com/jini/.

Universal Plug and Play

In January 1999, Microsoft announced its Universal Plug and Play (UPnP) initiative, which seeks to define a set of lightweight, open, IP-based discovery protocols to allow appliances such as telephones, televisions, printers, and game consoles to exchange and replicate relevant data among themselves and the PCs on the network. Universal Plug and Play information is available at www.upnp.org.

HAVi

Home Audio/Video Interoperability (HAVi) is a consortium of consumer electronics companies organized to define the interoperability standards among next generation network-connected, digital home entertainment products. HAVi has its own proprietary service discovery protocol. HAVi is described at www.havi.org.

¹⁰ IETF RFC 2165

¹¹ Strictly speaking, not all devices have to be Java/Jini-enabled. One (or more) of the Java/Jini-enabled devices can act as a proxy for the other non-Java devices, making them visible to the Java/Jini-enabled part of the network.

Bluetooth

Bluetooth is a consortium developing a short-range wireless communication protocol. As part of this effort, the Bluetooth Software Special Interest Group is defining several layers of a software stack – one of these layers is Service Discovery. It is optimized for the highly dynamic nature of Bluetooth networks, and is a simple, efficient protocol that allows Bluetooth devices to discover services offered by or through other Bluetooth devices. Details on Bluetooth can be found at www.bluetooth.com.

The service discovery protocols listed above are the most important in home network environments. There are many other service discovery protocols and technologies; some are specialized for certain environments, and some are research efforts under development that may emerge in the future. IBM participates in the definition and implementation of many of these service discovery technologies."

Service Discovery Interoperability: the key to Versatility Axiom

None of these discovery protocols is likely to dominate. Some of these protocols (SLP, Salutation) are deployed primarily within the enterprise or office environment, reducing the likelihood of penetrating the home networking market. Other technologies like Jini, UPnP and Bluetooth were conceived for a more informal, *casually connected*¹² environment, which could include networked vehicles and small offices as well as home networks. Each has its strengths, and none has a dominant position in the marketplace.

Consequently, good consumer networking solutions should be able to accommodate heterogeneity, both in terms of underlying connectivity, and in terms of the discovery infrastructure that is supported.

Common Features of Service Discovery Protocols

The discovery protocols discussed above share some common attributes, which could form the basis for a high degree of interoperability. Let's examine a set of common characteristics of self-configuring service discovery protocols:

1. Client agent: The client agent is a software component that runs in a device and searches the network to find services needed by applications running in the device. Note that services themselves can be clients of other services.
2. Service agent: For devices that provide services to other devices, the service agent is a software component that advertises the services provided by the device. In the case where a service provider implementation does not require hardware,, a service agent can be based entirely in software.
3. Registry: In order to provide efficiency and scalability, some of these protocols provide for a (perhaps optional) registry where information about available services is maintained. Typically a registry contains an entry for each service advertised by a service provider. The registry can be centralized or decentralized (distributed).
4. Registry update mechanism: This pertains to the protocols the service agents use to update their entries in a registry.
5. Registry cleanup: This topic addresses how obsolete or incorrect information is purged from the registry.
6. Discovery mechanism: The discovery mechanism is that part of a service discovery protocol that specifies how a client locates the service discovery infrastructure such as a registry.

¹² By casually connected, we mean devices which occasionally are connected, and come and go with some frequency

7. Client lookup mechanism: The client lookup mechanism defines how a client queries the registry (if there is one) to locate a service it needs, and how it locates the service in the absence of a registry.
8. Client access to service: This topic addresses how a client, once it has located the service that it needs, negotiates access to the service, including “quality of service” issues and security issues.
9. Client use of services: Once a client has located a service, and has successfully negotiated access to the service, it must determine (and perhaps acquire) the protocols to actually interact with the service (for instance: IPP, LPR, HTTP, FTP, Java RMI).

All of the service discovery protocols listed above share most of these common features. Therefore it is possible to construct bridges among protocols. Pair-wise protocol bridges already have been constructed: Jini to SLP, Salutation to SLP, and so on. These bridges could reside on a home PC, on a *thin server* or on a specialized home network controller.

These bridges are the beginnings of an interoperability solution. More universal, multi-way interoperability solutions are possible. IBM, through its participation in many of these service discovery protocol initiatives, is well positioned to provide these interoperability solutions and is building them.

Conclusion

For consumer networks of information appliances to be successful, these systems must be simple, versatile and pleasurable. Self-configuring service discovery is an important technology enabling home networking to achieve these goals.

Multiple satisfactory service discovery protocols exist, but this multiplicity of incompatible protocols significantly reduces the versatility and simplicity of home networking systems. Achieving the maximum benefits of self-configuration in this heterogeneous environment requires that self-configuring networks and systems work well together. To address this issue in a constructive fashion, IBM is actively pursuing solutions that allow these various service discovery protocols to interoperate.

Appendix: A Possible Home Networking Scenario of the Future

Tom is a busy insurance salesperson. Although he uses a PC daily, he does not consider himself *technically sophisticated*. Tom likes technology to be invisible.

Like many other insurance agents, Tom uses a notebook computer in his work. When Tom returns to his small insurance office after visiting a client, his notebook computer uses UPnP to discover and communicate with other devices in the office, like the printer. Tom frequently brings his notebook computer home from work. The notebook computer dynamically joins the RF-based home network in Tom's home and uses UPnP to discover the printer attached to the PC in Tom's den. Tom can print documents from his notebook computer at home. The notebook computer also uses the *home gateway*¹³ connecting Tom's home to various service provider networks (including his ISP). Using the Internet sharing function provided by the home gateway, Tom can surf the Web at the same time as his daughter Laurie.

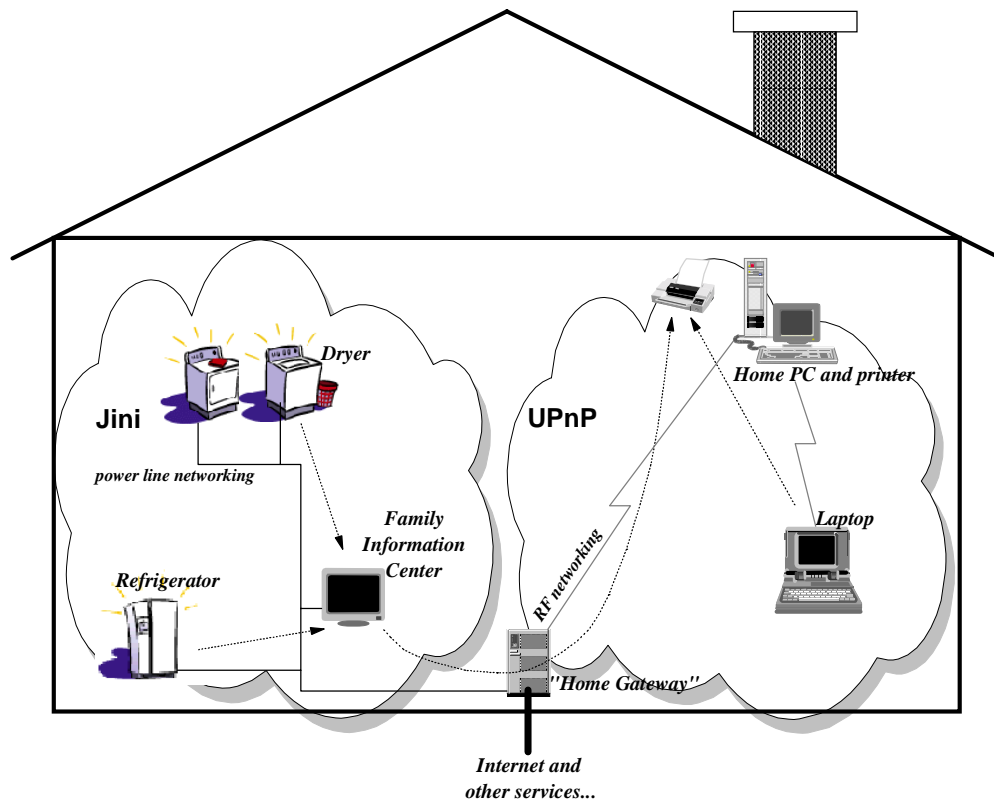


Figure 1 – Overview of the Networks in Tom and Mary's home

Tom and his wife Mary replaced their household appliances opting for the latest *smart* appliances that incorporate power line networking and Jini technology. These smart appliances can discover each other (and each others' capabilities) and exchange information, using the existing AC wiring in the house. One example of this system of smart appliances is that the Jini-enabled clothes dryer can discover the *Family Information Center* appliance in the kitchen and display a message that the clothes in the dryer are now dry. The Jini-enabled refrigerator also can discover the Family Information Center. It displays a warning

¹³ This home gateway function could reside in a PC, on a *thin server* or on a specialized home controller

message that it has detected increased energy usage. The message recommends cleaning the cooling coils to regain energy efficient operation. The versatility of the home gateway means Mary can use the Family Information Center to look up recipes on the Web at the same time that Tom and Laurie are surfing the Web. This is possible because the home gateway incorporates Jini technology and is connected to the power line network. It also supports UPnP and is part of the RF network as shown in Figure 1. Using this interoperability technology, the Family Information Center can dynamically discover and use the home gateway.

While searching for recipes on the Web, Mary comes across one that she would like to print for her recipe file. However, the Family Information Center does not have a local printer. The only printer in the house is attached to the PC in the den. Furthermore, the PC is a UPnP device, not a Jini device like the Family Information Center! If these two realms of the home network cannot interoperate, the seemingly simple task of printing the recipe becomes unnecessarily complex. Fortunately, the home gateway can translate the Family Information Center's Jini-based attempt to locate a printer into the UPnP protocol. It can translate the PC/printer's UPnP-based reply back to the format that Jini uses (it can also *bridge* the underlying physical media, in this case, power line networking and RF networking). The versatility of the home gateway allows Mary to print the recipe from the Family Information Center on the PC-attached printer, even though they *speak different protocols*.

This scenario illustrates several points:

- **Simplicity:** The systems *just work* for Tom, Mary and Laurie. They do not rely on any complicated set up to get these systems to interoperate.
- **Versatility:** These systems use multiple different service discovery protocols and physical networks, yet Tom, Mary and Laurie need them to work together to accomplish various tasks. Mary is interested in printing the recipe; she is not (and should not be) concerned with the underlying network infrastructure and technology. She knows that all of the networked devices in her home can interoperate, so there is no need to consider which systems can or cannot be used together.
- **Pleasurability:** Tom's and Mary's buying decisions are not constrained by technology. When they wish to purchase a new appliance or other device for their home, they can easily determine that it will work well within their existing network. This allows them to choose devices that are the most suitable and pleasurable based upon their own needs; they need not worry about details of the networking technologies.