Gateways in Pervasive Computing

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Abstract

Many types of gateways are related to the concept of pervasive computing. Connectivity gateways enable new devices to connect the Internet. Transcoding gateways modify information and presentation of web content suitable for new devices. Residential gateways create true home networks and connect them to the Internet. Tunneling gateways enable a protocol travel inside another one. Proxy gateways enhance speed, security of Internet connection or provide other transparent services. Back-end gateways bring services of back-end systems accessible from the Internet. This paper shortly explains each gateway type.

1 INTRODUCTION

In this chapter, basic concepts and terms needed to understand this paper are explained.

1.1 Pervasive Computing

Just decades ago computing was living its mainframe era. Massive servers performed programs in applications where numbers of complicated calculations were needed. Personal computers (PC) and local area networks (LAN) became popular in 80's. PCs became general-purpose tools to perform many work and personal tasks. LANs provided new way of collaborating between PCs and servers. Still, computers were usually "visible" devices having screen, keyboard etc. This era can be called personal computing era. Now evolution of computing is shifting us to new era of pervasive computing (or ubiquitous computing). The success of the Internet offers us change to connect the "global network" practically from anywhere. New portable devices like smart phones follow us anywhere we go, and new devices not only let us talk with friends, but also provide new services. New embedded chips and standards are spreading small computers to almost any device and everyday goods. Little by little these devices will get smarter – one day pair of your best shoes might have their own internet addresses and they will lead the way while you are still wondering the way to the next whiskey bar (and they do not ask you why).

This evolution towards pervasive computing era is far from being complete, but even now, we often do not think we are using a computer or a network to perform some tasks. True pervasive computing mean computers will be embedded everywhere, but most

often we do not know or care about it – we are probably just happy to use new applications or services.

1.2 Gateways

Traditionally gateways are devices that connect diverse computer networks together. Simpler network devices such as repeaters and bridges can only merge uniform networks such as Ethernet networks. One of the main factors of the Internet success is its network level protocol – Internet Protocol (IP). IP was actually designed to merge various networks. Beneath IP, we can have many kinds of protocol standards and hardware from small home networks to national backbone networks. These networks cannot be merged without a "connection point" between the networks; some kind of apparatus is needed to perform the work of Babel fish translating the messages of one network to the language of another. Traditional IP gateways, such as routers, are devices to perform this task.

More generally, gateway is any internetworking system connecting two or more networks. A gateway can also mount a single device to a network and possibly through another gateway to a device on the other end. A gateway can connect two physically different networks understanding the very same IP by translating the link layer messages. An advanced gateway may be working on a higher protocol layer possibly translating the network protocol or changing the presentation of messages between two networks. As we will discuss later in this paper, applications of pervasive computing might need highly sophisticated gateways changing the presentation or even information itself.

The definition of the term gateway is not unambiguous, but in this paper, we refer to term gateway being any system connecting networks, back-end systems and devices enabling them to communicate. A gateway can transparently modify the “messages” travelling through it, but it does not provide content. Accordingly a gateway is not is a content service or especially not a portal of any kind. A gateway can enable services or offer access to portals, but gateways itself should work mostly transparently (to be called gateway).

1.3 Pervasive Computing and Gateways

Most gateway types presented on this paper are more or less directly originate from the evolution of the Internet and pervasive computing. New devices are often small and low capacity. Gateways will not only enable these devices to connect the Internet, but they also do much work on behalf of the device. For example, changing the presentation of a web page suitable for small screen (like Palm Pilot) is much more efficiently done in a gateway that in the device itself. When using a service, many types of gateways are involved. For example, when reading latest news using a WAP phone, all the gateway types presented in this paper can be involved.

2 GATEWAY TYPES IN PERVASIVE COMPUTING

This chapter covers an overview of gateway types followed by paragraphs explaining each type in deeper detail.

2.1 Overview of Gateway Types

Gateways of pervasive computing can be divided to number of types. Hansmann (2000, p. 315) presents three categories – *connectivity gateways*, *transcoding gateways* and *residential gateways*. In this paper, we introduce more categories – *tunneling gateways*, *proxy gateways* and *back-end gateways*. These three categories are not so closely related to pervasive computing devices, but they enable many services that go along with the concept of pervasive computing. Table 1 lists a short explanation and examples of each category. Of course, this kind of categorizing is only one way to see things. For example, Nokia (2001a) calls their residential gateway product "Home Connectivity Gateway".

Table 1 Gateway types in pervasive computing

Gateway type	Main purpose	Examples	Product examples
Connectivity Gateway	Enables a device to connect to a network. The gateway translates the messages from the network to the protocol of the device.	A TCP/IP protocol of the Internet conversion to a protocol optimized for wireless or other low rate data transmission (and vice versa).	WAP gateways, Palm Webclipping Proxy
Transcoding Gateway	Enables an information content to be presented on a device. The gateway transcodes the presentation from a network to suitable form for the device. Often the devices have limited capacity and small screens, so information must be compacted or presented differently.	Converting video stream to image or series of small images etc.	IBM Transcoding Proxy, WebSphere Transcoding Publisher, ProxiWare
Residential Gateway	Enables a small network to connect to an external network. Usually we talk about home or small office networks connecting to the Internet.	Residential gateway devices PC and an operating system working as gateway.	Many manufacturers (D-Link, SMC etc.)
Tunneling Gateway	Enables a protocol's data units to travel through a network that does not directly support the used protocol. The gateway encapsulates (tunnels) the data units of the unsupported protocol inside the supported one.	TCP/IP packet sending using mobile GPRS telenetwork. Security tunneling.	Cable Modem manufacturers IBM SecureWay Wireless Gateway SSH

Gateway type	Main purpose	Examples	Product examples
Proxy Gateway	Adds a transparent service or other extra value to a connection from a network to another.	Proxy services offering security, caching etc. Content proxy for content providers.	Many proxy products. Anonymizer.com Comptel Chinchilla Proxy
Back-End Gateway	Enables a network host to connect a back-end system. The gateway translates the queries from the network to the presentation of the back-end system.	Gateways to payment servers.	(mostly specialized gateways)

2.2 Connectivity Gateways

Connectivity gateways enable devices, such as WAP phones or PDAs (like Palm Pilot) to connect to networks – usually the Internet. Most pervasive computing devices are by nature small and portable. Because of the size, today's technology does not allow them to be as powerful as our desktop PCs are today. The natural communication channel for portable devices is through air. Thus, wireless data transfer sets some barriers to the communication speed. Today, the wireless transmission rates and memory resources of truly mobile devices (mobile phones, some PDAs) are as limited as the PCs and modems of 80's. Good example of the devices and the programming problems is found at Lee's (2001) article *Serious KVM Programming Page*.

These technical and physical limitations have lead to wireless communication protocols that are efficient and do not need much processing power. Devices using these protocols are not sheltered out from the Internet, if we have an appropriate connectivity gateway to perform the protocol translation task. The main purpose of a connectivity gateway is to translate an Internet protocol to "lightweight" protocol the device uses. The translation is usually done on a higher protocol layer than IP or even on application layer.

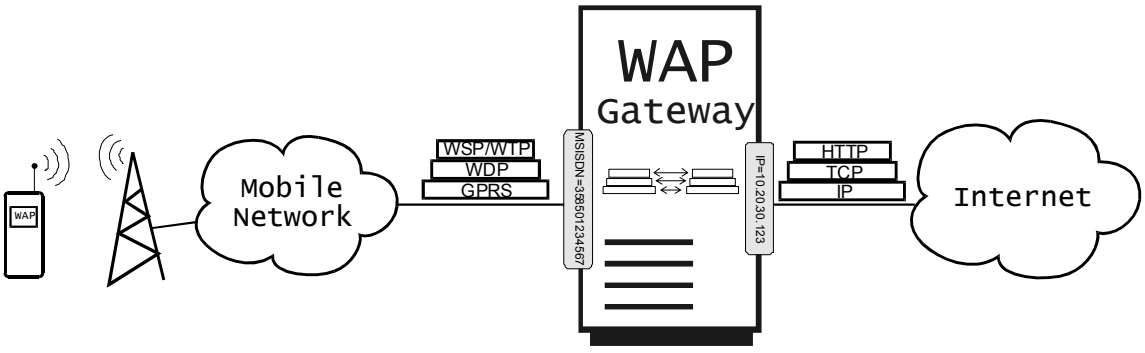

Figure 1 WAP Gateway

Connectivity gateway might not give connection to any and every service the network (the Internet) provides. For example, the WAP Gateway on Figure 1 provides the connection to WAP services only. In the Internet WML pages of WAP are encapsulated

into HTTP packets of TCP/IP. WAP gateway transforms the protocol stack suitable for mobile network. In the figure, the carrier protocol in GPRS, but other protocols are also supported.

Connectivity gateways exist for not only mobile phones, but PDAs and other (portable) devices too. Using a connectivity gateway technology is very advantageous as we can use the existing network to carry service information. For example, a service provider offering services to WAP phones, Digital TV, PDAs etc. can build up a service physically anywhere that is connected to the Internet. Operators and device manufactures take care of setting up the gateways where needed.

2.3 Transcoding Gateways

The sizes of mobile or near pervasive devices of today are already quite small. Presenting information on a small screen is a challenge itself. Sometimes we cannot (or do not want to) use displays at all. Some sophisticated applications of today are already voice operated. For example, the Lernout & Hauspie (2001) voice operated hands-free mobile phone for cars is a good example of a situation where one really appreciates no displays and no buttons to touch. Still, most services today are designed for big screens of high performance PCs. It would be very useful to get these services to our small, time and space independent devices, too. Presenting complicated information in such devices is a challenge that transcoding gateways try to crack down.

Transcoding is a content adaptation technology that transforms the format and presentation of information for the needs of a specific device. Transcoding comprises two dimensions (Hansmann, 2001; IBM, 2001):

- *Modality:* Types of multimedia (video, images, text, audio, links, interactive elements etc.) transcoding to other formats (for example: video → image).

- *Fidelity:* Reducing the fidelity of information i.e. compressing and filtering to make data presentable on a device (for example: image → smaller image).

IBM (2001) defines transcoding framework called *InfoPyramid Framework*. The framework manages media objects with different modalities and fidelities. Figure 2 presents how one media object can be transcoded to different versions according modality or fidelity needed. The arrows in figure show the order how media object versions can be converted. For example, a video clip can be converted to the still image (modality changes) but usually not other way round. A video clip can also made smaller in size, cropped or compressed more efficiently (fidelity changes), but to convert from lower to higher fidelity makes no sense.

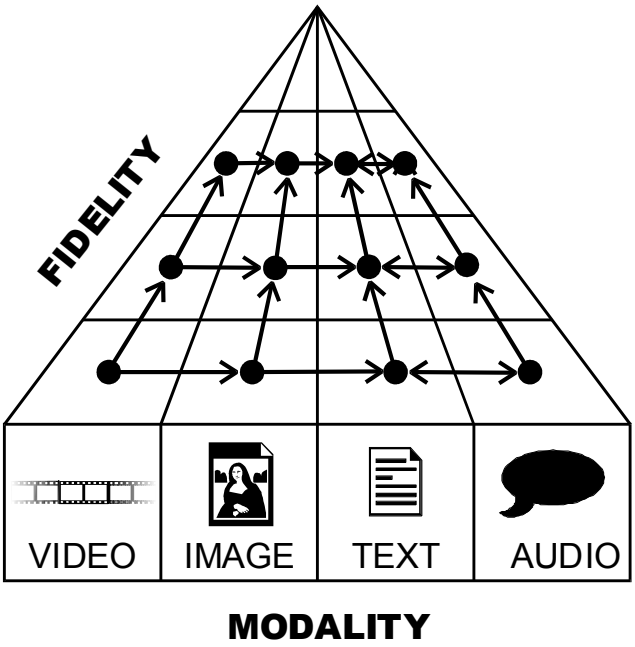

Figure 2 InfoPyramid Framework (after IBM, 2001)

From a service provider point of view, transcoding is the divine solution. The service provider would only need to write service once (for a web browser or using a special markup language) and the transcoding gateway would change the presentation suitable for any other device. Unfortunately, the technology is still on its way there, and transcoding might not ever be so good and automatic that no per device customization of a service is needed. Nevertheless, transcoding makes it possible to present information on devices that the content was not designed for. A working example is Pumatech's browse-it (Pumatech, 2001) that translates any Internet HTML page suitable (at least readable) for Palm handhelds.

2.4 Residential Gateways

Home networks are becoming more popular, as families tend to have more than one PC. Internet connection sharing, printer sharing and network games are good reasons enough to wire two PCs into small home network. For many companies, internal networks and all house Internet connection is a matter-of-course. For homes it will be, and a residential gateway is one key on way it.

Physically a residential gateway can be an ordinary PC or an integrated device solely working as gateway. A PC running Windows or Linux is more flexible and extensible, but an independent device can be cheaper and surely easier to use and configure. Nevertheless, logically they work alike. Residential gateways have two major purposes:

- connecting PCs and other devices into the home network
- connecting the home network to the Internet

Home networks of today are mostly like the networks at work connecting computers and computer devices. Some experimental homes have taken the next step connecting more devices to the home network. For example, home security systems might send an alarm to the bedroom and an SMS to the mobile phone if something suspicious seems to be happening.

Connection to the Internet is a must on the home networks of today. The residential gateway has to take care not only shared connection to an Internet Service Provider, but it has to secure home network from unauthorized use. In contrast to company firewalls and routers, residential gateways have to be much simpler to use and configure.

2.5 Tunneling Gateways

Often it is convenient to design simple lightweight protocols. For example: transporting full TCP/IP stack on a low bandwith connection can be inefficient in many cases. On the other hand, in some cases we are behind secure firewalls only allowing HTTP traffic, but we need to use another protocol (lets say TELNET) to connect a host. We also may want to secure all our unsecure traffic to build virtually private network running on public Internet. All these cases can exploit tunneling technique.

Tunneling is technique allowing us to “tunnel” a protocol or protocols inside carrying one. Tunneling works on point-to-point connections because actual messages (tunneled protocol) must be packed to (encapsulated) or extracted from carrying protocol before they can be used. Tunneling gateways performs these tasks. Real life examples using tunneling gateways are Virtual Private Networks (VPN) and home connections to the Internet provided by some Internet Service Provides (ISP).

2.6 Proxy Gateways

Proxies are gateways that (more or less) transparently adds extra value to a network connection. For example, an ordinary proxy server is adding value, because the surfing experience is probably smoother and more secure than without proxy. More advanced proxies exist. A good example is anonymizer.com (2001) that let a user surf in the Internet truly anonymously.

Pervasive computing devices often take advantage of proxy technology. The problems of slow connections can be minimized using an efficient local proxy. For example, if an already visited WAP page is in the proxy of the mobile phone, it does not have to be necessarily reloaded. As this example shows, the proxy usually works better, closer it is to the end-user.

2.7 Back-end Gateways

Back-end system is a concept referring to a system that offers access to data, information or set of services. This system is not usually used directly, but through client software. For example, a bank ATM is the “front end” and all the real money transactions are done in a “back-end” system running in somewhere else. In the Internet

back-end gateways are hosts offering access to back-end systems. A gateway is usually needed for many reasons. For example, the interface of the system can be offered as HTTP and the system can be secured from unauthorized use. There are many forms of back-end systems around, and back-end gateways are often specialized.

3 THE FUTURE OF GATEWAYS IN PERVASIVE COMPUTING

In near future we will get more high-end devices with higher bandwidth, more computing power and memory. The incoming version of Internet Protocol (IPv6) takes the needs of pervasive computing into account much better than the current dominant IPv4. This evolution can downsize of the importance of connectivity gateways as more and more devices will work on top of Internet Protocol. This is unlikely to happen over night. Variety of connectivity gateways will be needed for many years, and perhaps the new applications will need new kind of connectivity (like minicomputers inside our body).

Although we will get devices that are more powerful, and have more memory and higher transmission rates, the physical dimensions of these devices can and will get smaller than they are today. True pervasive computing means these devices will get invisible and pervasive computer systems will be integrated to places we would now think not useful (for example clothes). The future is interesting and so are the design challenges of pervasive computing as computers take place practically everywhere (Thackara, 2000). Transcoding will be an important research subject and we might see transcoding gateways doing “miracles” presenting information in our cars, sunglasses – everywhere (that is what the real pervasive computing is about).

Residential gateways and home networks are still maturing. In the future, we can expect more devices to be connected on home networks and the Internet. Even now, it is possible to build a smart home, but it often means one have to choose from a limited set of home devices. Truly open systems will come and one day we can plug in any new device (from lights to microwave) and expect it to work in conjunction with our home network and other devices. Emerging technologies such as service discovery and new home network technologies working on existing wiring (power or phone cables) are bringing up the real pervasive home networking to reality. A residential gateway is the motor of such network connecting any device to the network and the Internet. Open Service Gateway Initiave (OSGi, 2001) is one suggestion to bring up an open interface for home and automobile device manufactures and their products.

Proxy technology will be always used, but probably proxies will get closer to devices, because then proxy technology is more efficient. Sometimes proxies could be useful “on the other end”; a content service (for example news or goods) could be behind a “content proxy gateway”. For example, a proxy could provide easy way to create content that is subject to fee. With such proxy, a content provider does not have to implement integration to many payment systems. The proxy could also keep user anonymous for service provider.

Back-end gateways will be needed as long as we have back-end systems. In the future though, the interfaces could be more standardized because of open APIs being developed.

4 SUMMARY

Many gateway types exist relating to concept of pervasive computing. To summarize this paper and to get clearer picture how gateway types relate to each other, an imaginary example of two scenarios is presented in Figure 3.

In order to get latest news one can use traditional media such as newspaper, but new alternatives are already here. To get news to our web browser or WAP phone will involve many types of gateways. In the example of Figure 3 news are bought from a commercial news house. User will pay little fee to news provider with the help of a content proxy gateway. The payment will be charged from a bank through a back-end payment gateway. The news will travel through the Internet and in the case of WAP phone, a conversion to lightweight protocols is needed with the help of a connectivity gateway.

Another scenario is closer to sci-fi movie, but could be implemented even today. A family is coming home from winter holiday and they want their home to be warm. The head of the family could just tell the advanced car computer to heat the house up to 25° Celsius. This message is transferred to a highly advanced transcoding gateway that transcodes the request to HTTP. The residential gateway at home would receive this request after it traveled through the Internet – tunneling gateways is be used in order to request travel over cable TV network of an Internet service provider. At home, the residential gateway tells the radiators to put more heat on.

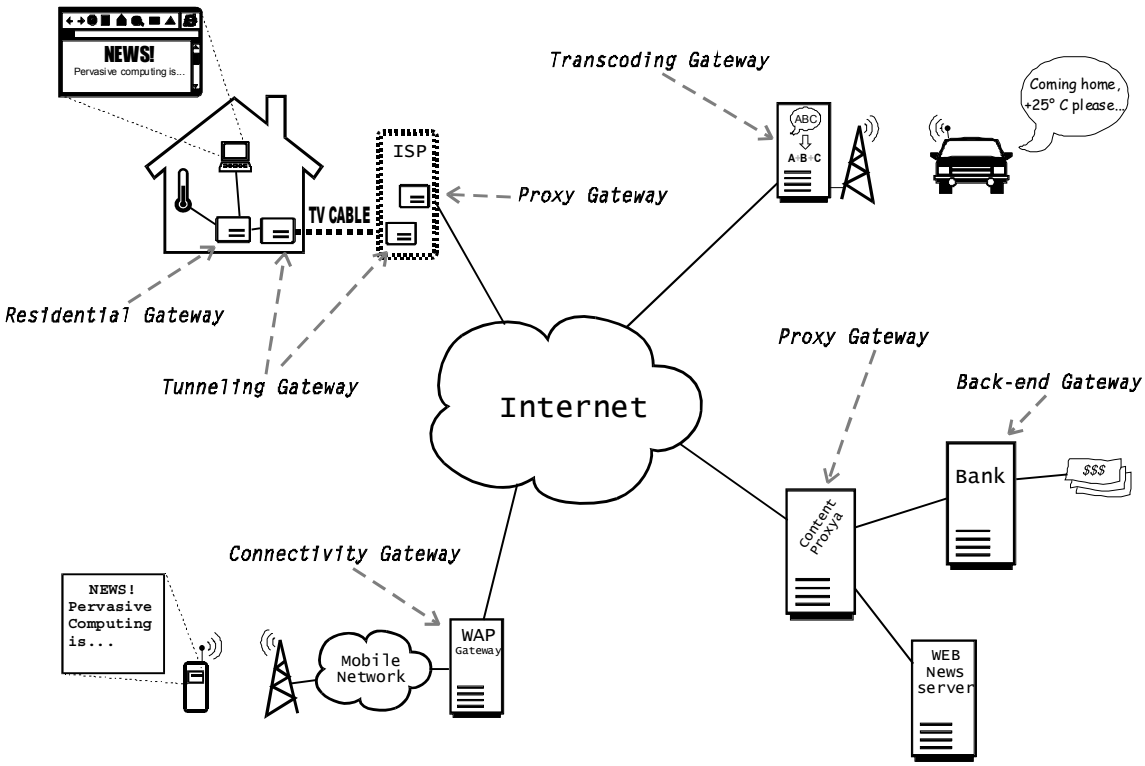

Figure 3 Gateway types and examples in pervasive computing.

These examples show that gateways are essential part of the evolution toward pervasive computing. As long as networks or devices need to be connected, we will need gateways.

REFERENCES

Hansmann, U. 2000, *Pervasive Computing Handbook*, Springer, 409 p.

Nokia, 2001a, Nokia Broandband Access,
<http://www.nokia.com/networks/systems_and_solutions/innovations/1,23799,106,00.html>
referred 2001-11-26

Lee, Shiuh-Lin, *Serious KVM Programming*,
<http://www.jshape.com/kvm/article/kvmprog.htm> referred 2001-11-26

Nokia, 2001b, Nokia WAP Server
< http://www.nokia.com/corporate/wap/wap_server1_1.html> referred 2001-11-26

Lernout & Hauspie, 2001, Voice Operated Hands-Free Mobile Phone
<http://www.lhsl.com/automotive/solutions/communications.asp> referred 2001-11-26

IBM, 2001, *Internet Transcoding Technologies for Universal Access*
<http://www.research.ibm.com/networked_data_systems/transcoding/In_Depth/in_depth.html>
referred 2001-11-26

Pumatech, *Pumatech Browse-it*
<http://www.pumatech.com/browse-it.html> referred 2001-11-26

Anonymizer.com, 2001, Online Privacy Services
<http://www.anonymizer.com/> referred 2001-11-26

Thackara, J. 2000, *The design challenge of pervasive Computing* <*http://www.doorsofperception.com/projects/chi/*> referred 2001-11-26

OSGi, 2000, *Open Services Gateway Initiative* <*http://www.osgi.org/resources/docs/specoverview.pdf*> referred 2001-11-26