A Taxonomy of Internet Appliances[1]

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Abstract

The world is evolving from one in which almost all access to the Internet comes from personal computers (PCs) to one in which so-called Internet appliances (IAs) will make up a greater share of end-user equipment. Today's PC is a general-purpose, highly configurable and extensible device – an "intelligent end-node" of the sort the Internet's designers had in mind. As such, it allows users much freedom of choice (such as which service provider to use, which Web sites to visit, and which new software to download) in exchange for dealing with associated complexity.

An IA is a device connected to the Internet, but beyond that there is little consensus on functionality and target markets. There is, however, general agreement that it reduces the level of complexity seen by the user. A variety of approaches to reducing complexity are being pursued. These fall on a spectrum from totally fixing the function of devices, to automating the configuration of more general purpose systems. In the middle are devices whose functions appear more or less fixed to the user, but which retain some limited capability for upgrade through their Internet connection.

We argue that truly fixed-function Internet-connected appliances make no sense unless they are extremely cheap, throwaway devices. We speculate that general-purpose end-user equipment will endure but evolve into a more modular form, driven by user frustration with a proliferation of devices with overlapping functionality and the desire for consistency across multiple environments (such as home, car and office). Finally, we observe that most appliances being developed today fall into the middle category. These vary in the degree to which they bind users to particular service providers, both technically and through their business model. Our analysis suggests that appliances in and of themselves do not introduce new opportunities for walling the Internet garden, but that industry players seeking to consolidate control over potential Internet choke points, such as broadband access networks or WAP gateways, may attempt to leverage appliances toward this goal. To the extent that appliances provide services already available over the PC-based Internet, we speculate that such efforts will fail.

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Introduction

The world is evolving from one in which almost all access to the Internet comes from people using personal computers (PCs), to one in which so-called Internet appliances (IAs) will make up a greater share of end-user equipment.[2] In this paper we consider whether this shift has implications for industry structure that might require regulatory intervention. We conclude that in most cases technology and market drivers will perpetuate the wide range of business models presently observed, but that policy makers may need to intervene if industry players use appliances to further leverage control over existing monopolistic choke points.

As a general-purpose computing device, the PC has complemented the flexibility of the Internet's architecture to support a spectrum of business models with varying degrees of vertical integration. Broadly speaking, the more vertically integrated the service, the easier it is to use but the less flexibility it provides to users. To date, multiple models have co-existed, serving groups of consumers differentiated by their relative weighting of these two attributes (ease of use vs. flexibility).

At one extreme lies a fully disaggregated model selected by consumers who place a premium on flexibility and freedom of choice. In this model the consumer buys her own PC and phone line, selects an Internet service provider (ISP) from among many competitors, loads the software of her choice (any Web browser, e-mail program etc. conforming to Internet standards) and configures it to visit whatever pages she wants, download email from whatever server she wants, and so on.

In the middle lie semi-integrated models such as broadband Internet access delivered via cable modem or America OnLine (AOL). The consumer still buys her own PC, but other portions of the overall package are bundled. Cable modem services, for example, bundle the cable-based network access with ISP services such as assignment of e-mail and IP addresses. The user gives

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[2] Our primary focus in this paper is on consumer access to the Internet. Appliance-like devices that are deployed first in commercial settings (e.g. vertical markets such as rental car operations, point of sale or inventory control applications, factory or office environments) or are embedded in other devices in a way that is transparent to the consumer (e.g. in automobile engines) are beyond the scope of the present discussion.

up the freedom to choose her ISP in exchange for the enhanced connectivity service (higher speed, always on) that broadband provides. AOL bundles even more, packaging network access[3] together with AOL-specific application software and services, such as an AOL email account. In exchange for the convenience of this bundle, the user gives up the flexibility to mix and match components: for example, she can't use non-AOL email client software (such as Eudora) to read her AOL email.

At the other extreme lies a fully integrated business model exemplified by the various "free PC" services that have been tried. In this model, the PC is contractually bundled with ISP and application services. By giving up her choice of which PC to buy and which service or service elements (e.g. which application software) to choose, the user gets in exchange a complete package that works out of the box and can be set up without any error-prone configuration or time-consuming research among competing alternatives at many levels.

Clearly, these different models appeal to different types of users. Some people appreciate how easy AOL's email client is to use and don't want to be bothered with competing alternatives. Others are accustomed to more powerful client programs from their workplaces and find it greatly limiting not to be able to access their personal email in the same way. The key point is that the user has the choice of which model to adopt depending on her individual preferences. Further, because in all of these models the user access device is a general purpose PC, the user can shift among the models reasonably fluidly. A free PC user whose comfort level rises as she uses the box has the technical capability to take off the training wheels (so to speak), if she is willing to wait for the service contract to expire or simply eat the financial commitment.

Although not all Internet users will select the fully disaggregated model, the fact that some do helps drive the innovation engine of the Internet. For example, several years ago non-AOL email clients introduced the capability to attach Web pages to messages and view them from within the email program. As a result, it became common practice for people who used such clients to send Web pages around via email. AOL users who received such messages began to

[3] Typically dialup today, with broadband soon to become more prevalent.

want this capability as well, eventually leading AOL to integrate this feature into its email client (Hu 2000).

A key policy question about Internet appliances is whether they threaten the fully disaggregated model that helps drive the rapid pace of Internet innovation. Where will they lie on the spectrum of business models and how much of the fluidity among different models might they pre-empt?[4] Will IAs be designed and marketed like free PCs or will the training wheels be, in effect, welded to the bike because of the appliance nature of the device?

This question is impossible to answer in the abstract because today there is no single definition of an Internet appliance. Several factors contribute to the diversity of views and products in this space, including different perspectives on the industry depending on one's position within the value chain,[5] and differing notions of who the target customer is. The first part of this paper gives an overview of the driving forces behind Internet appliances and explains why we find it useful to segment the space of potential products into three classes:

- *Class 1* appliances are truly fixed function: they always do exactly the same thing they were built to do;

- *Class 2* appliances appear more or less fixed function to the user, but retain some degree of upgradeability through their Internet connection;

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[4] Although this fluidity is desirable for users, it is not particularly desirable from the perspective of service providers, who are able to impose switching costs even in the fully disaggregated Internet model with access from the PC. For example, most consumer e-mail addresses are not transferable across service providers, websites do try and introduce such sticky applications as personal information management services (calendar, phone directories, account information) to keep customers from switching, and compatibility issues across different hardware and software platforms can limit end-users ability to freely change content or service providers.

[5] For example, when X hears "Internet appliance" they think as follows:
- Mobile telephone carrier => turbo-charged cell phone
- Cable service providers => set-top box connected to home entertainment center
- PC manufacturer => smaller, cheaper PCs throughout the home
- Communications equipment provider => home LAN equipment (router, network printer etc.)
- Consumer electronics manufacturers => Internet-enabled gadgets (digital camera, digital picture frame, game console, screen-phone, Web tablet, etc.)
- Automakers => GPS empowered Internet radios

- *Class 3* appliances retain the full general-purpose functionality of today's PCs, although they may be quite different both "under the hood" and in their appearance to the user.

The rest of the paper explores the business model question posed above in the context of each class, asking whether appliances of each type threaten to retard the Internet innovation engine. We conclude that Class 1 and Class 3 appliances do not pose a serious threat: the former because they are unlikely to succeed in the marketplace unless they are extremely cheap and therefore readily replaceable, and the latter because they do not restrict the user. Class 2 appliances, on the other hand, encompass a wide range of intermediate approaches in which many gray areas are likely to present themselves to regulators seeking to preserve the openness and rapid innovation that today characterize the Internet.

Internet Appliances: Drivers, Definition and Classes

The space of Internet appliances – products that actually exist, are in development or are still at the prototype or concept stage – is diverse because it is driven by a number of different factors. Some of these factors reflect supply-side pushes (things the industry can or wants to do) while others are demand-side pulls (things people actually want). Clearly, a large part of the success or failure of any individual Internet appliance will have to do with how well it matches industry pushes with market pulls.

Supply-side pushes have their origins in both technology and the industry's desire to expand markets. The technical progress that constantly makes digital technology better, faster and cheaper (commonly referred to as Moore's Law) pushes two kinds of Internet appliances. First, it enables small cheap processors that can be embedded into portable devices. This trend drives the integration of cellular networks and the Internet, as users who have grown accustomed to portability through their mobile phones and personal digital assistants (PDAs) come to expect portable Internet access from those devices as well (leading to products like the Palm VII wireless PDA and Sprint's Wireless Web phones in the U.S., Wireless Application Protocol (WAP) phones in Europe, and NTT DoCoMo's I-Mode phones in Japan). Second, Moore's Law drives multimedia capability into digital technology, as access networks, storage and processing devices all become able to handle the large volumes of bits required by audio-visual content. This trend drives a collection of entertainment-oriented Internet appliances such as digital photo displays (e.g. Ceiva, Storybox picture frames), net-top boxes (e.g. WebTV, AOLTV), and digital VCRs (e.g. ReplayTV, TiVo).

The industry's desire to expand its markets encompasses three different product directions depending on the nature of the expansion: to non-PC users, to existing users who wish to do more, and to new product niches not yet dominated by a competitor. The first type of product arises from the general consensus that PCs are too complex and hard to use, and that products whose main goal is simplicity (e.g. Netpliance's i-opener, Landel Telecom's Mailbug, Compaq and Microsoft's iPAQ IA-1) can expand the market beyond current users of PCs. Many of these products were originally conceived as substitutes for the PC, although they are unlikely to remain exclusively positioned that way.[6]

The second category arises because the things that existing users do can be expanded, which is especially desirable for service providers if it creates new revenue-generating uses for existing infrastructure, or strengthens user loyalty to the service. For example, RCN, a broadband and dial-up ISP, markets support for a portable e-mail device (Research in Motion's Blackberry) as a premium (read: extra charge) service for its users. AOL's recent AOL Anywhere announcement includes a service called AOL By Phone, which lets a user call a toll free number to listen to their email or check news and stock quotes (Hu 2000). Products in this category are clearly positioned as complements to the PC and the traditional services that go with it (e.g. desktop e-mail).

The third category arises from the desire of many players in the industry to increase profitability by moving beyond desktop PCs. In other words, the desire is to create new product segments that are not already dominated by the Wintel hegemony. Developments in this area include thin-

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[6] This may happen if devices marketed for simplicity raise naive users' comfort level with the Internet to the point that they are ready to venture into more functional devices, or if appliance makers find a winning fixed-function formula that appeals to existing PC owners as a second, probably cheaper device for rooms other than the home office (for example, if it's cheap enough you put in your bedroom a device with buttons for checking the local weather on the Web, much as many people use a TV in the bedroom to tell them what weather to dress for in the morning). In March of this year, Netpliance estimated that 30 percent of its customers were not first-time Internet users (Davis 2000). Similarly, producers of the Mailbug have added complementary Web-based services for the portion of their customer base that also has a PC.

client boxes targeted for business use[7] and wireless Web tablets targeted for non-work-related use of the Internet at home.[8]

Amazingly enough, some of these supply-side pushes actually coincide with demand-side pulls. The consumer market for Internet appliances can be segmented as follows:

- People with less disposable income than today's PC owner. This segment is constantly shrinking as PCs get cheaper, and is rarely (if ever) mentioned explicitly as a target market for Internet appliances.

- People with less technical sophistication, confidence, or simply patience for the PC's complexity. The assumption is that these people (or at least some of them) want to use the Internet (or at least some aspects of it), just not from a PC. Products aimed at this market segment (such as the i-opener, Mailbug and iPAQ) are pitched as substitutes for the PC.[9]

- People who are comfortable (even happy) with the PC but who also want to extend its functions around their homes and wherever else they go, preferably with a unified and synchronized view of the same information (e.g. archived email, personal calendar, Web bookmarks and so on). Makers of countless wireless gadgets (including Blackberry e-mail device, Palm VII PDA and Web tablets) are aiming at this segment, as are the operators of many related services (Web sites that synchronize information from personal organizers, AOL By Phone, etc.). All of these products and services complement existing PCs, which works for this market segment.

- People who couldn't care less about using the Internet per se, but appreciate how the Internet makes something they were already doing better or cheaper (for example, imagine a VCR with no knobs but screen-based control from a Web site).

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[7] (Nicholls 2000) describes a trial of Internet appliances designed to access the Web in order to run enterprise programs remotely i.e. through an Applications Service Provider (ASP).

[8] Personal correspondence, Ken Anderson, MediaOne/AT&T Broadband.

[9] A year from now, it will be interesting to determine what percentage of these devices' adoption actually matches this positioning.

Products aimed at these different segments are typically marketed very differently, even if they are functionally similar. For example, both the Mailbug and the Blackberry have e-mail as their primary function. Because the Blackberry is a wireless device, however, it commands a significant price premium over the Mailbug. This premium reflects the Blackberry's mobility but also its positioning as a complement to the PC (never miss that critical deal-making email just because you have to attend your wife's labor), rather than as a device to make e-mail easier to use for the grandparents.

Out of these many pushes and pulls, we identify three characteristics that define an Internet appliance:

1. It's not a PC; rather, it exhibits particularity of purpose and it "just works;"

2. It connects to the Internet; and

3. It wouldn't make sense in a non-networked world.

By "not a PC" we don't mean "doesn’t run Windows." Rather, we mean that the device does not present the user with the same kind of confusing complexity that arises from the collection of essential features that characterize today's PCs. Aside from the presence of some form of processor, storage and a general-purpose operating system, these features include user-customizable hardware (ability to choose or add slots for multiple boards), software (ability to load multiple applications), and system (ability to integrate components from multiple vendors). These attributes of the PC make it general purpose – and of course also complex and unreliable.

Complexity, unpredictability, and general-purpose, user-customized operation are not part of what people think of as appliance-like behavior. To be an appliance, the function of the device must be readily understood and manipulated by the user. When you buy a toaster, you expect it to toast bread. Particularity of purpose does not preclude devices from performing more than one function: a toaster-oven is still an appliance even though it can burn potatoes as well as toasting bread. Rather, particularity of purpose means that somewhere before the end user's view of the device, its purpose(s) is (are) fixed.

"It just works" encompasses two related ideas. First, it should be obvious on the face of it how to use an Internet appliance: people expect toasters to present them with simple, intuitive controls, like buttons and knobs for on/off and light/dark. Second, the device's behavior should be predictable and reliable: when you flick a light switch, you don't expect that half the time it will turn on the lights and half the time do nothing (for no apparent reason, of course).

Our definition requires that an Internet appliance connect to the Internet, but not necessarily always, and not necessarily as a "first-class" Internet citizen. In other words, it is still an Internet appliance if, like the digital picture frames from Ceiva and Storybox, it dials up a server on the Internet for only a few minutes each day. Likewise, a mobile phone that doesn't run the full stack of Internet protocols (TCP/IP) but instead communicates with a helper device -- an Internet gateway running the suite of Wireless Application Protocols (WAP) -- may be a second-class citizen on the Internet, but it is still an Internet appliance by our definition. On the other hand, a digital television that has no connection to the Internet is an interesting gadget for the digital age, but not an Internet appliance.

Finally, by our definition an Internet appliance is a device that wouldn't make sense in the absence of a broader networked world. A portable MP3 player, for example, is useless without the rest of the Internet value chain that creates, stores and helps users find audio files. A digital picture frame that accepts a memory module (such as early models from Sony) is useful for displaying photos you've taken on your own digital camera, but it is not networked. It becomes an Internet appliance when it can download photos stored on the Internet, decoupling the source and destination of the photos (you take digital photos of your kids and display them to the grandparents who live elsewhere).[10]

[10] A very different segment of the media coverage of "Internet appliances" concerns the notion of connecting traditional household appliances (e.g. washing machine or refrigerator) to the Internet. We are not aware of real products in this space, only prototype concepts.   Some of these concepts make sense (e.g. connecting thermostats so you can program them through a Web site, not have to reset time when power blinks, perform remote diagnostics on large appliances, etc.) while others seem like concepts destined to evolve (e.g. Screenfridge which bundles PC with refrigerator – and will be obsolete long before people are ready to replace fridge). Unlike an MP3 player, an oven makes plenty of sense without an Internet connection. So these don't strictly meet our definition of Internet appliance, rather we simply think of them as appliances connected to the Internet.

Our definition of an Internet appliance does not include some attributes that are present in many products in the appliance space but which we don't consider essential. These aspects include:

- Instant-on (no long booting sequence);
- Form factor issues such as those needed for portability (small, lightweight, battery-powered), household use (it comes in colors other than beige, matches the décor in the den, etc.), or familiarity (if you have to speak into it, it should have a telephone-style handset);
- Adapted to environment of use (speech interfaces in car, wipe-clean surfaces in kitchen); and
- Cheap (may have more than one in a house).

Not all of these aspects are present in all products. However, they are worth mentioning here because they are often lumped together with the particularity of purpose, ease of use and predictability that truly define appliances.

Particularity of purpose is the attribute of appliances that is most relevant to policy makers. This attribute is not an either-or characteristic but rather an axis defined by different points in the value chain at which a device's function may be fixed. Different appliances will vary along this axis, leading to different answers to the questions of who controls how each appliance can be used, and whether opportunities for strategic foreclosure exist and are likely to be exploited. To analyze these questions, we identify three classes of appliances based on points along this axis:

- *Class 1*: Device's function is fixed by the manufacturer.
- *Class 2*: Device's function is fixed by a service provider.
- *Class 3*: Device's function is fixed by (at) the user.

Class 1: Function Fixed by Manufacturer

A device in this class has no capacity to change its function once it has been built. It has no slots into which cards can be added and no capacity to accept downloads of new software of any type, thus eliminating the hardware and software customizability of the PC. It may have system-level customizability if the manufacturer equips it with plugs to connect to other devices, but the nature of these plugs cannot be changed.

Devices in this class are the closest to traditional appliances – they always do just what the manufacturer built them to do. Because their hardware and software cannot be customized, they can be much more fully tested by the manufacturer, and therefore made much more reliable than a PC. Finally, because their function is truly fixed for all time, the manufacturer can equip them with buttons so that the appliance's main functions "just work" i.e. it is (more or less) self-evident to the user how to manipulate the device's functions.

Fixing a device's functions at the time of manufacture is the standard way that non-Internet appliances are built, from toasters to (pre-Internet) cell phones. We argue that this is not a viable approach for any but the cheapest Internet appliances, however, because the Internet exhibits too much static and dynamic diversity. By static diversity, we mean the support that the Internet's "hourglass" architecture provides for the co-existence of many different technologies and standards at any given time, both above and below the spanning layer.[11] By dynamic diversity, we mean the Internet's ability to support new technologies and standards that evolve over time.

To see the kinds of challenges posed by static diversity, consider the Mailbug e-mail device pictured in Figure 1.[12]

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[11] In the architecture of the Internet, the spanning layer is exemplified by the Internet Protocol -- the one layer that everyone absolutely must have in common. Layers above this include applications (e.g. e-mail, Web) and document formats (e.g. HTML, text, MP3, video formats such as Windows Media Player and RealNetworks, etc.), while layers below it include network infrastructure (e.g. Ethernet, ATM, wireless). Because these other layers, both above and below, can be "wider" (i.e. support more than one alternative) this architecture is often drawn in an hourglass shape. See (Lehr & Kavassalis 2000) and (CSTB 1994).

[12] See references at end for links to further product information for the examples discussed throughout this paper. Our inclusion of the Mailbug in the Class 1 discussion is not meant to imply that this particular product is a non-upgradeable device (Mailbug's product literature is not clear on this point) but rather to explore the challenges inherent in making a device of this nature fit into Class 1.

Figure 1: Landel Telecom's Mailbug e-mail device

First, consider diversity below the spanning layer: what kind of network plug should an e-mail appliance have? The MailBug builds in a modem and plug for an analog phone line, and there are no slots in which to add any other form of network card (such as an Ethernet connection). This is fine for most home users, especially for non-PC homes who are the primary target market. It will prove painful, however, in any office with a PBX, and a step backward for homes with broadband connectivity and/or home data networks, in which a MailBug could otherwise complement existing PCs by providing e-mail in the den, kitchen, bedroom etc.

The manufacturer could choose to create alternative models with different types of plugs, or include more than one network plug (analog modem and Ethernet, for example) on the same model, but either approach adds cost and complexity for both the manufacturer and user. The latter is the approach taken by multi-mode cell phones, where it works well because the phone's selection of network access method (e.g. analog vs. digital) is automated. The picture is different for a wired device, though, because the user has to learn enough to understand which port to plug a wire into, and possibly get it wrong.

Next, consider diversity above the spanning layer: what kind of message formats should an e-mail appliance support? The Mailbug can only support messages and attachments that can easily be converted to text, meaning that attachments such as Microsoft Word (or Excel or Powerpoint) documents or music (MP3) files attached to an e-mail message are simply stripped off. Will such a device really seem easier to use than a PC if it turns out that many emails can't be handled in the way that the sender intended?

Even if this isn't the case when the device is first purchased, the dynamic diversity of the Internet is bound to make the problem worse over time. New media formats have a way of multiplying: in the PC-based Internet, these rely only on new software and are therefore relatively inexpensive to develop.[13] Devices that can't download the software to handle those new formats will by their nature be at a disadvantage.

Another kind of challenge posed by dynamic diversity is illustrated by the example of a major PC manufacturer that wished to develop a portable scanner that could print to any printer. It would certainly be possible to load such a device with all the firmware necessary to drive all printers known about at the time the scanner was manufactured. But how could it deal with features on future printers not yet invented? It is conceivable that standards for communication with printers are robust enough to enable least-common-denominator printing on fancy future devices. The problem is a lot simpler, however, if new printer drivers can simply be downloaded into the scanner.

In other words, there is a fundamental tension between truly fixed functionality and the Internet's design for diversity and constant change. While static diversity can be supported at a cost (like a multi-mode cell phone), dynamic diversity simply cannot be supported by class 1 appliances. Given the rapid pace of change on the Internet, this implies that any fixed function device may look good when it is purchased but will rapidly become outdated as new formats are introduced that it can't handle. The one case in which this may prove acceptable is if the devices are very cheap (which is possible because of Moore's Law) and readily replaceable with newer versions

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[13] For example, compare what is required for someone like Real Networks or Microsoft to deliver video files over the Internet with the requirements for digital television. Real and Microsoft can develop a file format which can be sent over the existing Internet infrastructure and understood by software on the end-user's equipment (assuming it is a PC). Digital TV, in contrast, requires expensive upgrades to both end-user equipment (TVs are hardware devices that can't load new software to understand new video formats) and the broadcast equipment used by content producers, TV stations and so on. The Internet's decoupling of applications and their associated content formats from the underlying infrastructure thus provides a cheap platform for innovation, avoiding the chicken-and-egg network effects that stymie adoption of new technologies in more integrated architectures. As end user devices that can't download new software to understand new formats, Internet appliances undo some but not all of this decoupling (new formats can still travel over the same network infrastructure). However, incentives to innovate will still come from the PC-based segment of the market, which need not be very large given how cheaply new ideas can be tried out.

(which is possible if service contracts do not have excessively long terms, and appliance vendors keep up with the pace of Internet innovation).

One might reasonably question whether devices that require frequent replacement will really appeal to the techno-phobe or techno-indifferent user at whom Class 1 devices are often aimed. Evidence from cell phones, however, suggests that this is not a serious stumbling block. Data in (Cahners 2000) show that the average time to replace a cell phone in the U.S. went from once every four years in 1990 to once every two years in 1998, even as roughly 66 million new subscribers joined the pool of cell phone owners during that period. Worldwide replacement rates are estimated to be somewhat lower than in the U.S., but still reasonably rapid (between 2_ and 3 years).[14] Consumers, it seems, are willing to replace fixed function appliances reasonably quickly if there is a reason to do so.

In sum, Class 1 appliances are only likely to succeed as very cheap devices with short life spans.[15] Because they will be replaced frequently, we do not see fixed-function devices threatening the Internet innovation engine. Rather, we expect the threat to run in the opposite direction: rapid Internet innovation will render any given fixed-function IA obsolete very quickly.

Class 2: Function Fixed by Service Provider

On the surface, devices in this class may look very similar to class 1 devices. They appear fixed function to users, with buttons for common activities. The buttons may be made of plastic and do things like fetch email (Mailbug-style e-mail devices), display particular Web pages (companion devices for AOL and Microsoft Network (MSN)), or select items from an on-screen

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[14] (Plunkett 2000) estimates that "worldwide…subscribers tend to replace their phones on average every 3 years" (p. 80); (ITU 1999), p. 31 states that "The replacement market was estimated at around 40 per cent of total handset in 1998" (meaning that subscribers replace their handsets every 2_ years on average); and (SG Cowen Securities Corporation 2000) contains data showing global wireless handset replacements at approximately every 3 years in 1998 and every 2_ in 1999, with a forecast of every 2 years by 2001.

[15] This conclusion refers only to the consumer-oriented appliances considered in this paper. There will undoubtedly be a role for fixed-function devices designed for commercial settings or embedded in other equipment in ways that are transparent to the end-user. Such applications are not addressed here.

menu (Internet-connected mobile phones). Alternatively, they may be "soft" buttons displayed on a screen (some Web tablets, next generation PDAs, etc.).

Class 2 devices differ in two crucial ways, however. First, the business model for this class includes not only a device but a service. The definition of an Internet appliance precludes devices that are standalone in the technical sense. It does not, however, require that the box be part of a pre-determined service to work. For example, a user can buy a portable scanner independently of any ISP and still be able to send scanned images over the Internet. A class 2 appliance, in contrast, is designed to work only as part of a particular service. The Netpliance i-opener, for example, not only works out of the box with Netpliance's Internet service, but won't work with anyone else's. Ditto for Compaq's iPAQ IA-1 which is designed to work only with MSN (Lewis 2000, Mossberg 2000), AOL companion devices being developed by Gateway (Miles and Davis 2000), and so on. Pricing reflects this bundling, with most devices priced lower if the user is willing to commit to a longer term subscription to the associated service.

The second key differentiator of class 2 appliances is that under the hood they retain some capability for change. Class 2 devices vary in exactly what kinds of changes can be made to the devices (e.g. reconfiguration, changes to menus and soft buttons, upgrades to new functionality) and who can initiate such changes (user or service provider). At one extreme lie devices, like very high-end Web tablets, that come very close to being PCs: they have disks and users can choose to download new software to them. The other extreme is much more common: devices that have no disk and can only be configured or upgraded at the discretion of the associated service operator, such as the Netpliance i-opener, AOL and MSN companion devices, and lower-end Web tablets.

The importance of control over device upgrades is illustrated by what happened when a Las Vegas engineer figured out how to add a hard drive to a Netpliance i-opener, allowing the device to run Linux and bypass Netpliance's associated Internet service. As (Davis 2000) reported:

> An otherwise amusing story about people who love to take things apart was suddenly turning into a potentially big problem for the company ...Investors selling the stock today may have had visions of throngs of programmers lining up to buy a computer that's only cheap because the cost of the device is subsidized by

> the cost of the Internet service--which suddenly wasn't required if a few more hardware tweaks were made.

Although this particular "tweak" was sufficiently complex and expensive that it didn't ultimately destroy Netpliance's business, it is clear from this story that the more users are able to upgrade their devices whenever and however they wish, the more they are able to revolt against their service providers if they so desire. A classic example of this point is Internet telephony, an innovation which in its earliest forms consisted of users downloading new software to their PCs in order to undercut high calling rates, especially for international phone calls.

The high-level policy issue raised by class 2 appliances, then, is whether the next such important innovation will be prevented by service providers exerting overly tight control over appliance upgrades. On the one hand, it is not in a service provider's interest to alienate customers by limiting their experience too much. As we discussed with regard to class 1 appliances, devices would become increasingly less useful over time without upgrades to ensure their ability to handle new applications and formats that will appear on the future Internet; in other words, customers are likely to pressure service providers to incorporate at least the most popular innovations into their devices. On the other hand, a user who just committed $1,000 for an iPAQ IA-1 and a few years of MSN service, or even a few hundred dollars for an i-opener that only works with the Netpliance Internet service, is a lot more locked in – and therefore at the mercy of the service provider's decisions regarding which innovations to incorporate – than the new PC owner who received a free AOL CD in the mail and decided to give it a try.

One might argue that this kind of lock-in will not materialize because consumers will simply not go for it. The success of AOL, however, suggests otherwise. Just as AOL's bundling of network access with services simplifies the user experience, so too does the addition of appliances to the bundle. At least some consumers will be willing to pay a premium for the added simplicity, and the current flurry of activity in this space ensures that marketers will eventually understand the correct size of that premium, even if they haven't got it quite right yet.

What policy makers need to watch for is anti-competitive abuses of the greater customer lock-in potential that is implicit in the Class 2 appliance model. We worry about two kinds of abuses. The first is the trend to "wall the Internet garden," that is, to break the Internet's characteristic interoperability and the universal access (i.e. anyone can get to anything from anywhere) that flows from it. For example, many Class 2 Internet appliances (WebTV, some Web tablets, MSN companions and so on) will not support some features of the Web, such as Javascript. As a result, users will not be able to access some fraction of Web pages. Often, such a limitation is technical: many of these devices have limited memory. The line between a technical and a strategic limitation can be fine, however. (Mossberg 2000) reports that the iPAQ IA-1 MSN companion doesn't support RealNetworks audio and video file formats. RealNetworks, of course, competes vigorously with Microsoft's Windows Media Player. Given how prevalent RealNetwork's formats are on the Internet, this choice might hurt the IA-1 more than it hurts RealNetworks – today. One might recall, however, that at one time Netscape's browser was also quite prevalent on the Internet.

The second potential for anti-competitive abuse arises when appliances are tied to services provided by operators that occupy a monopoly or near-monopoly position in the value chain. To see why this might be an issue, consider the question of what should appear on the screen when an Internet-enabled wireless phone is turned on. The screen on such a device is very small and can only display a few lines of text. In addition, navigation is limited (imagine how difficult it would be to type a URL on a tiny phone keypad). A menu item that appears on the first one or two screens is much more likely to be accessed than one that requires navigation through multiple levels. Within this environment, who gets to decide which services should be most easily accessible?

Some European mobile service providers thought it should be them, and set up the phones for their services so that they automatically went to their so-called portal sites. Consumers and regulators begged to differ, however. As (Carney 2000) reports:

> On June 21, Britain's BT CellNet Ltd. bowed to pressure to allow its wireless customers to choose rival Internet portals as the home page on their cell phones rather than its own default home page. In May, France Telecom was forced to take similar action. "It's valuable real estate for the carriers, and they're going to have a hard time letting it go," says IDC wireless analyst Callie Nelson.

Valuable real estate indeed: if the mobile service provider can shut out competing portals, it effectively gains control over what content and service providers have any chance of success in the mobile market – control it can use to extract rents from would-be content providers, or from consumers who become captive to advertising and so on.

A similar issue arises with Web tablets. As an industry contact put it when asked whether users would be able to select what Web page appears when they turn the tablet on: "That is technically possible but no business model supports it." By linking the device to the service, the service provider is able to compel the tablet to drive eyeballs to its Web site, which in turn drives revenue from ads, link placement and so on.

This linkage is not necessarily anti-competitive if customers are able to switch to a different service with a different portal. The problem arises when tablets are tied to broadband service providers that are either the only game in town or one of a very small number of options. In this scenario, the market power that arises from lack of broadband competition may be leveraged to create portal-based information services that are a lot more closed than what we might call the "software-only" portals of today such as AOL and Yahoo.

In sum, Class 2 devices are likely to increase the extent to which users may be locked into particular services. Regulators need not save people from themselves, but they should be on the lookout for anti-competitive extensions of this greater degree of lock-in.

Class 3: Function Fixed at User

Class 3 devices are the logical successors to the PC platform that is presently the principal mode for accessing the Internet for most users. From the perspective of the taxonomy presented here, the PC is special because it is a general purpose device that may be configured by the user to support multiple Internet applications in a flexible manner. Neither the equipment vendor nor the customer's Internet service provider controls the configuration of the machine nor does either intentionally limit the end-user's ability to upgrade or customize the device. The ability to install new software and hardware and upgrade existing software and hardware makes the PC much more flexible, adaptable, and customizable than the typical Internet appliance. Most important, the ability to customize the device is managed by the customer. Today, this reconfiguration is cumbersome and often complex, and depends on the end-user being willing to download drivers, open the chassis to install new cards, or complete other tasks that assume a level of sophistication and computer knowledge that is inconsistent with the "it just works" view of the Internet appliance.

In the future, we expect that much of this complexity can be hidden from the user, while retaining the ability of the class 3 device to adaptively support multiple applications. We refer to class 3 devices as ones for which the function (or functions) are fixed *at* the user to signal that the specification of the device's function is set by the user or by software acting on the user's behalf. The idea is to have cake and eat it too: to retain the general-purpose flexibility of the PC, but automate the configuration aspects that introduce complexity.

We expect class 3 appliances to be a generation of devices that develops when today's computer is decomposed into what the user sees as its constituent functional elements: display, keyboard, speakers, microphone, pointing device, etc. These various components are currently organized by the operating system within a standardized PC architecture that is collected into a single box. With connection via LANs (wired or wireless) and the Internet, it will no longer be necessary to keep all of the cooperating components together in close physical proximity. Different components may in fact serve similar functions in different environments. For example, there may be different types of displays in parts of the home (a high-quality large screen for movies in the den, a small less expensive display serving as a household control panel in the hallway, etc.) or input-output devices that are appropriate to the environment (ear-piece for the cell phone, speakers throughout the house for audio output; microphones, pointing devices, and keyboards for input depending on the mode of input most appropriate to the environment and task). A display for caller-id may consist of a small screen next to the office phone, while in the car it may be a speaker that plays synthesized speech. Of course, this vision only works if caller-id functionality can be made smart enough to select the appropriate output device from what is present in any given environment, perhaps with assistance from standardized, general-purpose "composition" protocols at layers below the caller-id application.

Class 3 appliances perpetuate the general-purpose functionality of today's PC because they can be composed together in different ways to support a wide array of tasks. Intelligence (protocols and the software that implements them) will be needed to assist the user in automatically negotiating and configuring the appropriate array of devices to support particular tasks. These tasks will include not only the kinds of things PCs do today (standalone-type office applications such as word processing, spreadsheets, and presentations as well as communications tasks like email), but also many other kinds of activities that would formerly have been performed by special-purpose, fixed function and often analog appliances: TVs, fax machines, VCRs and so on.

When things like ear-pieces and displays become Internet appliances, the annoying (to the user) proliferation of devices with overlapping functionality can slow down. Instead of having several incompatible ear-pieces for your cell phone, MP3 player, and PDA, you will carry a single ear-piece that can serve as the audio output device for all three applications; or, instead of having separate displays on an email-only device, a home control center, and a tablet for browsing the Web, you will have displays that can be integrated with other class 3 component devices to support each of these applications.

The PC is too useful to disappear. Although service providers may like to see specialized devices replace general-purpose devices, there will be a continual tension to offer these general purpose devices. First, the hardcore minority of power users will continue to provide a market for new capabilities. These early adopters continue to demand more computing and communications power and are willing to put up with quite a lot in the way of complexity and poor reliability to get performance improvements. We do not see this group ever saying that they have enough memory, speed, bandwidth, or computing power. While these core users may not support a mass market, they encourage continual innovation at the margin. When coupled to the engine of Moore's Law, this makes it feasible to anticipate incorporating the capabilities demanded by the few in the products offered to the many at a price that is competitive with the earlier generation of mass market products. In the quest to differentiate their mass market offerings, vendors will be continually squeezed as product features previously targeted at niche markets are included in lower end systems.

While it is possible that this device may be a WinTel PC successor, other architectures may also be important. As noted above, there is no shortage of would-be competitors for the rents captured by Microsoft and Intel because of their strong market position in the Internet access market. Purveyors of competing operating systems (Linux, Real Time Operating Systems such as

BeOS or VxWorks, Java, etc.), consumer appliance makers (Sony, Phillips, or Panasonic), and chip-makers (National Semiconductor, AMD, Transmeta, etc.) are all pushing different architectures for building Internet appliances. Many of these are targeting their offerings initially at service providers (Hambrecht & Quist, 1999) and the designs allow the service provider to customize the devices to tie them to the service provider. The underlying hardware/software architectures are general enough, however, to support the design of multiple types of Internet appliances for many types of service provider applications. This generality is needed to realize the scale and scope economies that are needed to make these devices cheap enough to be attractive to residential consumers. This in turn creates a technological platform for supporting the creation of general purpose devices at a cost point that is not much different from that achieved by the specialized device.

Once general purpose flexibility can be added at minimal cost to the vendor, and perhaps only with a moderate increase in the complexity offered to consumers, some entrepreneur will find it advantageous to go this route and allow users to benefit from a more flexible, more general purpose device architecture.

The evolution of the Web tablet provides a case in point. These devices are envisioned as magazine-sized, wireless devices that are initially targeted for basic Internet services such as web-browsing and email. Ethnographic research has demonstrated that these devices have the potential for changing the way consumers utilize the Internet.[16] The flexibility and mobility afforded mean that consumers can use these devices in areas of the house (e.g., kitchen, bedroom, den) and during times/activities (e.g., during play time, while watching a movie, while cooking dinner, etc.) where traditional PC use was not available. Typically, these devices lack such common PC components as disk drives, user-configurable memory, and key boards. They stress such attributes as ease of use, lightness, long battery life, etc.

A number of the current devices are targeted at Internet Service Providers who are expected to sell these as a way of adding incremental service revenues both from current subscribers who

[16] "Unleashed -- Web Tablet Integration into the Home." Presentation by Patricia Somers of MediaOne at MIT Internet & Telecoms Convergence Consortium members' meeting, January, 2000.

will be on-line more often than if they only had a PC connection and new users who find a PC too cumbersome or expensive. The basic need they address, however, is already met in part by portable computers. These however are currently too heavy, power hungry, expensive, or not wirelessly networked to offer strong competition today. However, the PC offers substantially more in the way of generality, upgradeability, and flexibility to the user. The tablet makers will find it tempting to continuously add functionality and flexibility while retaining the convenience of the form factor. We believe this will push the tablet towards specialization in what it is best suited to do (portable display and basic IO), while relying on other class 3-type components for additional capabilities. It doesn't make sense to have separate speakers and displays on every device. This is both expensive and cumbersome, especially once these devices are networked. The generality of the Internet will help drive the class 3 access devices towards *specialized generalization*: for example, the pointing device that works with any application or the speaker that provides audio output from any digital source in the home.

Other examples of class 3 devices we expect to see include the following::

- Home networked printer that provides paper output for email, faxes, web pages, etc.
- Home networked storage for all digital media in the home.
- Home networked speakers for audio output

Realizing this scenario will require a number of important technological developments that currently exist as research agendas rather then complete products. One important element that will help catalyze the emergence of this vision will be the home or personal router. Essentially this device will provide the gateway, switching, and control nexus for these componentized appliances.

In sum, the Class 3 appliance will offer specialized generality. We view it as the logical extension of today's PC. It will be inherently general purpose with respect to the higher-level application services it supports, but will be specialized to address a specific task (display, IO, storage). Each of these appliances will be useless by itself, but will be expected to be used in conjunction with other components to flexibly support computing and communications within home, mobile and potentially also office environments.

Conclusions and Policy Implications

The PC's obvious flaws as an access device constrain demand for Internet services. The PC is too complex, unreliable and feature-rich (read: costly and confusing to use) for what most users need to do on the Internet. On the other hand, the PC is a general purpose device that is readily customized to suit individual tastes and reconfigured to support new applications. In other words, the PC vests the end-user with much more control over her communications environment than was afforded by traditional communication appliances connected to traditional networks (e.g. telephones, televisions, faxes, etc.). This end-user control has helped sustain rapid service innovation and enhanced prospects for competition all along the Internet value chain.

With the transition from PC- to IA-based access to the Internet, policy makers will need to consider the impact of these offsetting forces and whether certain appliance architectures are likely to be more pro-innovation and pro-competition than others. All three classes of devices discussed here are likely to stimulate increased demand for Internet services. New classes of devices can help augment demand by increasing Internet traffic from those already on-line (e.g. from home office to other parts of home, or from fixed locations to mobile) and from expanding the user community to segments not currently served (largely, those who are unwilling to put up with the current complexity and lack of ease of use from today's access devices). *Ceteris paribus*, a larger market is likely to be more competitive and provide enhanced incentives for innovation. Which classes of devices will contribute most to generating this aggregate demand-side pull remains to be seen, as different approaches are tested in the market.[17]

The taxonomy developed in this paper is based on the extent to which the device's function is controllable – i.e. customizable and upgradeable – by the end-user. Different classes of devices may pose different types of risks for the Internet innovation engine, and therefore be of differential concern to policy-makers. We do not believe class 1 appliances pose a serious threat to innovation. Class 2 appliances *may* pose a threat, but not a concrete enough one to warrant any special action at this time. Class 3 appliances have the greatest potential to combine the

[17] The answer will depend on what types of consumers prefer what types of devices and whether the increased demand from existing consumers using the Net more intensively is greater or less than that from the new customers that are added.

benefits of appliance-like ease of use with the continued ability to innovate, but also the biggest challenges for realization.

Class 1 appliances do not pose a threat to innovation because they are unlikely to succeed unless they are inexpensive, frequently replaced devices. As such, Internet innovation can be accommodated by replacing the edge devices on a regular cycle. The low cost of replacement means that customers will not face substantial switching costs, minimizing the risk that a consumer will be locked in by an adoption decision she subsequently learns to regret. Put another way, a Class 1 appliance is fixed function, but only for the duration of its short economic life.

The effect of class 2 appliances on innovation depends on where particular devices fall on the spectrum of user vs. service provider control over device functionality and upgrades. Class 2 appliances are designed to give users access to a subset of the Internet (a so-called "walled garden"), with the size and nature of that subset determined by the particular device and service.[18] The more users can control the device, the more opportunity they may have to expand the subset. We say "may" because this opportunity will not always be freely granted. As the case of wireless Internet portals discussed above illustrates, even phones that functionally give the user the ability to customize what Web site her phone visits by default may not actually reflect that control to the user in the absence of customer outcry and/or regulatory intervention.

A question to consider is when customer outcry is likely to be loud enough to force a business model to give users more control. We speculate that the historical legacy of Internet interoperability has conditioned expectations in this regard, so that services that are either the same as or similar in nature to existing Internet services will generate the same expectation of interoperability. So, for example, a class 2 email-only device has to be able to send and receive e-mail from any other Internet user. It would not be acceptable for an AOL companion appliance to handle e-mail only from other AOL users: this fully closed service model (the ultimate walled garden) was resoundingly rejected by users who effectively put early online

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[18] For example, content and service providers can make their Web sites compatible with NTT DoCoMo's i-mode wireless data service and phones relatively easily compared to WAP services and phones. The predictable result is that much more content is accessible through i-mode (Guth 2000).

services (like Prodigy and CompuServe) out of business while flocking to the Internet's universality.

On the other hand, instant messaging (IM) is very similar in nature to e-mail, although it originated with AOL, not the Internet. AOL's IM service does not interoperate with many non-AOL IM services (most notably Microsoft's), a situation which has not provoked mass AOL user revolt. We further speculate that this tolerance represents a slippery-slope phenomenon. Users buy AOL because it provides them with open enough access to the parts of the Internet they care about. Once the customer base is established, however, it is easier for AOL to strategically exclude other parts of the Internet, because by themselves these parts do not sufficiently motivate users to make the additional effort to switch service providers. In other words, there is a path that starts with service providers limiting choices that customers don't care about and extends to limiting choices they do care about as the service providers lock in customers and consolidate their power. This path is of even greater concern as appliances, with their greater potential for lock-in, enter the picture – an AOL-proprietary IM device, for example, would only add to customer switching costs.[19]

Even more worrisome are devices that eliminate the possibility of user control altogether. One might argue that these would simply be rejected by consumers, but that will only be the case if consumers have a choice. If appliances are bundled with monopolistically-provided broadband services, then the customer who wants the simplicity of an appliance will have little if any choice of service providers. Although such services have not been introduced yet by broadband providers, it is only a matter of time. Any such initiatives would bear close monitoring by policy makers.

Pressure from customers and regulators are not the only forces mitigating against attempts to wall the Internet garden. The desired degree of openness varies depending on one's position in

[19] The Internet Engineering Task Force (IETF) has recently launched a working group to develop open Internet standard instant messaging protocols. In the software-only PC world, such a standard would unify all of AOL's competitors and create a wedge to drive out AOL's fully closed approach. This trajectory would be less likely if AOL users couldn't adopt or interoperate with the IETF standard because they are using AOL companion appliances instead of PCs.

the value chain. In particular, we expect both appliance manufacturers and content providers to retain a vested interest in keeping the Internet open.

Manufacturers prefer an open Internet because it enlarges the market for their products. We can loosely divide appliance manufacturers into two groups: firms with a vested interest in perpetuating the dominance of the WinTel paradigm[20] and those who seek to overturn it.[21] The former have a vested interest in preserving the openness of the Internet as a core driver of demand for their legacy products. The latter need to rely on the externality and scale and scope economies inherent in an open Internet to facilitate their assault on the WinTel market. Both can agree that a closed Internet (unless, of course, they controlled it) would limit demand for their products without providing an edge in competition with their chief rival.

Content providers have a similar incentive to keep the Internet open. However, vertical integration has the potential to alter the incentives of supply chain participants in keeping the Internet open. The recent AOL acquisition of Time Warner has raised anew concerns of content-conduit mergers posing a threat to competition and consumer choice.[22] The fear is that the vertically integrated service provider might deny access to its content to limit competition from alternative conduit or transmission infrastructure providers, or might limit access to its bottleneck facilities to restrict competition from other content. While such mergers raise valid concerns, we are not overly worried at present. With the exception of specific types of programming (e.g. local news or sports, perhaps), we doubt that content is inherently scarce and that such leveraging strategies will prove attractive in the long run. Or, if attempted, that regulators will be unable to respond effectively.[23]

[20] Microsoft, Intel and all of the firms selling complementary hardware, software, and services that preferentially favor the Windows and x86 PC architecture.

[21] Everyone else who sees the move to IAs as a chance to wrest market share from Microsoft and Intel. This includes other chipmakers such as National Semiconductor and AMD, vendors of alternative operating systems such as Be and RTOSs (Real Time Operating Systems), application software developers such as Oracle, etc.

[22] It is noteworthy that AOL dropped its advocacy for mandatory unbundling of cable modem Internet access once it chose to acquire Time Warner.

[23] For example, as when cable system providers were required to provide program access to direct broadcast satellite competitors.

Therefore, barring further vertical integration that dramatically realigns incentives along the value chain, we conclude that there are strong supply-side forces that will help assure that any attempt by infrastructure service providers to use a closed Internet appliance architecture will be unsuccessful. Therefore, a watchful eye on merger behavior and continued regulatory oversight of local access facilities, as long as those remain a bottleneck, are likely sufficient at this time.[24]

Finally, Class 3 appliances pose a more complex risk. Class 3 devices may speed the pace of innovation if current research efforts succeed at developing an architecture and technologies to hide from users the configuration steps necessary to recognize and incorporate new devices into the user's computing environment. In the class 3 world, limits on the pace of innovation may arise more from people's ability or willingness to tolerate changes in functionality than from any technical limitations.

Realization of this future is likely to depend on the development of suitable Class 3 protocols to support on-the-fly configuration of specialized general Class 3 components to support multiple applications. The optimal architecture may require these protocols to be widely implemented (like TCP/IP), and if so, these standards may provide sticking points to further innovation unless these are designed with due consideration to their architecture to assure that these are as flexible, scalable, open, and adaptable as the basic TCP/IP core protocols have proven to be over time. Further discussion of how this might be done, however, is beyond the scope of this paper.[25]

Although this paper has focused on the effect of Internet appliances on innovation, other policy implications of appliances include:

- *Intensity of Competition*: The proliferation of devices with differing combinations of functions (e-mail plus some Web, Web plus some e-mail, etc.) on the one hand moves away from the commodity-style competition that today characterizes PC hardware, but on the other hand increases the ability of devices from different parts of the industry to substitute for one

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[24] Regulatory attention to access to set-top boxes and other potential points of interconnection to what may be a bottleneck local access facility remains warranted at this time.

[25] However, this is very much part of our on-going research agenda in the MIT Internet and Telecoms Convergence Consortium (http://itel.mit.edu).

another. So, for example, while today a Palm Pilot and a cell phone serve distinctly different purposes, tomorrow both will likely bundle wireless connectivity with personal organizer functions (and in so doing compete with products like the Blackberry as well). The origins of these different products may create a situation in which products have the same functionality but very different associated industry structures. The Palm Pilot, for example, has always provided an open platform for third-party software developers. Cell phones, on the other hand, are just beginning to acquire support for Java as a means to enable independent third-party development of new mobile applications.

- *Regulatory Boundaries:* The continued evolution of IAs will make regulatory boundaries ever less clear. The lines between customer equipment and network services, and between industries such as communications and broadcasting, will continue to blur. This will intensify existing problems of classifying particular services, industries and providers as subject to regulation or not.

- *Consumer Protection:* As appliances expand the market for Internet services to include less sophisticated users, and as more functions become automatic and hidden, the need for consumer protection and trust in the security of the environment only intensifies.

- *Privacy*: As appliances spread throughout user environments (home, mobile and office), exchanging information with each other and with service providers, there will be many more points at which information can potentially be collected about an individual's location and activities. In the relatively closed environment of class 2 appliances, this suggests a need for clear and enforced guidelines on what information may be collected and how it may be used (especially since profiling and customization are likely to be essential elements of class 2 business plans). In the more open and interoperable class 3 environment, this issue suggests a need for careful design to avoid the incidental exchange of identifying information, research to understand what kinds of privacy controls are intuitive and valuable to users, and guidelines analogous to the class 2 situation on what can be done with information that does get exchanged.

In conclusion, appliances do not resolve but rather intensify many policy considerations that already exist for the Internet. These policy areas bear watching as well as providing fruitful areas for further research.

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Product Information

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Mailbug (e-mail only device): http://www.mailbug.com/,

http://www.pcworld.com/top400/article/0,1361,12165,00.html (See Figure 1.)

i-opener (e-mail, Web device designed for naïve users): http://www.netpliance.com

iPAQ IA-1 (MSN companion device):

http://athome.compaq.com/showroom/static/ipaq/intappliance.asp

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Picture frames: http://www.ceiva.com/, http://www.storybox.com

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