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Abstract

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Push Technologies for Enhancing Awareness and Coordination

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ABSTRACT

This paper examines the interfaces and potential social impacts of a variety of push technologies. Push technologies are designed to make users aware of information. If this information concerns coworkers or shared tasks, then the resulting awareness can improve the coordination of work. This paper examines how a variety of systems accomplish this: what kinds of information do they use and through what kinds of interfaces do they make the user aware of the information.

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1 INTRODUCTION

Awareness is an important factor for enhancing coordination. Any task that involves multiple people working together requires that those people be aware of one another. In the physical world the examples are obvious. Whether its awareness of glance and gesture that allows people to point to and discuss objects [20] and give directions, awareness of task that insures that two people don't engage in conflicting or redundant tasks, or awareness of voices that enables people to learn new aspects of their job just by being able to overhear more experienced people [46], awareness is a key aspect of any complex task. If musicians were not aware of one another, how could they make music together? In the physical world, this type of awareness is communicated within the work environment primarily through site and sound, but also by touch (ice dancing teams), taste (chefs) and smell (chemists, machinists). Now that many forms of work are now done on computer, how are these common place forms of awareness to be communicated? This survey looks at how push technologies have been used as one solution for creating awareness of work related information.

1.1 Push Technology

Push Technologies are generally defined as a style of software that automatically presents information to either the user or the user's computer when the software determines that it has information of relevance to the user. Specifically, these tools are designed to determine when there is new information available in which the user might have an interest, and to automatically make the information available to that user. A strict definition requires that a *push* server monitor the information source and when new

information is discovered, push it to either the user or the user's machine.

In fact, there are many types of systems that have the same effect, appearing to the users as though they are push technologies, but implemented differently. The two main examples of these are *Scheduled Pull* (a client repeatedly polls the server asking if there is new information it can present to its user), and agents (the client may determine for itself what the user needs to know, how to get it and when to get it). As this survey is most interested in an approach for creating awareness, and not the implementation details of that approach, any push-like system will be treated as a push technology.

The focus of this paper is not awareness in general, because there are in fact many approaches for providing awareness, such as continuous video connections between offices and buildings, email, group calendars, etc. Many of the alternatives are *pull technologies* which use a polling strategy. Polling is an information gathering approach supported by interfaces that present information to the user each time the user requests it. For example, bboards and web pages only tell users that new information has arrived if they launch the appropriate software and navigate to where the new information would arrive. The users must do this each and every time they want to detect a change.

The beliefs behind the design of Push Technologies is that polling is an inefficient use of a user's time. Among its drawbacks are:

1. Polling too frequently results in finding no new information. New information will often not have arrived at the time the user put in the effort to check for it, resulting in wasted effort.
2. Polling frequently causes redundancy. Information that was there the last time the user polled is still considered current news by the information site, even if there are a few new items as well.
3. Polling infrequently misses information. Information that would still be new to the user is out of date, and either no longer useful or has been replaced by even more recent information
4. Users have no way of knowing if any of the new information will be interesting enough to make it worth checking the site.
5. Polling many sources of information is very time consuming.

Push technologies attempt to avoid these issues by eliminating or reducing the need to poll information sources. People can instead register an interest in the various information sources and then engage in other tasks pausing only when informed that new information matching their interests is available.

One last issue that must be addressed before plunging into the body of this survey is the question of what is meant by the term "awareness".

1.2 Awareness

According to American Heritage Dictionary, the term awareness has the following two meanings:

1. Having knowledge or cognizance.
2. Archaic. Vigilant; watchful.

In common usage, awareness means to have knowledge, as in, "I am aware of the research in your field". It also means to monitor something so as to be aware of change. If I am aware of my surroundings, then I know the moment someone enters those surroundings.

In order to focus on a definition for awareness with meaning for collaborative computing, we must combine these two dictionary definitions. Awareness is *knowledge acquired by monitoring one's environment*. This definition allows considerable leeway in the definition of the terms: "monitoring", "knowledge acquired" and "environment".

1.2.1 Monitoring

For purposes of this paper, there are two types of monitoring. One can monitor through peripheral senses while engaged in other tasks, and one can monitor by focusing one's attention on whatever is being monitored. A person can become aware of a body of research by focusing their attention upon it (i.e. by reading research papers in the area). If one wished to know if a building was on fire, one could focus on other tasks and let nose and ears sense smoke and fire alarms. There is also a borderline area between these two possibilities where a person monitors by flicking their eyes (or other sense) briefly away from the focus of the attention in order to monitor something that isn't in the person's focus but also can't be sensed using peripheral senses. A common example of this is a car's rear-view mirror whose display is not the focus of a driver's attention and can't be effectively used with peripheral vision, but can be used by frequent brief glances. This borderline area will be referred to as Pseudo Peripheral Awareness. The distinction between information gathered from the focus of a user's attention and the peripheral senses has also been described as foreground awareness and background awareness [19]. This study recommends that user interface developers harness more "background" information sources in order to communicate more information to the user through

underutilized senses. Most approaches instead attempt to squeeze as much information as possible inside of the user's focus, or using only a single sense (sight).

1.2.2 Knowledge Acquired

Knowledge can be acquired consciously and subconsciously. Much peripheral information is acquired subconsciously, and may never make it into long term memory.

1.2.3 Environment

This is another broadly defined term. A person can become aware of information from a variety of different types of environments, ranging from the physical environment in which they work (office, hallway), the physical environment in which their place of work exists (building, campus, downtown business district), the organizational environment (a company or part of a company, perhaps distributed across the world), the technical field (being aware of the literature in one's area of expertise), virtual environment (documents and other electronic objects, or Avatars representing coworkers), etc.

Combining these three terms shows the perspective on awareness taken by this paper. Monitoring through focusing ones attention or through peripheral senses on any kind of environment to gain knowledge for either long term or short term memory.

1.2.4 Other Definitions of Awareness

A definition that more concisely defines why awareness is an important subject comes from Dourish and Bellotti:

Awareness is an understanding of the activities of others, which provides a context for your own activity. This context is used to ensure that individual contributions are relevant to the group's activity as a whole, and to evaluate individual actions with respect to group goals and progress. [7]

In other words, awareness is a key aspect of coordination, and is an important topic of research because of its potential to enhance coordination and therefore productivity of groups.

Furthermore, awareness can be divided into two aspects: awareness of coworkers, and awareness of objects shared with coworkers. Awareness of the status of documents, patients, systems and other sources can enhance coordination in much the same way as awareness of the people working on those documents, patients or systems [7],[15].

A different analysis of awareness is shown in Table 1 which breaks the definition of awareness into four different quadrants based on whether it is providing near-real time awareness vs. awareness over long periods of time, and whether the awareness focuses on

individuals or groups [21]. Studies have also attempted

Table 1: Four Types of Awareness

Unit of Observation		
Frequency	Individual	Group
Seconds to Minutes	What is a person's location and current activity? (example tools are Portholes, office-share, Piazza) [8],[9],[18]	Is there a group meeting? Where? What types of tasks is the group working on? Who is in the group? (example tools are Video Windows, wOrlds).[29],[42]
Days to Months	What is a person trying to accomplish this week? What are a person's plans for this week? What problems is a person working on solving? (example tools are various calendar applications and distribution lists).	What is a group working on this week? What kinds of problems is the group encountering? What changes has the group made in the task the group is working on? When will the task be complete? (Knowledge Depot, Information Lens [28]).

to formalize and or quantify various aspects of awareness, such as the strength of awareness and the focus vs. the periphery of awareness [36],[30],[21].

Library sciences use the term Awareness for tools that help people to maintain an awareness of what new documents, medical studies, and other publications a library has received within a person's area of interest [43].

In fact, awareness is not just about coordination, but learning as well. A study of telemedical consultations showed that peripheral participation in conversations results in learning; radiographers learn about interpreting x-rays as a result of overhearing doctors discuss the x-rays. Nurses and friends of patients learn more about a patient's condition and treatments by overhearing doctors talk with patients [46, 47]. In an office situation, novices are often placed directly next to more experienced people so that they can learn how things are done by overhearing the experienced person at work.

1.3 Motivations for Studying Push Technology and Collaboration

By presenting information to users (especially summaries of information) push tools help users to maintain an awareness of the information source that the push tool is monitoring. While these tools are not necessary for users to monitor the information source (which can always be done via polling), they reduce the effort for users to monitor the information. People who

were already polling will save much effort. Many of the people for whom polling was too much effort will find the effort of monitoring reduced to acceptable levels. Thus push tools enhance awareness of information. If the tool monitors information concerning the work being done by coworkers or other groups within an organization, the awareness it provides can enhance coordination.

Studying how push technologies can enhance collaboration can provide insight into the various types of effects these tools have had and can have on the users and groups. This insight can help motivate adoption, development and research of mechanisms for distributing information within different types of work environments. Typical mechanisms for sending information to users do not adequately take into account the user's interests. The following techniques are common for distributing information, but have flaws that can be overcome by an appropriately designed Push Technology:

1.3.1 Broadcast Mail

Broadcasting mail to everyone within a group or organizational unit (such as a university department) is a common way to distribute information when the sender is unsure who might be interested in the information. At Bell Atlantic Science & Technology, it is common to broadcast mail to everyone announcing that a car's lights were left on. Everyone gets this mail, but it is only relevant to one person. Most broadcast mail is like that: relevant for only a small subset of the recipients. This technique for distributing information results in significant quantities of junk mail. The more junk mail a user receives, the more likely they are to mistake relevant information for junk mail. This is not an effective method for disseminating information unless it is used only for information that affects everyone.

1.3.2 Selective

When sending announcements to small groups, it is often the case that people who need or want the information but who are not part of that group fail to receive the information. Often they will hear about the information by word-of-mouth, have the information forwarded by someone in the group or they may not find out about the information until too late.

1.3.3 Mailing Lists

Mailing lists and List Servers enable users to easily add and remove themselves from receiving all mail sent within a discussion group. This allows users who feel that a type of information is relevant to them to start receiving that information. Unfortunately, many discussions on these lists aren't of interest to all list members, resulting in junk mail. This junk mail problem is aggravated when the user is a member of many

lists, each relevant to a different aspect of their work.

Push technologies enable people to specify and refine their interests, and to only receive information that matches those interests. Furthermore, the focus tends to be on sending summaries of the information rather than the information itself. By combining many messages which individually may have been junk mail into a single message (digest) that summarizes the set, awareness can be increased and junk-mail decreased.

Furthermore, the concepts described here should not only be thought of as ideas on what kinds of collaborative systems can be built, but also on what kinds of features all systems could easily have added to make them collaborative. Most systems can be designed with a notion of people who are interested in certain types of information and should be notified when that information changes. If it is word processing software, a co-author may benefit from being automatically sent email describing changes when someone changes the paper or a specific section of a paper. If a component in an architecture changes, all developers working on components that connect to that component should be notified. If a server crashes, email could be sent to a list of users and developers who feel that they need to know. This research direction came about as a result of doing exactly that: taking a group memory, and enabling people to inform it that they are to be notified of new information matching their interests.

1.4 Previous Research in Push Technology

There has not been a lot of research explicitly aimed at Push Technology. Past research on push technology has focused on the technologies for providing efficient service rather than on the effect it has on the user [12],[49]. A recent paper gives a very elementary analysis of the types of push systems that exist [12]. This work describes three key characteristics of push technologies:

1. **Request Mechanisms** is either Client Pull or Server Push: when information changes, does the server push that information to the client, or does the client software only find out when it next polls for changes?
2. **Request Scheduling** is either Periodic or Aperiodic: does the client poll for changes periodically, or does it poll when certain conditions arise? Does the server send data to the client periodically, or when something changes?
3. **Data Transfer Mechanism** is either Unicast or 1-to-N: does the server broadcast notifications, or send change reports to one client at a time?

Table 2 illustrates the types of systems that fit into the various request mechanisms and scheduling quadrants.

Table 2: Scheduling and Request Model

	Client Pull	Server Push
Periodic	Portholes clients request updated information every 5 minutes	Knowledge Depot pushes information to users once every X days
Aperiodic	Eudora (not really a push technology) checks for new mail every time a user sends mail	EDEM sends mail whenever it detects a set of events

While work that calls itself push technology research is very limited, there has been research in fields that are either synonymous with push technologies, or key components of push technologies.

1.4.1 Notification Servers

Notification servers are an important component of push technologies, and are sometimes distributed separately to simplify the task of implementing new push tools. For example, Elvin [11], CQ [24] and Keryxsoft [34] are examples of systems that list themselves as notification servers. These servers receive information from assorted information sources, and notify users whose preferences match that information. The implementation of the notification server determines how flexible it is in terms of what types of information sources it can monitor, and in how flexibly a user's interests can be specified. A taxonomy of notification servers can be found in [35]. Notification Servers are only required components for True Push technologies, and not for information gathering agents and scheduled pull implementations of push-like technologies.

1.4.2 Event Monitoring

Event monitors are also an important part of many push technologies. Combining an event monitor with even a very simple notification server can create a simple push tool. EDEM [16] and Babysense [48] are both event monitoring systems. One monitors user interface events, and when it detects events that match the interests of the system developers, sends a report of those events to those developers. Babysense monitors a baby's physical activities and notifies parents of various types of activities using specialized output devices located throughout a home or office. Both technologies monitor events and push information to people interested in the information. These two technologies focus on monitoring, and could in fact have sent the information that they detect to a more powerful notification server to be distributed to a wider or more carefully selected set of interested users or output devices. Instead they use very simple models of where

to send their information. Figure 1 illustrates the relationship between the event monitors and notification servers.

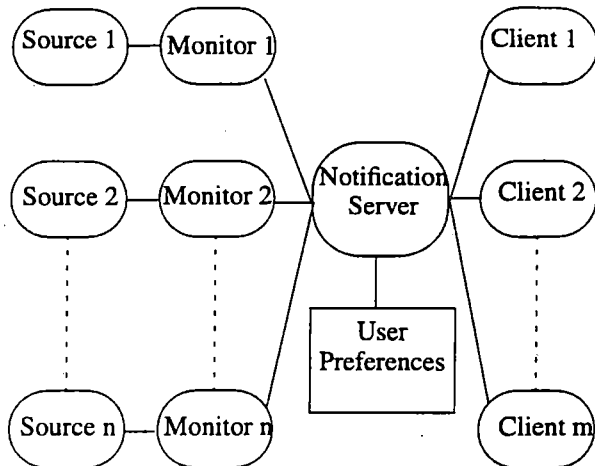


Figure 1: Generalized Push Architecture
(True Push Only)

There are actually many types of monitoring systems in existence, monitoring a wide range of systems from power plants, factories, networks, switchboards, traffic, weather, etc. Most monitoring systems simply report to visualization software that enables people to monitor large complex systems. However, some send email, pager messages, bring up alert dialog boxes, or use other mechanisms to contact affected parties when some dangerous condition is detected.

1.4.3 Industry Work

While systems that monitor for information and push that information to users are common, the term "Push Technology" is in fact only commonly used in industry where it implies any technology that makes information quickly available to users based on the interests that

those users have specified. Discussions of push technologies are generally centered around publishers and content providers, whose goal is to efficiently get their content to their readers. Such discussions focus on comparing various standards and deployment tools. Therefore, most published materials provided by industry are not relevant to this survey because 1. this survey focuses on the user experience of receiving information rather than creating information, 2. this survey does not limit itself to published content as most other push technology discussions do. For a survey of push systems available in industry, see [40].

1.4.4 Visualization Systems

In general, any interface designed to monitor complex systems and send events to all of the users who are running visualization software can be considered a push technology. The visualization software takes these events and presents them to users, enabling them to actively monitor the status of various parts of a factory, network, software system, etc. This paper does NOT delve into research into these types of systems where the focus is on users monitoring information in real time, but does include systems when they illustrate interesting directions for collaborative awareness.

2 Attributes of a Push Technology

While the classification schemes of previous research are relevant to understanding Push Technologies, they do little to help understand how to design a push system to create different types of user experiences. The attributes of push systems described below are only those attributes that directly affect the users. These attributes are applicable to push and most push-like technologies, and not just for those explicitly designed to emphasize group or organizational awareness. Each attribute listed below will also have a list of possible values. These values will be assigned to the systems examined by this survey. In some cases, a set of values will be needed to best describe certain attributes.

2.1 Configurability of Interests

Table 3: Configuring Interests

Name	Definition
Sources Accessed by Tool	
Single Source	System is designed to access only a single source of information
Preset Sources	Select from a set of built-in information sources, and receive all information from those sources. Typical sources are CNN news, NY Times, and other general and specialty news sources.
Methods for specifying interests in a source	
Existence	If the system knows you exist, it sends you all of its information, otherwise, it sends you nothing.
Form Based	Select checkboxes and other form elements to specify what information to receive from the requested sources.
Keyword Filters	Specify keywords to search for in the specified sources.
Query Based	Specify database queries and formulas (numerical or logical) describing what kinds of information or conditions are of interest.
Methods for adding new sources	
User Provided Source	User can specify a source not built into the system (i.e. cnn news is generally built in, but being able to select any web site in the internet to monitor means that the user is not restricted to a bound set of sources, and that one can create one's own information source to monitor)
Developer Provided Source	Same as user provided source, but the user needs to be able to develop software to enable the push technology to access the content.
Administrator Provided Source	A company can push its own information using some push technologies by purchasing a licence and creating a special group within the company that produces information for the rest of the company.

All Push tools provide some mechanism by which a user can specify what kinds of information they are interested in. This may be as simple as telling a listserv that you are interested in their discussions or going to a web site that is of interest, and telling that web site that

you want to be notified of changes and sent newsletters describing those changes [39]. It also could be a set of complex of filters, database queries or forms specifying what does and does not interest a user. Possible values for this attribute listed in table 3.

2.2 Notification

There are two aspects of notification associated with Push Technologies and that define the user experience: 1) "notification of change", and 2) notification of "notification of change". A very simple example illustrates the difference: a web site changes and the user is emailed a notification that the web site has changed. The next time the user checks their email they will read this "notification of change" message, and become aware of the modified web site. On the other hand, if the email client gives a special beep to notify the user when the notification has arrived, then the user has received a notification of "notification of change" message. The user has been notified that they have received a "notification of change", and depending on how carefully the beep has been configured, they may be aware even before reading the "notification of change" what type of change has taken place. To be a push technology, there must be a "notification of change", as the purpose of pushing information to a user is to notify and provide access to new (or modified) information (there is one exception to this rule that will be mentioned later in this paper). For time critical information, there must be a notification of "notification of change"; otherwise, users might not notice the notification -- or not until too late. This paper will use the phrase Metanotification to refer to notification of notification of change, and Notification to refer to notification of change.

One should also note that notification and metanotification are interdependent. They are both attributes of the push notification process. When an alert box pops up on a user's computer saying that the building is on fire, the alert box is the metanotification (grabbing the user's attention, telling them that important information is being imparted), and the text in the alert box is the notification of change itself. Other approaches such as email do not have the two intertwined to the same degree.

Finally, while only meta-notification and notification are discussed here, it should be understood that there are more layers than that. For example, a notification of change may summarize a news article and have a link to the article. The notification of change sent to the user reflects that there was a change in the database of articles (a result of adding the article). The article itself is a notification of change occurring within the real world (the article summarizes some political, economic or other change).

Table 4: Notification Elements

Name	Definition
Metanotification	Notification of a "notification of change" (optional)
Notification	Information sent to user summarizing some change. Information created, modified, or removed, or some other event occurs.
Article	Detailed "notification of change" such as a news article that was simply summarized in the notification. (optional)
Observed system	The system being observed. Even a news article describing a news event is only an attempt to summarize in a small amount of text all of the complexities of a real world event. The system could also be the stock market, a software system, a document that is being edited by a group of people, etc.

2.2.1 Configurability of Metanotification

Notification of "notification of change" (metanotification) is an important part of determining what role the tool will perform for a user. If the new information is that the building is on fire, the metanotification must grab the user's attention, perhaps with a dialog box popping up on every computer in the building making alarm sounds. When a stock price has made a steep dive, people heavily invested in that stock may want to be able to react quickly to the change. One way to do that would be to have the notification sent to their pager so that the pager will beep to obtain their attention and inform them of the drop in value of the stock. If the new information is that the latest weather report says tomorrow is going to be a sunny day, such intrusive metanotification mechanisms will be resented.

The ability to configure the metanotification allows users to set different strengths of metanotification for different types of information. A highly configurable metanotification allows users to configure strong (highly intrusive) methods of grabbing the users attention for time critical notifications, and progressively weaker metanotifications for less critical information. For example, a price drop in an investor's most important stock should result in the investor being paged, but a less important stock should only result in email being sent.

Another important aspect of metanotification is that the manner in which it grabs the user's attention can also be highly informative as to what type of notification has been received. If it grabs the user's attention by playing a fire alarm sound, then the user will know before even looking at the notification that something is on fire. If the metanotification is a coffee icon lighting up and

making gentle coffee maker sounds [11] then the user will know that some group is going to the lounge for a coffee break. A screen saver taking over the computer and showing a storm would be a metanotification that some kind of important weather change information is being sent out.

Table 5: MetaNotification Types

Name	Definition
None	Many push tools do not deal in time critical information, and/or use an interface that is not designed to obtain the user's attention.
Unconfigurable	There is only one type of metanotification provided, and all notifications use the same metanotification. This attribute is often modified with weak or strong indicating the intrusiveness of the preset metanotification.
Email notification	This is a function of the user's email client. Some email clients enable users to specify subjects and authors for incoming mail, and associate them with specific sounds and actions. Some don't. Email metanotification has the potential to be highly configurable, but this depends upon the user's environment and patience
Highly configurable	Some tools comes with the ability to associate different types of information with different types of metanotifications.
Notification Paths	This is for tools that try a sequence of metanotifications until one succeeds in gaining the user's attention.
Highly Informative	This can be combined with other values for this attribute, and is used for metanotifications that are highly informative. A highly configurable metanotifications that allow users to choose between email, pager, and other media are not adding to the informativeness. If a pager gives the same type of beep for every type of information it receives then the fact that it has beeped has not told the user anything about the nature of the information received. Email notification is highly informative if the user has the right email client, and invests the time to configure it.

2.2.2 Informativeness of Notification of Change

A notification of change consists of some type of summary of what has changed. Generally the change is the addition of new information, so a summary may be the headline, title or subject of the new information, but the summary may also be a paragraph summary or excerpt. In some cases, there is only a notification that there was a change, with no description of what those

changes were. The effectiveness of these summaries has a strong effect on the use of this information. CNN sends news summaries each day which contain headlines, summaries of each article, hints on what else is in the article, and a link to the article itself if the recipient finds it interesting enough. Recipients then use the summaries to keep up on the news, and to discover the few articles that are interesting enough to read in full. Summaries that just contain headlines are not nearly as effective for staying aware of what is happening in the news or for finding interesting articles. However, due to its conciseness, presenting headlines only is useful because it can be presented to users in various formats such as a scrolling marquis that displays headlines while a user works. For some types of information, simple headlines are preferable. A report on changes to stock prices for the last hour would be frustrating to read if each change is accompanied by a full paragraph analysis of why each stock changed the way it did. Finally, some notifications of change don't provide any information other than the fact that something changed. The Dartmouth Informant [6] sends out email reporting on new web pages matching a search. The report consists of a message saying that new information had been found and that the user should go to their web site to see if any of it is relevant.

Table 6: Notification Types

Name	Definition
No Information	No information is provided.
Headline	The notification consists of a one line summary such as a news headline or a subject line.
First Paragraph	This is a simplistic approach to providing more information. Usually consists of a headline followed by the first paragraph, first n characters, or y minutes of audio or other information easily taken from the document.
Hand written or AI generated summary	An abstract for a research paper, a handwritten summary for a news article, a computer generated summary reporting the status of a system, etc.
Entire Document	The notification of change contains the entire object that has changed.

2.3 Peripheralness of Awareness

As discussed when defining awareness, there is peripheral awareness for information detected through

peripheral sensory information, knowledge awareness that results from a user focusing attention upon the information, and between these two poles, pseudo peripheral awareness for information picked up in momentary glances or shifts of attention. While peripheral awareness seems similar to meta-notification (which will often use peripheral messages such as beeps and blinking icons to notify that there is new information), peripheralness is concerned with how the information is communicated rather than how the arrival of the information is communicated. Most tools are knowledge awareness tools which, regardless of any beeping or other metanotification, communicate the nature of the information when users focus their attention on it. For tools that do communicate through peripheral information, the metanotification can easily

Table 7: Peripheralness

Name	Definition
True Peripheral	This is information detected despite the fact that the information was not at any time focussed upon by the user. This can be done using senses not needed to focus on the current task (sound if the person is reading), or through the periphery of the sense the person is using (aware of music playing even though the person's attention is focused upon a conversation)
Pseudo Peripheral	As with the rear-view mirror, this isn't truly peripheral awareness information because a user is focusing their attention to acquire the information. However, it takes only a glance or a very brief disruption of their task to become aware of the information. Systems that provide this type of information usually allow users the option to not just glance, but to look carefully at the information to obtain knowledge
Knowledge Awareness	This is information that must be scanned or read to become aware of knowledge. It is whatever information the user is focusing their attention upon. Sometimes the knowledge that the user becomes aware of is that relevant information exists, other times it is knowledge of the information itself.

be confused with peripheral information. For example, a change from hearing the sound of rain to the quiet absence of rain metanotifies a person of the fact that there was a change in weather (change in sound often catches a person's attention). The steady sound of the new weather carries the information to be communicated.

It is important to note that most pseudo peripheral systems are designed for users to briefly shift attention to and from the interface, and to do this frequently. As a result, it is very rare for such a system to use

metanotification to deliberately draw the user's attention. While one counter example of this rule is presented later in the paper, it is generally assumed by this paper that pseudo peripheral systems do not use metanotification.

2.4 Ease of Access to Detailed Information

Most push technologies enable a user to more rapidly access the information being summarized by the notification of change.

Table 8: Ease of Access

Name	Definition
No Document	There is no original document to link the user to for more information. The event being reporting on may be an event detected in a system. A report on a user's activities sent by EDEM does not have an original document, nor does a tool that reports changes in temperatures as measured by an instrumented thermometer.
Reference to Site	The notification of change informs users that they can go to a web site and search the web site for more information.
Reference to Source	The notification of change (or each notification of change in the case of cnn news which sends an email message containing many headlines and summaries) contains a link to the original document or article.
Document Downloaded	The document is downloaded automatically, allowing the user quick or off-line access to it if needed.

2.5 Event Model

A distinction that is also important to the user experience is whether the Push Server sends events to the user as they are detected or sends a batch of reports periodically (called a digest). This is connected to the attributes in table 2 (Periodic vs. Aperiodic, Client Pull vs. Server Push). For example, a system that aperiodically sends out summaries of new information is generally sending these reports as the new information is detected, while a system that sends reports periodically will generally be sending out one report with all of the events to take place within the last time period. This distinction is important for the user because it determines to what extent the system can be used for critical notifications, and to what extent it is simply an awareness tool. For example, a system that monitors events on a network to detect network problems needs to notify network administrators quickly when a problem occurs [41]. A system that monitors smoke alarms should notify the fire department as soon as it detects an alarm going off.

Whereas aperiodic event monitoring systems detect the event itself (new data being entered into a database, a fire alarm going off, etc.), Digest generators generally poll for new information just as a user would. Every half hour, retrieve the latest stock prices and send the user a digest of all noteworthy changes to stocks in the user's portfolio. Every 24 hours, email the user the newest world news summaries [17],[32]. Once a week, email users a list of new books available [1].

Table 9: Event Models

Name	Definition
Event Monitoring	System detects events and immediately informs users. These are Aperiodic Server Push systems or periodic systems that check frequently
Digests	System reports on a set of events to happen since the last report

3 Types of Push System Interfaces

Push technology interface styles can be categorized as follows:

1. Scrolling Marquis/Ticker
2. Screen Saver,
3. Information Browsers
4. Email
5. Hybrid

3.1 Scrolling Marquis/Ticker

This interface typically provides an floating palette docked to the top or bottom of a screen, showing a sequence of headlines, stock quotes, and other simple information. Some of these work by scrolling the information from right to left, others simply flash a single headline, and then after an interval, flash the next. Both of these interfaces allow users to click on the headline to obtain more information about the article. This type of interface is also common away from the desktop computer. TV stations often show emergency weather conditions by scrolling textual warnings under the show being broadcast. The entrances to the University of California, Irvine are guarded by large displays that scroll announcements of upcoming events. The UCI student center cafeteria once had an LED display scrolling news reports to keep students aware of the news.

The goal of all of these tools is to create pseudo peripheral awareness in hopes that users will be able to focus on their activity (work on a computer, watch tv, drive safely into the University) and still be able to notice when information relevant to them appears and to get the gist of the message without seriously disrupting their task (which disruption could result in reduced productivity or a car accident blocking the entrance to the university). If the information is important to the person, then they will become aware

that the important information is available to them, and they can click on the headline, set the tv channel to a weather or news station, or call the University's Information line. This is pseudo peripheral awareness rather than true peripheral awareness because for a moment, people must glance at the scrolling line of text if they are to learn its subject. The only information that people pick up through peripheral vision is that there is some kind of information scrolling across a display.

The main pros of such a system are:

1. The information can be viewed within a users work-space without obscuring or being obscured by the work. This allows users to glance quickly at the palette and then back again to their work.
2. It provides simple unobtrusive information
3. It usually provides links to the information being described (hyperlinks on a computer, telephone numbers on public displays).

Some drawbacks of such an interface are:

1. Constantly changing information can distract people from their work. (Some people adjust to this better than others, and some tasks are easier to be distracted from than others).
2. Information generally cycles. The palette shows its headlines, and keeps showing them over and over because it has no idea whether or not the user has noticed them yet. Once the user has seen a large percentage of the headlines available, future glances are more likely to show a headline they have already seen than one that they aren't yet aware of.
3. A headline often isn't informative enough to decide whether or not to obtain more information. Sometimes, a summary needs to be a full paragraph to show how it differs from knowledge the user already has. For example, the headline "US Warplanes Bomb Iraqi Defense Sites" has appeared repeatedly in the news, and the headline alone does not indicate how this instance of the headline differs from when the same headline appeared yesterday or the day before.
4. While designed to exist within a user's peripheral vision, it generally fails to take advantage of this. Peripheral vision can tell a person when text is scrolling and when it isn't, and it may be able to notice if the text is in an unusual color or font size. Based on personal experience, this author can rarely notice the actual words in the headline without focusing on them.
5. Most of these systems can not be used to notify users of important information because 1) they are oriented at displaying all information equally, and generally do not make one headline stand out from the next (through color, size or sound effects that draw the attention to headlines that users could have configured as more important than others), and because 2) these types of systems have no way of insuring that the user sees the information. If a user

is focusing on work every time the message "the building is on fire" scrolls past, then the user won't know that the building is on fire until a true peripheral sense (smell and sound) detects smoke or sirens.

3.2 Screen Savers

Screen savers are another common approach to Push Technology. They provide a screen full of summaries (and advertisements and graphics...) and cycle through pages of content to enable users to be aware of different information each time they glance at it. Summaries can be full paragraphs or simple headlines, and are hyperlinked to the information being summarized. These tools vary slightly in how they go about enhancing awareness.

Screen Saver interfaces are designed to activate themselves when the user is not using the computer. This means that each time they return to their computer (or glance at the monitor when doing noncomputer work) they will have an opportunity to notice if some new and interesting piece of information has arrived. This tries to achieve a weak form of pseudo peripheral awareness. The user doesn't need to stop and read the page, its just there where they can glance at it while doing other things. It is also the first thing that their eyes see when they return to the computer. To encourage this type of use, the font tends to be very large and eye-catching, which also means that these interfaces often don't have space for paragraph summaries.

Some other push technologies use the same general approach: use large windows, cycle through information, allow users to glance at the information to become aware of some set of headlines and advertisements. These tools are included in the screen saver category despite the lack of a screen saver feature. These tools can be used on an extra monitor or next to the application that the user is using. These tools are included within the screen saver category.

The effectiveness of these types of interfaces depends on the user's work environment. For example, a user who spends time at their desk with at least one computer idle will gain more than users who are constantly using all computers at their desk.

Pros for these types of interfaces:

1. Interface has room to display more information than just the headline (even though this extra space is often used to make the font larger and to add large advertisements). This additional information can help make people aware of what is going on and to help them decide whether or not they need more information.
2. The interface is not limited to textual information like a scrolling marquis.
3. Very unintrusive interface.

Cons for these types of interfaces:

1. Screen savers cycle when monitoring an information source. The window shows its headlines, and keeps showing them over and over because it has no idea whether or not the user has noticed them yet. Once the user has seen a large percentage of the headlines available, future glances are more likely to show a set of headlines they have already seen than one that they aren't yet aware of.
2. Users of these systems often complain that they contain large quantities of advertisements and other unhelpful (and slow to download) information and a relatively small amount of useful information.
3. Many implementations of these systems hog network bandwidth.
4. It takes a second monitor or a second computer to make these interfaces most effective.
5. Most of these systems can't be used to notify users of urgent information because they are oriented at displaying all information, not at notifying people of specific information.

3.3 Information Browsers

Information browsers such as web browsers and the Pointcast browser display lists of headlines, and periodically update that list. They are designed to enable users to browse for new information whenever they are able to stop their current work and switch to the browser application. Therefore, these are knowledge awareness tools. Unfortunately, these tools do little more than simplify the task of polling; instead of the polling the information source, users poll a browser that shows what is at the information source.

3.4 Pager

The pager/cell phone approach allows short messages to be sent to a pager that will loudly beep (or vibrate), obtaining user's attention and drawing it to a one line description of information that they need to be aware of. This allows users to maintain awareness of sources regardless of their physical location.

3.5 Email

Email is almost exclusively a knowledge awareness tool. While it is possible to use email as a peripheral awareness tool by keying special sounds to messages with specific subjects and authors (like an alarm sound announcing email that reports a possible security breach on a network), this only works if users specially configure their mail client. The ability to do this is not directly supported by the email message or server, only by each individual user's willingness to go to the effort of configuring their mail tool. The effectiveness of email as a means of notifying users of important information depends upon the urgency of the notification and how the user interacts with email (how often are they on-line, how soon do they find out about new messages and process them, etc.).

Pros for this style of interface:

1. Avoids repetitious cycling through information.

User can clearly distinguish between read and unread information, as well as being able to go back and look at old summaries at need.

2. Can be used as a reliable mechanism for notifying users of new information because it has permanence and simple metanotification (i.e. it beeps or causes icons to blink or light up to notify the user that there is new information). Unlike other interfaces, email will wait for as long as it takes the user to view it.
3. Information is not constrained in real-estate. Email can summarize as much information as needed, and users can scan through as many pages of summaries as they need (whereas the screen saver style interface can only show one full page at a time). Also, email can achieve anything a web browser can if the user has support for html mail.
4. Not very intrusive upon work, unless user handles each email message as it arrives.

Cons for this style are:

1. Often limited to textual information, with no hyper-linking (unless user has an html aware mail client).
2. Effectiveness of metanotification depends upon how much time a user spends on line and how they have their mail client configured.
3. It is easy to subscribe to too many sources, resulting in too much mail to handle.

3.6 Hybrid

Many systems are hybrid; they provide multiple interface styles allowing the user to choose either which interface to use, or which interface should be used for notifications of different types of information.

3.7 Real Time Visualization and Monitoring Systems

Systems that are designed to be the focus of the user's attention and task and which present real time information to visualize a system are also common. While the techniques are similar to those of Push Technology, such systems are not discussed in detail here due to a key difference in the goal: these tools are an aid to help a user monitor a system full time rather than a tool to free users from having to monitor the system themselves).

3.8 Nonstandard Interfaces

There are a number of Push Systems that communicate with users using different mechanisms than the standard ones listed above. There are also systems that use dialog boxes and alert windows, computer generated voices, photographs and more. However, these systems are relatively uncommon and so are clustered in the nonstandard interfaces category.

4 Survey of Existing Collaborative Push Systems

This section discusses various awareness tools that use push approaches. Each technology is categorized based on attributes discussed above (Table 14 at end of report). For a tool to be included in this survey, it must have the following characteristics:

1. It must have some notion of users having an interest in a type of information. Overly simplistic models (i.e. if the users name is in a list, then send that user all information) are generally uninteresting.
2. The tool must support collaboration or awareness at either the group or organizational level. Even if this is not an intended use for the tool, this type of use must be a reasonable application for the tool.
3. The tool must summarize information for the user. Usually these summaries are just headlines, paragraphs, photographs, charts, etc. This requirement excludes Video conferencing, telephony and other highly synchronous forms of communication that involve continuous connections with a constant flow of information (rather than a summary). One particularly interesting type of tool which is left out by this requirement are video awareness tools such as Video Windows and Office-Share which maintain continuous video connections between remote sites or offices so that people in distributed sites or offices can gain more of the awareness benefits of being colocated [29], [9]. Chat room style tools are not considered highly synchronous in this work.

4.1 Historical Systems

4.1.1 IBM's Business Intelligence System

The logical place to start this survey is with one of the earliest push systems to support group awareness. In 1958 IBM published a paper titled "A Business Intelligence System" [25], which remains one of the Push Technologies best oriented towards the goal of organizational awareness. The tool required that an organization's librarians enter every document produced within the company into their computer system. The system then generated an abstract based on its analysis of the document, and compared the abstract with specifications of the tasks of each group within the organization. If it determines that there is sufficient overlap between the task description and abstract, then it sends a report to each matching group providing them with the author, title and serial number for the document. Reports are sent to the group by sending it to a printer located near that group. Users can respond if interested in the document by telephoning the computer and dialing that document's serial number. The computer responds by sending the abstract to the group via office mail, telefax, or TV display.

4.2 Scrolling Marquis/Ticker

4.2.1 TickerTape

Tickertape [10] is the best example of an implementation of this type of interface for supporting collaborative work and group awareness. Users of this system specify preferences for which information sources to monitor, and filters for what types of information to take from these sources. Users can subscribe to news, bboards, group discussions, and to other information sources that with a little programming they can connect to Tickertape's Elvin

Notification Server (i.e. monitor documents for change, databases for new information, etc.). The group discussions provide a common center for light weight communications such as "I'm leaving for lunch, who is joining me?" and other simple messages that allow people to maintain an awareness of what is happening with members of their group. This tool can also be used to announce changes to documents or web sites, and transmit other simple awareness and coordination information.

This tool partially avoids one of the main drawbacks of typical scrolling marquis by having a time-out model for when a message has been around for too long and no longer needs to be repeatedly scrolled across the window. When a user sends a message to a Tickertape discussion group, they specify a group to send it to, when the message should time out, and an optional attachment that users can view by clicking on the message as it scrolls past.

Tickertape appears to have the same shortcomings as all scrolling marquis style interfaces in that it doesn't have any way to make some messages stand out as more important than others. However it is quite possible that at some point the interface will be improved to enable users to associate colors and sounds with messages that match specific filters. Catching the user's attention via peripheral vision and senses can increase the probability that the user will be aware of important items of information. This could significantly add to the usefulness of this tool.

4.2.2 CoffeeBiff

Also based on the Elvin Notification Server, CoffeeBiff is an icon docked in a corner of a screen that lights up and makes appropriate sounds whenever a coworker announces that they are taking a coffee break. The icon scrolls the names of all coworkers who are currently taking a coffee break. Users will therefore know when people they need to talk with are taking a break, can join those people, discuss work over coffee, and then return to their offices. A simple tool that enables users to coordinate their breaks and, as a result, provide opportunities for impromptu and informal meetings.

Even if many of these meetings don't discuss work, they present the opportunity to discuss and collaborate on work should people need it. Even conversations that don't discuss work can be beneficial in helping to coordinate work [22]. For example, a comment about a skiing trip can help coordination by making people aware that a person will be gone that day and that any discussions and tasks requiring that person will need to take place before or after that date.

Unlike other scrolling marquis type systems, CoffeeBiff uses peripheral vision and sound to communicate with users. This interface only has motion when there is activity, unlike other tickers that have constant motion all day long. When there is constant motion, the existence of motion means

nothing, for CoffeeBiff, motion peripherally communicates activity.

4.2.3 7am News Ticker

The 7am News Ticker is another version of this style of interface that also has features capable of enhancing coordination. This implementation of the ticker style interface differs from others of its type in that it is a java applet designed to be added to web pages (as opposed to being docked at the top or bottom of a computer screen). As part of the specification for the applet, the web page author places parameters specifying which news sources are of interest to people who would read that web page. The web master can add custom news articles as well, helping users to maintain an awareness of news from the people providing the web page. While not explicitly designed for collaborative work, the applet parameters could be generated by cgi scripts, such that each time a user loads a page, it will come with a new set of information. A web page used to access and share source code could contain messages scrolling across the top indicating who has checked out documents accessed on the page, who is currently viewing the web page, and other awareness information. All of this information could also have been put directly into the web page, but by scrolling it across the top, it becomes awareness information instead of content that users must navigate through to find what they seek.

4.3 Screen Savers, Information Browsers, Paggers

Most tools using these interfaces are discussed in the hybrid category, however, there are two screen saver interfaces that do not provide any alternative interfaces.

4.3.1 NetReach

The NetReach screen saver has a simple system concept. Some content provider within a group or organization must create PowerPoint slides containing information that they want users to be aware of. These slides are then displayed on the screen savers of group members or employees. This can be used to make company announcements, introduce new employees (show their photos, with a description of how they will fit into the company), and other information to help employees become aware of what is new in a company, and maintain an awareness of the status or existence of projects and people who are no longer new [38]. Lack of any user control over what information they receive is a major shortcoming of the tool.

4.3.2 Bell Atlantic News Network

While not strictly a screen saver (and providing no user preferences), Bell Atlantic's TV station behaves in a comparable manner. This is a television broadcast that presents one screen-full of text with optional images included, and no animation. Periodically it will move from one screenful of text to the next. Each screenful of text summarizes a news item of what is happening in Bell Atlantic or what is happening in the world that can affect Bell Atlantic. As with screen savers, it keeps cycling through information so that if you glance at it,

you may or may not see a news item you have seen before.

The key difference between this and a screen saver interface is in how this type of tool can be used. While the user can no longer interact with it by clicking on an item for a more detailed description, users are no longer restricted to getting news when their screen saver turns on. Bell Atlantic places televisions showing their news within cafeterias and lobbies. Employees who eat in the cafeteria or wait for rides or busses in lobbies can become aware of what is happening in the company by glancing occasionally at the television while engaged in tasks requiring relatively low levels of concentration.

This is a relatively low tech solution, but by making people aware of news at times when they are not at their computers, they won't be distracted from work by various push tools.

4.4 Email

Email is one of the most common push tools (though often not thought of as push tools by those who use it to automatically push information). Two of the examples chosen here are developed at the University of California, Irvine.

4.4.1 EDEM

Event Detection and Event Monitoring (EDEM) is an agent that is distributed with software and monitors how the system is used [16]. When it detects user interface events or failures of events to occur, it sends mail to the developers reporting on how the system is being used. This is designed to allow developers to see how system usage differs from how they expected the system to be used. The result is to automate communication between users and developers: users' needs and understanding of the system are captured and communicated to developers who respond by improving the system to take those needs into account and to communicate a better understanding of the system to the users. This is an indirect coordination mechanism that requires little or no effort from the users.

4.4.2 Knowledge Depot

Knowledge Depot is a shared information repository which automatically captures and categorizes discussions and information emailed between users of the tool. Each category contains a formula specifying what type of information it should receive a copy of (so that when Knowledge Depot captures a new item of information, it will make the information accessible from all categories with appropriate formulas). Furthermore, users can create and modify categories at any time. If users discover that there is a category capturing information highly relevant to their work, they can subscribe to it and be emailed reports summarizing all new information to be captured within that category. Because users can create new categories, users can subscribe to whatever subset of information is of interest to them. There are two versions of

Knowledge Depot: a web based version, and a Lotus Notes version.

The Lotus Notes version enables users to subscribe not only to Knowledge Depots, but to any Lotus Notes database. Serious users of Lotus Notes store all information they create in Notes databases. By enabling users to subscribe to these databases, they are enabled to maintain an awareness of a wide variety of different types of information. When a new entry is made to a Name & Address database (a database listing all employees within the company), the report sent to subscribers indicates that a new person has joined the company, is working with a certain group and has the following expertise. Subscribing to databases or Depots where people discuss design issues enables people to maintain an awareness of potential design changes that can affect the overall task of a large group.

4.4.3 MedFetch

MedFetch [31] is a web site that allows users to specify searches to be performed on Medline (a medical library database). Users specify keywords to search for, and whether to receive summaries of new publications on those topics weekly or monthly. Medical researchers and practitioners can then have information pushed to them, informing them of new studies and publications in their area of research or practice. The result is that members of medical communities can be more closely tied together; people will know when someone publishes a study that may affect their patients or their research. This awareness can enhance collaboration within these communities.

4.5 Hybrid

4.5.1 Pointcast

Pointcast is one of the products that made the term "Push Technology" a big hype term in 1996. This service provides access to a large number of news and information sources. Companies that use their own Pointcast Server can provide their own content. The clients use three interfaces: Screen Saver, Pointcast Browser, and scrolling marquis. Users switch between these based on their needs and current activities. The Screen Saver presents information when they return to their computer from a break, ticker continues to try to keep them aware of issues as they work, and the PointCast Browser allows them to deliberately look up what information is new. Pointcast supports awareness within companies by allowing companies to buy Pointcast servers and distribute their own information (news about the company, its partners, customers and competitors). This enables users to maintain an awareness of events, projects and decisions within the company that can affect their work.

4.5.2 Diffusion

Diffusion is a Push Technology designed to be a "Customer Relationship Manager" [44]. Its goal is to automate the communication between customers and service providers by pushing information from service

providers to all of the employees of the customer organizations. Individuals within a customer company specify which information provided by the service company is of interest to them, and whether it should be automatically be sent to them, or whether they should just be notified when the information is available. Customers specify how the Diffusion Server should notify them when new information is available. Options include: telephone, pager, E-mail, fax, printer, and overnight mail. Users can specify notification paths (if the telephone is not picked up, contact the customer using a pager). Each notification of change that the user receives includes information on how to quickly respond to the information. For example, if the customer is monitoring a stock, and instructs the Diffusion Server to notify him immediately if the stock value drops below a certain value, the notification of change might include a phone number telling them who to call to quickly buy or sell the observed stock. For types of information that aren't urgent enough to require notification, users can use the web interface to learn what information has been released, and to read, print, or request that a hard copy of the information be sent.

This system uses Push Technology to enhance communication between different groups of people (researchers/consultants who provide reports and information, and the people who depend upon that information). It creates awareness by notifying people of the availability of information that they have specified as being important to them

4.5.3 Verity's IntelliServ

Using web browser forms, users configure personal and group information profiles. IntelliServ then monitors file and web servers, databases, Lotus Notes and Microsoft Exchange servers for new information matching those profiles. User preferences determine whether they are notified by email, scrolling ticker, pager or through a web interface. It also determines whether they are notified as information is detected (Event Monitoring) or periodically via a web page of summaries that are generated every few hours, days, or weeks (digest). As with Knowledge Depot, this tool allows users to monitor much of the information within an intranet, whether that information is documentation, purchase orders, calendars and other sources with many of the same types of coordination benefits of Knowledge Depot.

4.5.4 WaveTop and AirMedia

WaveTop and AirMedia mirror many of the capabilities of other push products, but provides services via TV tuner cards rather than through internet access. Using special TV broadcast frequencies, information is broadcast to all users, and each computer filters and saves any information that matches the user's preferences. These systems also distribute news articles, reports, shareware, new medical findings, product announcements as well as notifications for individual users telling them when new email has

arrived in their email accounts. Companies can create their own channels to send information to their employees or clients. Much of this information is downloaded automatically, notifying the user of the information after it has downloaded. The user can request information that they have been notified of without having to request it over the internet (since it is already on their machine), and without increasing the load on their local network by constantly having documents downloaded in the background (because the download takes place over tv frequencies rather than over the internet).

4.6 Real Time Visualization and Monitoring Systems

4.6.1 Arkola

Arkola [13] was actually a system to enable groups to monitor a factory simulation. The Arkola system was designed to study collaborative monitoring that combined sound and sight. Each user focused their display on the part of the factory that they were to monitor. This would allow them to detect and "repair" problems when they occur in any of the factory components within their view. Different components made different sounds, so that if parts of the factory broke down that were not within a user's view (but were in another user's view), both users would be aware of the problem even though only one could see it. This awareness enabled them to converse about the nature of the problem in a way that did not happen without the sound. By pushing events in the form of visual and auditory information to all users monitoring the system, it acted as a notification and awareness tool that created collaboration by involving all users in the problem solving task.

4.7 Other Interface Styles

4.7.1 Nomadic Radio

Nomadic Radio [37] is designed to help people stay aware of work and work environment related issues even when not at their computer. The Nomadic Radio uses speakers, microphone and buttons to interact with user. Information that the user should be aware of is sent to the radio (which is worn by its user), which then determines whether and how to notify its user. Nomadic Radio uses the following information to determine how to notify the user:

1. Priority of the information as indicated by the user's preferences which specify sources or subjects and their priority.
2. User's current receptiveness to notifications. If the user has recently aborted attempts to notify, then don't bother that user unless the information has a very high priority. If the user has recently requested more information on a number of different notifications, then notify them of information even if the priority is low.
3. Is the user currently engaged in a conversation (detected by Nomadic Radio's microphone)? If so,

only interrupt with high priority notifications.

Notifications can be communicated at any of five levels of intrusiveness:

1. **Silence:** Used for very low priority messages, or medium priority messages when user behavior indicates that interruptions are inappropriate
2. **Ambient Cues:** The radio creates peripheral awareness by continuously playing the sound of water flowing, and modulating that sound to indicate different types of events. Using sounds that will eventually become part of the background noise, small modulations can make a user aware of activity without distracting them from their current task.
3. **Summary:** Speaks a description of the information (such as who an email message is from). Makes user aware of the presence and general nature of information.
4. **Preview:** Speaks the first 100 characters, or if message is audio, plays first portion of audio. Makes user aware of presence and specific nature of information.
5. **Full Body:** Speaks entire textual or audio message.
6. **Foreground:** Interrupts any work being done, loudly speaking the entire message

Changes in the ambient noise notify a user that a notification is about to be delivered, and either draws the users attention so that they are listening when notification is recited, or allows them to press a button to cancel a notification before it can present a potentially awkward interruption. Pressing the button also notifies the system that interruptions might be unwelcome for a period of time.

Users can be notified of whatever types of information they can configure their systems to handle, including newly arrived email, imminent events on their calendar, and information about coworkers. After the user has been notified of the presence of a new item of information, the user can press a button on the Nomadic Radio to have the radio read/replay the entire item of information that was summarized in the notification.

With a system like this, it is difficult to distinguish between metanotification and the notification of change. Changes in ambient sound that warn users that the radio is about to speak a notification are part of the metanotification. The nature of these ambient sounds may also communicate the priority of the notification. The manner in which the notification is presented (summary, preview, full body or foreground) also communicates the importance of the notification, drawing the users attention to the words that are actually being spoken (the notification of change itself).

4.7.2 Portholes

The Bell Atlantic Portholes [23] displays photographs of offices and public spaces, updated once every 5 minutes, on a user's web browser. The photographs

enable users to maintain an awareness of who is available, and who is either out of their office, in a meeting or on the phone. This type of awareness enhances people's ability to collaborate by letting them notice that someone they needed to meet with is available, and to notice that an impromptu meeting is taking place that the user may wish to join. Users control which people and sites are displayed in their Portholes Viewer, and also are provided the option of having the occasional random person and place appear in the viewer (enabling them to become aware of people that they don't normally work with, but with whom a better awareness of might encourage future collaboration [22]).

4.7.3 Chat rooms, MUDs, MOOs, Instant Messengers

Chat rooms, MUDs and MOOs all have a notion of rooms or locations. Users register an interest in the activities of the room by entering a room, at which point all discussion and activity within the room is sent to the user. Some systems enable users to listen to more than one room at a time, and some allow discussions to include many rooms (via such mechanisms as shouting). For users who constantly keep a chat or MUD window open (such as in the Churchill study [5]), the tool gains some of the same collaborative and awareness benefits of Tickertape discussion groups. As MUDs and MOOs also permit the manipulation of objects, these tools can also promote awareness of changes to shared objects such as documents.

Instant Messengers such as the AOL Instant Messenger [2] are also designed as a form of chat tool. Instead of having a notion of rooms, it has a notion of buddies. Users specify which people they care about, and the Instant Messenger window shows them which of their friends is on-line and therefore available for a "chat". Obviously, if the people work together, this awareness also provides them an opportunity to collaborate.

4.7.4 BusinessLink/PUSH

The BusinessLink [4] push technology is one of the few push system that not only pushes content, but also pushes executables. For example, an applet can be sent around which will pop up on user's computers announcing that there is a surplus supply of some item, and providing users with a text box where they can enter how many of these items they want to buy. This type of interactivity can allow voting, organizing lunches, and a variety of other types of collaborations.

4.7.5 SISCO Desktop

The SISCO Desktop [30] is designed to provide a user group with a shared desktop to help make them more aware of one another. The SISCO Cooperation Layer captures user actions (events), storing them, and pushing them to other group members. The system provides a visualization to enable users to see what documents other users are working on. This awareness can help both with versioning control (preventing more than one person at a time from modifying a document, while letting users know before trying to access the

document that it is checked out) and for more general coordination that results when people know what other people are working on.

4.8 Document sharing Push Systems

4.8.1 Marimba, Backweb

Backweb and Marimba's Castanets are both designed to distribute documents and updates. While Castanets focuses on automatically distributing applications and updates to those applications, BackWeb focuses on distributing documents. These tools are not generally used to make users aware of changes, but rather to make sure that when they access information (such as a price list), or run a program (to calculate a price) that they are actually using the most recent information (the most recent price list or the most recent formulas for calculating a price). Synchronizing users is a form of collaboration, but not nearly as interesting a form of collaboration as others mentioned in this paper. This technology is interesting because it is one of the few types of push technologies that does not require a "notification of change" (though it still may choose to send them). Document updates can be pushed to the user without notifying them of the change, and they will still use the most recent list when they use their computer.

5 Goal Attributes of Push Technologies

The attributes of push technologies discussed above are those attributes that describe how the technology was implemented. Attributes described here are derived from understanding the systems described above, and attempting to apply the basic attributes to them. The two attributes discussed here relate to the goal of the tools: the notification goal and the collaborative goal.

5.1 Notification Goal

What is the system's goal, to notify users or to make them aware? For example, the goal of Portholes is to make users aware of co-workers, not to notify users of their co-workers' every move. Users are expected to occasionally glance at the portholes window and know when people are available. The system does not assume that users will see all of the photographs that it displays, and in fact the system would be working quite normally if users were to miss a few hour's worth of photographs. The tool's goal is to make users aware but makes no assumption that users will notice any specific item of information.

On the other hand, a window that pops up telling a user that the building is on fire is attempting to notify the user rather than simply enable them to be aware. Users are expected to notice the notification; the system would have failed in its purpose had the user failed to notice. Furthermore, a notification system may have an expectation of the user receiving a notification within a certain time-span. For a user to receive a notice that the building is on fire an hour after the fire was detected would mean that the system has failed.

Email, one of the most common push technologies, doesn't fit cleanly into either of these categories. For example, if an email is sent to a user to notify that user of a drop in stock price, it may be trying to notify the user of an important event. However, if the user only checks email once a week, it will have failed in a very important aspect of a notification system: quickly obtaining the user's attention and drawing it to the notification of change. Even for users who are constantly connected to the internet, if the email client does not notify the user of new messages, then while the user may discover the message within an hour, there is still a considerable delay because the system failed to metanotify the user.

To simplify analysis, this paper assumes that people who subscribe to email services that send email once a day will check their email at least once a day, and those who subscribe to email notifications that can arrive at any time will be constantly connected to the internet. We also assume that the email client will notify users when mail arrives. However no assumption is made about how the email client is used. Some users check their mail as soon as they hear the metanotification, others may let it pile up and check it once every few hours.

So how do we define whether the goal of an email message is to notify or to enable users to stay aware? A user who configures an email client to speak the phrase "stock value dropped" whenever email arrives reporting on a drop in stock value will have shifted the goal more strongly towards notification, whereas a mail client that does not notify the user of incoming mail will have shifted the goal more towards awareness. We can not categorize this on a per-user basis. Instead we focus on previously defined attributes to determine what kind of goal the email has.

The answer to this question is in two parts:

1. Email messages in the form of digests, such as CNN mail messages summarizing all of the news from the past day are focused on awareness. While the probability of a user seeing the email is high, the probability of a user seeing any one headline within the mail message is much less. The goal is to make the user aware of the news, especially of aspects of the news that are of interest to the user. The goal is not to notify the user of every news article from the past day.
2. Email messages that result from Event Monitoring such as a tool monitoring the stock market are notification tools. While there is no guarantee that the mail client will obtain the user's attention quickly and cause them to focus on the notification, if the user chooses to configure the mail tool to grab their attention then the tool will do so. The goal of the message is to notify the user of the event.
3. While user configuration may change the nature of how the email is used, typical users will not take

advantage of this. Furthermore, we can not categorize email on a per-user basis.

The goal attribute is derived from other attributes. A tool that uses meta-notification to alert users to the arrival of new information is a notification tool, those that do not are awareness tools. The one exception to this is email, where messages that result from event monitoring are notification tools, and digests are awareness tools.

Note that there is a third possible goal here for systems whose purpose is real time monitoring such as Arkola.

To further understand the implications of the Goal attribute, it can be compared with the various basic attributes.

Table 10: Notification Goal

Goal	Definition
Notification	Notify users of change by either: <ol style="list-style-type: none"> 1. Obtaining the user's attention and focusing it upon the notification of change (meta-notification) 2. Email sent as a result of Event Monitoring
Awareness	Make users aware of information by either: <ol style="list-style-type: none"> 1. Making information easily accessible to them but without making any effort to draw the user's attention to it, and having no guarantee of the user seeing it (no metanotification). 2. Emailed digests.
Real-time Monitoring	Visualization software designed to allow users to constantly monitor complex systems

5.1.1 Analysis of attributes with respect to notification goal

This section discusses the trade-offs of different values of different attributes when designing notification and awareness oriented systems.

5.1.1.1 Configurability of Interests

Configurability of interests is much more important to notification oriented systems than to awareness systems. While it is not critical to the use of notification oriented push systems, it is critical to scaling up users to monitoring many information sources. If a company has five simple information sources that are monitored, and each source has a few employees who want to be notified when the simple source has changed, then even the lowest level of configurability is sufficient (subscribing means receiving all changes to source). However, if users are interested in multiple sources, or

there are significant amounts and varieties of information added to a single source then configurability is critical. Repeated interruptions from irrelevant notifications would disrupt work. An awareness oriented system on the other hand is designed to make it easier for users to ignore or skim over uninteresting materials without being distracted from work.

5.1.1.2 Configurability of Metanotification

Metanotification is associated with a notification goal. However, some systems enable users to turn off metanotification for information they want to be aware of without having to be notified of every change. Diffusion for example allows users to route critical information to pagers and telephones, and information that they simply want to maintain an awareness of to email or even to a web page. Diffusion gives users the choice between notification and awareness, but most other tools do not provide this degree of configurability. Email configurability also places this control in the user's hands. However, studies have shown that most user's don't invest the time to configure their default environment to better suite their needs [26], and indeed, typical users of email probably do not go to great lengths to associate different sounds with different types of messages.

5.1.1.3 Informativeness of Notification of Change

This is marginally more important for notification than awareness. An uninformative notification of change will require that users be motivated enough to look up more information. Users will often be to busy to take the time to do this. This reduction in the probability of a user receiving the information needed to understand what has changed makes this more appropriate for an awareness tool. However, even awareness tools are less likely to make users aware with poor or oversummarized information.

5.1.1.4 Peripheralness

Pseudo peripheral systems are always awareness oriented, peripheral systems always notification oriented (though often having a strong awareness benefit as well), and knowledge awareness systems can be either. A notification oriented system must use either peripheral awareness or knowledge awareness in order to notify users and make them aware. A pseudo peripheral tool is designed for users to glance occasionally to maintain awareness, not to obtain the user's attention (as defined in section 2.3).

This paper has looked at both peripheral and knowledge awareness systems with a notification goal. Nomadic Radio uses peripheral sounds and CoffeeBiff uses both sound and peripheral vision. They both provide relatively low intrusiveness on the user's task. They get new information to users quickly but have much less than 100% certainty of getting information to users: users may be to focused on a task to note information arriving from the periphery.

Knowledge Awareness notification systems such as Diffusion, EDEM, BusinessLink and IntelliServ use either email or custom-built interfaces. BusinessLink which sends dialog boxes to its users to notify them of information can get information to users faster than the other systems (which depend upon email). Email is far less disruptive, and does not force users to stop their current task to deal with information popping up on their monitor. Email also has permanence; when a user clicks ok on the alert or dialog box, the box is gone. Which approach to building a notification system to follow depends upon the urgency of the information for the user's task. A dialog box interrupting work to tell people that the coffee pot is empty might seem excessive to most, but if the only person subscribed to receive those notifications is a person being paid to keep the pot full, then it may be quite appropriate.

5.1.1.5 Ease of Access to Original Information

This attribute affects the ease of use of the tool, but is of equal importance for both notification and awareness systems. The exception to this is if the notifications of change are uninformative, in which case, ease of access becomes more important for notification systems so people being notified can quickly understand what it is that they are being notified of.

5.1.1.6 Event Model

The event model has already been discussed as part of the definition for the types of goals. A digest email is aimed at awareness while an event monitoring email is aimed at notification. Furthermore, tools using interfaces other than email that are included in this survey have kept to this principle. Portholes for example presents a number of photos all at once, a digest of what is happening during a time period and aimed at awareness. CoffeeBiff presents information as it receives it (event monitoring), making users aware as the information is encountered.

Table 11: Achieving the Goal

	Notification	Awareness
Configurability of Interests	very important for scaling	important for scaling
Configurability of Metanotification	very important for distinguishing metanotifications and importance	Not needed
Informativeness of Notification	very important for rapid notification	important
Peripheralness	Peripheral, Some Knowledge	Pseudo Peripheral, Some Knowledge
Ease of Access	very important	important

Table 11: Achieving the Goal

	Notification	Awareness
Event Model	Event Monitoring	Digests

5.2 Collaborative Attribute

Now that we have looked at the manner in which push technologies can communicate with users and make them aware of information, it is time to look at how that awareness information can enhance collaboration. Specifically, what features of the systems in this survey made them support collaboration within groups, within organizations, or both (Project Awareness)? This is a

Table 12: Collaboration

Name	Definition
Within Group	Tool is designed to enhance awareness between members of a group
Within Organization	Tool is designed to enhance awareness of issues and events within an organization
Within and Between Groups	Tool is able to make people more aware of both their own group and other groups within their organization, also referred to here as "Project Awareness"

difficult question; in theory, any technique for pushing information to users could be used for either group information or organizational information. Portholes could be used to create one group photo that is assembled from the various photos of the users. This could be used to present group photos from across an organization. EDEM could be used to make developers aware of how an entire organization uses software, instead of a relatively small test group. 7am could be used on a company home page showing company news rather than on a group home page showing group related information. With appropriate tools for quickly publishing information in a format that Pointcast can distribute, even pointcast can be used by a small group. The user interface affects how a tool is used and the impact that information can have on work, but does not affect whether the information concerns the user's group or organization. Because this is not inherent in the user interfaces of all push technologies (some of which aren't even collaborative in nature), this attribute could not be discussed with the basic attributes.

For software to be adopted by users, users must see a reasonable return on their effort [14]. If the perceived benefit of creating and distributing a single document/notification is relatively small compared to the effort required to create it, then users will not willingly use the tool. It seems reasonable to assume that users will

see greater benefits to coordinating with group members, and be more willing to work towards that goal than coordinating with an entire organization or project (an organization is much less tangible, just as a university is much less tangible to a person than are coworkers). In fact any tool designed to create awareness is having a much less tangible affect (and therefore has less observed benefit) than tools for communicating directly with people, or for notifying them of information.

Even without push tools, people already create information and send it out to make people aware. Email is often used to broadcast announcements, and these messages can often be quite long (and presumably time consuming to compose). Providing a push tool however builds in a requirement for people to produce these announcements. Management, having paid the bill, will expect people to contribute information and to access other people's information (the same expectation that exists with Lotus Notes and the web -- and which users often fail to meet when the individual benefits of creating information and making it publicly available are perceived as insufficient [33]). While the users who were already producing and distributing announcements may happily continue doing so with the new technology, many other people will have no motivation to adopt the push tool.

To determine the effort needed by individual users, we look at the information source for each tool. Is the knowledge that is pushed to group members information that people are already producing, and which the push system is finding and distributing? If people create information specifically to be pushed, is it something that anyone can do (like typing a one line message over Tickertape, Chat groups or a MUDD), or does it take careful publishing work (NetReach, Pointcast)?

5.2.1 Requirements for Awareness Within Group

Tools such as Portholes, Knowledge Depot, Tickertape, Chat, EDEM, and the SISCO Desktop are effective at providing awareness within a group because the work required of each user is minimal. Once configured, many of these systems run automatically; collecting information as people go about their work (Knowledge Depot monitoring Lotus Notes databases and email, Portholes snapping photos and SISCO Desktop observing which users are accessing which documents). Tickertape, Chat and MUDD tools require only that users type in a brief message to send it out, and it requires only a little effort and screen space to view the responses. Effective use of push tools to support group awareness requires that most of the effort of producing and distributing information be automated.

Thus the real labor involved in getting such systems to work is in installing and in configuring the tools and the user's preferences or subscriptions. For example, EDEM requires that software developers use an event language to specify the information that they want to

subscribe to. Once the effort has been done, it runs automatically, but there is considerable effort in determining an appropriate set of event sequences to monitor and in specifying that set. Programmers are also required to write code to connect information sources to TickerTape and Nomadic Radio. Portholes contains many options that each user must select from to configure their preferences and begin using the tool. All of these are start-up costs.

Within a group, start-up costs are more acceptable than information production costs. Users can help one another install, configure and understand their tools, developers can link in the information source, and the disruption to work is finished, everyone goes back to work. If information production costs are high (such as for systems that don't automatically capture information and require users to design and distribute it), then the disruption to work never ends.

5.2.2 Within Organization

Push tools targeted at organizations often require a person or group to be charged with the responsibility of producing content (perhaps the same type of people who may have once produced company news letters). Tools like Pointcast or AirMedia must have a person or group who is charged with the responsibility for finding information and formatting it properly. Organizations can also use tools that capture and distribute information. Knowledge Depot, and IntelliServ can both monitor large portions of a company's intranet, making work-groups aware of what other work-groups are doing throughout the organization.

On the other hand, start-up costs per user can be a problem. The effort to make thousands of people go through complex installations and configurations can be extremely costly in terms of time lost for support personnel as well as users across an organization. This makes low cost start-up tools slightly preferable for an organization. Creating a small group of content producers or mandating that each group designate one member to produce content describing that group's status is unlikely to seem as disruptive.

5.2.3 Within and Between Groups

Systems such as Knowledge Depot and IntelliServ which monitor intranets, automatically capturing information that has been made publicly accessible to the organization, also support project awareness. Project awareness tools enhance the ability of members of large projects to maintain an awareness of all groups within a project whose decisions and progress can affect the subscribed user. Project awareness tools bear the same constraints as both within group tools and organizational tools: cost to produce information must be minimal (preferably automated), and start-up costs must be smaller (cost of installation and configuration per user).

The following table illustrates the conclusions of this section. Administrative start-up effort is the amount of

effort the manager of the group, organization or project is willing to invest in installing and having software written to link information sources to the push tool, and other costs to administrators. User start-up cost is the effort to configure preferences, install software and link personal information sources. Administrative Content Production is the effort that the administration is willing to invest in creating content to push to users. User content production is the effort of individual users to produce and push information. Note that the values listed below are not the required amounts of effort, but the maximum acceptable effort for an awareness system to appear to have sufficient benefits. While this

Table 13: Maximum Acceptable Effort

	Administrative Start-up	User Start-up	Administrative Content Production	User Content Production
Group	Medium	High	None	Low
Project	High	Medium	Medium	Low
Organization	High	Low	High	None

is presented without proof, it seems intuitive to expect that a small work group would not be willing to hire staff to produce group awareness information, and that individual users will be more motivated to make group members aware than to make organizations aware. Most push tools aimed at organizations do not allow users to submit information.

6 Future Directions

This section consists of various ideas for push technology interfaces, and where they might go.

6.1 Agents

Adding greater intelligence and initiative can result in far more usable interfaces. This was demonstrated by the Nomadic Radio which analyzed its user's current receptivity to notification and. There are many ways that such intelligent agents can be used in other tools. Nomadic Radio contained an awareness agent which had certain types of information to determine how and when to notify its user. Other notification systems could obtain access to other types of information to determine a user's availability. For example, users with high idle time, or who are accessing applications such as web browsers and email may be more receptive to notifications. Of course, if the agent determines that the information is a high priority, it can interrupt the user immediately. An agent designed to allow users to train an email client on how to categorize incoming mail [27] presents one approach: user training. Each notification can contain reaction buttons where user's can indicate if the interruption was at a bad time (zero idle time while working in a word processor) or if the interruption was appropriate for the given information.

The same type of intelligent agent approach can help evolve interests. Rather than requiring users to constantly respecify their interests as they attempt to refine them to include and exclude all of the appropriate information, let users train them, and allow them to learn over time as the user's interests change.

Intelligence would also benefit awareness tool. Many awareness tools cycle through information (screen savers and scrolling tickers) which would benefit from knowing which notifications of change a user has seen, and which one's users have requested more information on. This information can be used to remove notifications from the cycle (so the user doesn't have to see it repeatedly).

6.2 Information Sources

As many of these systems have shown, a proper information source, especially a flexible information source (such as the ability to monitor any web site or any Lotus Notes database) can result in leveraging work other people are already doing, and can enable users to monitor a wide variety of information.

Other tools such as the Elvin Notification Server have even greater flexibility, at the cost of requiring software developers to connect new information sources. While we've discussed using it to monitor documents and web sites for changes, it could in fact be used to monitor both on-line information and information from the physical world. For example, if the Active Badge Locator system [45] were to send notice to the Elvin Notification server whenever a person moves from one floor of a building to another, then users could configure TickerTape to scroll a message whenever someone they need to see happens to be near their office. Push technologies can be far more than the publish and distribute mechanism that was originally conceived by Pointcast, Marimba and other big names in the field, simply by creating access to new types of information.

6.3 Mobile Computing

Some of the tools included in this survey were not tied down to the internet (WaveTop/AirMedia), or to the desktop computer (Nomadic Radio, Diffusion). The possibilities though can only improve as the ability to connect to mobile computers improves. For example, AvantGo [3] synchronizes web sites with a PalmPilot. Their demo illustrates a customer representative synchronizing with a web site that contains a list of locations that he must visit in a single day. That list includes a description of the problems each customer encountered, information about the customer and a map to the customer's location. With PalmPilots going wireless, with cell phones gaining the ability to browse the web, new applications for push tools can arise. After having synchronized the PalmPilot with the schedule of sites to visit, changes to that schedule can be pushed as the person works (enabling clients to cancel appointments, and have that immediately propagate to the palmtop computer). And once you

have that, you can also link the PalmTop to an Active Badge locator system to help find people's current locations as you walk through a building looking for them, and other applications that are far more dynamic than were possible on the desktop.

7 Conclusions

A wide range of collaborative uses of push technologies has been explored in this paper. These uses included distributing company news, to enhance awareness of an organization (Pointcast), Customer Relationship Managers (Diffusion), discussion awareness (chat, Tickertape, Knowledge Depot), awareness of coworker availability (Portholes), as well as a variety of tools for maintaining awareness of any information of interest (Tickertape, Knowledge Depot, IntelliServ). Exploring these more proactive interfaces for distributing awareness information is an important area of study for both the user interface and computer supported collaborative work areas.

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