Implementation of a Caching Mechanism in a Pervasive Environment

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Abstract

The primary motivation behind this project is to take a step towards deploying pervasive environments. The scenario considered here depicts an environment, where information is made available pervasively and a user interested in obtaining that information, gets it with the least effort and high transparency. The pervasive information here is that of the paintings in an art museum and the user carries a device, enabling him to be a part of the environment. We have also made an effort to propose and implement an optimal caching mechanism on the user device to overcome the obvious limitations on information availability in such an environment.

Keywords: wireless networks, piconet, bluetooth, infrared

1. Introduction

With the exponential growth of the pervasive computing devices in every day life has encouraged the need for faster access for data using these devices. This has caused traffic overload at data sources and along network paths. It has created ``hot spots'' of network load with the same data being transmitted over the same network links again and again to thousands of users. One solution is that to place caches at points of traffic aggregation (network access points). When all requests generated by users of these devices, a University's students, or a company's employees are required to go through a cache, there is an opportunity for them to find popular content already stored in the cache, thereby avoiding the network entirely and hence reducing the congestion the network links.

This paper discusses the implementation of a scenario that uses a caching mechanism in a pervasive environment. The scenario that is considered is as follows:

David Williams, a lover of art, decides to visit a nearby museum on his lunch break. On entering the museum, he is given two options. The first option is to carry a Personal Device Assistants (PDA) that can be used to retrieve information about paintings while the second option is to join a tour group that will leave in an hour. Since his lunch break will be over in an hour's time and the guided tour will take a longer time, he decides to use the first option. When he goes from painting to another, he will receive messages carrying information about the painting nearest to him on his PDA. He shall then be able to receive this information as fast as possible as shown in the figure 1.

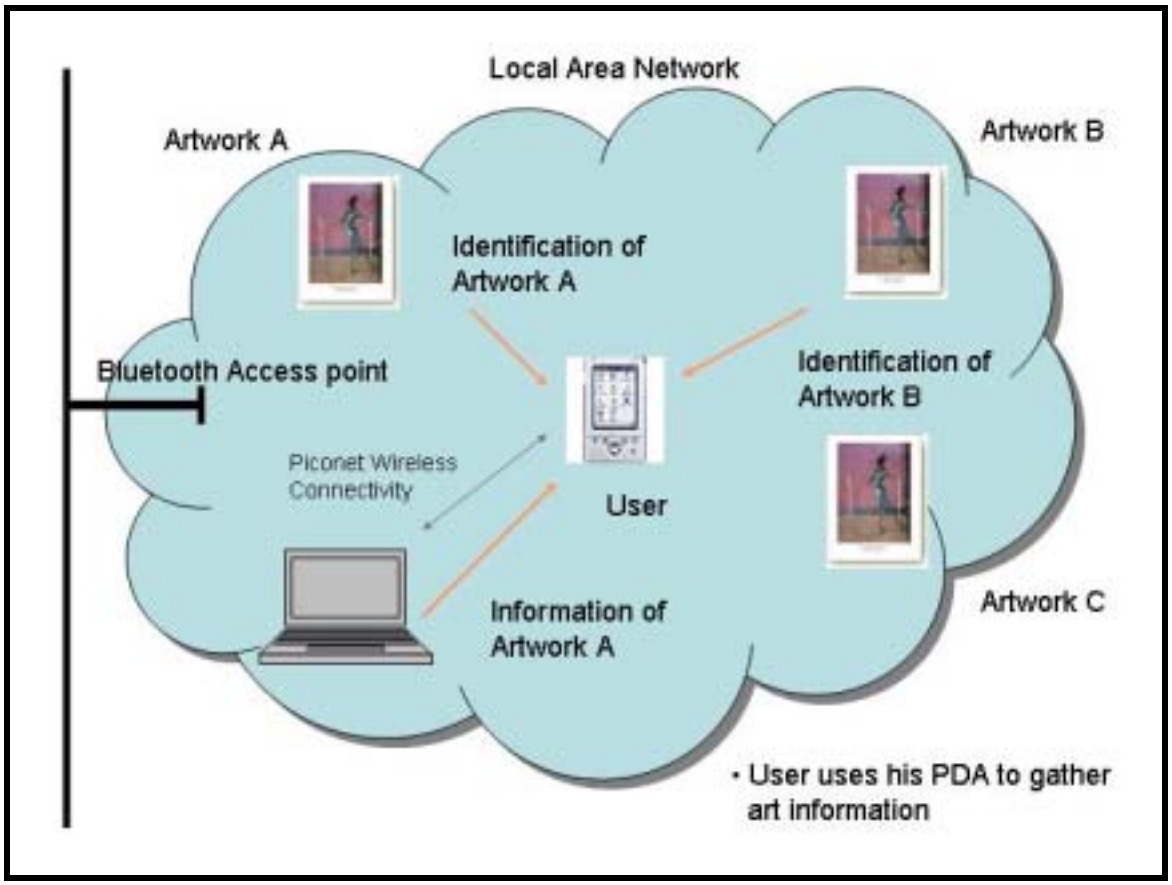

Figure 1: Scenario of the implementation

The requirements for this project are that the patron's PDA will be connected to the laptop via the Piconet wireless connectivity. Hence the Bluetooth network will discover the Bluetooth-enabled devices that are the laptop and the patron's PDA. The paintings

send its identification via a PDA through infrared communication. On receiving the identification, the patron's PDA will communicate with the laptop which will then send the information regarding the painting to the PDA. The PDA will use some sort of caching scheme to decrease the latency between successive reads of information relating to the paintings.

This paper gives an overview of various caching mechanisms and systems, and relevant information on Bluetooth, infrared and the PDA that is used in the implementation in section 2 and in section 3 provides information on how a simple caching scheme is implemented in the pervasive environment mentioned in the scenario above. In section 4, it discusses the experimental results and, discusses and concludes in section 5.

2. Literature Review

This section provides an overview of some of the existing caching mechanisms and systems, and relevant information on Bluetooth, infrared and the PDA that are used in the implementation.

2.1 Caching Mechanism

The driving principle behind every caching scheme is that despite the presence of large amount of information to the user, only certain portion of the information is requested more often by the users. In other words, many users will access the same server to get the same information. This is also true for cases pertaining memory accesses, file systems and distributed systems like the WEB.

The drawback of accessing the same information from the same server is that it will lead to link congestion. This implies that the resources along the link or path are consumed to the point that the server might not be able to process any more request from the server. The solution is to put the information as close to the client as possible so that end-to-end consumption of resources will not happen and the servers will not be swamped by requests for service. This will facilitate more users being added to the system and will also lead to a drastic decrease in the consumption of the resources by the system. In the case of the above scenario, placing the information on the PDAs' cache

will decrease the link congestion between the PDA and the laptop. Applications can be configured by the users to take advantage of the cache. Prefetching can also enhance the cache. Every time a user seeks information not only for particular painting, information pertaining to the painting next to it will be transferred. In this way the user will experience increased performance and appear to the user that there is no network latency between the laptop and the PDA at all.

However, such a scheme has reached its limitations in certain applications and networks. More caching storage will be needed for large files and more caches will be added in the network. Protocols for cache-to-cache communications have been developed and topologies, especially trees, used to manage caches. Also, protocols for automatic discovery and configuring of caches were added.

2.2 BlueTooth [4]

The Bluetooth technology emerged as a low bandwidth wireless solution, with small, mobile devices in mind. It is currently an open specification governed by Bluetooth Special Interest Group (SIG). The group aims at accomplishing the vision for the unique features of a bluetooth application, namely automatic completion of various functions, which happen manually today. For example, when a person wants to synchronize his appointments with that of his colleague, it happens automatically via Bluetooth, when they are in range of each other, without their manual involvement.

2.2.1 Bluetooth Specification

1. Frequency band of 2.4 GHz
2. Frequency Hopping mechanism to avoid interference with other frequencies
3. Total bandwidth supported upto1 Mbps
4. Support for both data (asynchronous) and voice (synchronous) communications.

2.2.2 The Piconet and the Scatternet

This is the ad-hoc method of interaction among bluetooth devices, which consists of one Master and a maximum of seven slaves. Two or more piconets that fall into each other’s range are characterized as Scatternets. Figure 2 shows an example of Piconet.

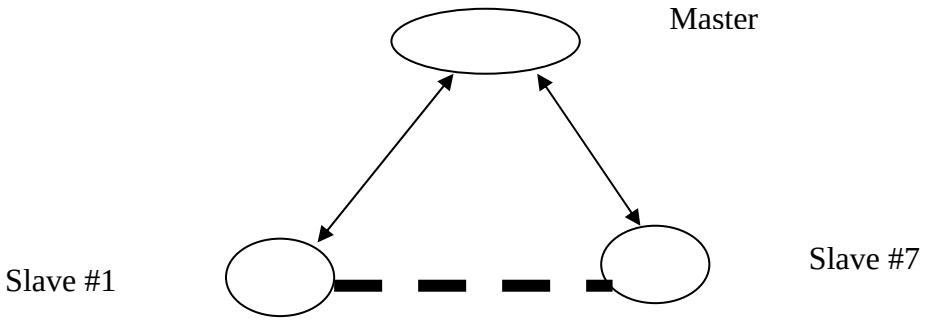

Figure 2 - Piconet

2.2.3 How we use it?

In our scenario, we use bluetooth as the media for automatic transfer of the painting information from the server to the client PDA. Bluetooth components and devices in our design

1. Palm PDA acting as the client uses a Palm bluetooth card.
2. The node that hosts the server uses a 3 Com bluetooth PC card.
3. A bluetooth enabled Access point.

Initially, the bluetooth-enabled devices discover each other and form a Piconet. In our configuration, the server node acts as the master and the PDA acts as a slave. Once the PDA gets the painting id from the painting via the infrared port, it sends the identification to the server over bluetooth, which sends back the painting information to it, in the same media.

2.3 Palm OS.

Since the introduction of the first Palm Pilot in 1996, Palm Powered products have grown to become indispensable tools for millions of people worldwide. Today, the Palm OS runs on almost two out of every three handhelds, and more than 80% of businesses include the Palm OS on their handheld standards lists. And in the months and years ahead, Palm OS will continue to lead the way in all the areas that matter the most to users, enterprises, developers, and handheld and smart phone manufacturers.

Palm OS has become the most popular OS for handheld devices because it treats mobile computing not as a miniaturized version of desktop computing, but as a unique user experience, focused on mobility as its design center. That simple concept gives Palm Powered devices big advantages over other handheld operating systems.

2.3.1 Palm OS Device Architecture.

At the highest level, the architecture of the Palm OS device, and most other PDAs, can be broken down into three layers Application, Operating System, and Hardware. Figure 3 shows the layers.

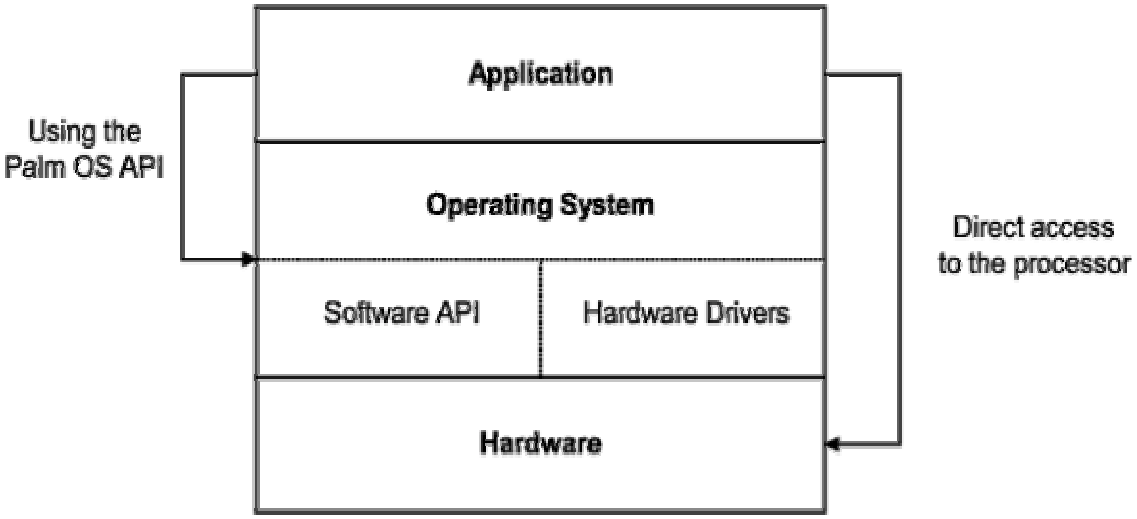

Figure 3: The architecture of Palm

Use of the Palm OS Application Programming Interface (API) provides the application developer with a notion of hardware independence and provides a layer of abstraction. If the API is used properly, recompiling of the application is all that is necessary in order to run on Palm OS devices based on different hardware.

2.3.2 Benefits of using Palm OS.

Every Palm Powered handheld comes with the famously easy to use Palm software suite, including calendar, address book, alarm clock, memo pad, calculator, and email. In addition to these more applications can be added to the palm handheld easily

which are available online. Palm Powered handhelds are designed to communicate with a PC. The Palm OS Hot Sync software also lets you make backup copies of your handheld information. With a press of a single button, your handheld's information is automatically backed up on the PC, so it can be restored if the handheld is ever lost or broken. The Graffiti text recognition program makes it easy to enter information using a stylus. In addition the system also provides an onscreen keyboard. An infrared "beaming" feature in most Palm Powered hardware makes it easy for handheld users to exchange information. Wired modems are available for many models. Add-ons support the 802.11b, and Bluetooth wireless network standards. Some Palm Powered systems include mobile phones supporting the CDMA and GSM networks. Or you can use infrared or Blue tooth to let your Palm Powered handheld communicate through a mobile phone. Palm OS is designed specifically for the needs of handhelds and smart phones. Because it's more efficient, it can give great performance with more efficient use of memory and processing power.

2.4 Pervasive Environments.

The essence of pervasive computing is to free the computing power from desktops and embed it in wireless handheld devices, automobile systems, home appliances, and commercial tools-of-the-trade. The basic insight behind pervasive computing is that as processing power gets cheaper and more compact, the bulky and complex all-purpose desktop computer is giving way to a new generation of smart devices like personal digital assistants, screen phones, kiosks, smart cell phones and even intelligent credit cards. The problem, of course, is to make all these devices, with their vastly different capabilities, work together seamlessly. Typically, a person will interact with smart devices throughout the day, in the home, on the road and at work.

Creating applications for pervasive computing is a challenging task, such environments are saturated with computing and communication capability; yet need to be gracefully integrated with human users. The need for graceful integration leads to smaller, less obtrusive computing devices. Device size also constrains computing power and storage capacity. Remote execution using wireless networks to access compute servers

fills a natural role in pervasive computing, it allows applications to combine the mobility of small devices with the greater processing power of large servers in the fixed architecture.

Support for mobile clients varies widely with location, some environments may provide plentiful wireless bandwidth others may be resource constrained with poor connectivity and little infrastructure support, pervasive application s must thus adapt to changing environment. Variation in environment and in client capability makes it quite difficult for developers to design the components of a pervasive application. Developers cannot decide statically what components of a pervasive application execute remotely, instead these decisions can be made dynamically when applications execute.

3 Implementation of caching scheme

This section discusses the assumptions and the algorithm of the caching scheme used in Palm OS.

3.1 Assumptions

1. The visitor visits the paintings in a sequence. For example, ave painting 1,2 & 3. The visitor visits them in the order 1, 2 & 3 or 3, 2 &1.
2. The cache size is assumed to be less than the no. of paintings in the museum.

3.2 Implemented Algorithm

1. Infrared signal is received from the first painting.
2. If painting not in cache retrieve the respective painting and the next painting in sequence (prefetch) from the server.
3. When the visitor moves to the next painting, the cached information for that painting is displayed and the information for the next painting is prefetched.
4. When the visitor tries to revisit the paintings in the reverse order the cache is checked for a hit and the information is retrieved from the server only when there is no hit.

3.3 Enhancements

1. Visitor should be able to visit the paintings in any sequence.

2. Prefetching of the painting information can be done by parts if there is insufficient memory for the cache.
3. Finding a cache replacement block can be based on timestamp. Replacement schemes like LRU, MRU etc can be used.

4. Discussion and conclusion

For implementing this scenario, we have considered communication mainly on bluetooth media. The primary inference and experience after using the technology is that, the communication is not very reliable. The bandwidth available also seems suited only for data transfer but we doubt the real-time data transfer to be very good on blue tooth. Also while we implemented caching, we also realized how much more it is important in such a scenario, where the information needs to be available without waiting, especially to keep up with the user's pace as he moves along the paintings. The algorithm we have tried to implement is a basic caching and prefetching mechanism but we hope to enhance it to an optimal one as listed under enhancements. A performance evaluation of the mechanism will be provided in the near future.

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