Context-Aware Content Adaptation in Access Point

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ABSTRACT

Instead of traditional content adaptation at servers or clients, we propose context-aware content adaptation at the Access Point (AP). We show that because of the special characteristics of the AP such as: being the last node at the edge of the network, no power constraint, and powerful computing capabilities, it can be the best candidate for context-aware content adaptation in high dynamic wireless mobile networks. In fact, it can adapt content more accurately and faster in a high diverse and dynamic context. Content adaptation at the application and MAC layers of the *AP* is introduced in this paper.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: *Wireless communication;* C.1.3 [**Other Architecture Styles**]: *Cellular architecture;* H.5.1 **[Multimedia Information Systems]**: *Video.*

General Terms

Algorithms, Management, Measurement, Performance, Design, Economics, Experimentation.

Keywords

Access Point; Content; Mobile; Wireless; Context-aware; Adaptation.

INTRODUCTION

The large spectrum of available mobile devices varies widely in their physical characteristics, such as screen size, screen resolution, battery capacity, and storage capacity. Given the limited resources (e.g. power, bandwidth, computing) of mobile devices, smart schemes are required to manage and adapt wireless multimedia content according to the device's characteristics. Not only should content be adapted based on the characteristics of mobile devices, but also based on the context, which can vary significantly for each device at different times and locations.

Even though content adaptation at the server for mobile devices have been studied and used, there are still several issues that have not been addressed in previous works. We surveyed the top 20 popular websites, gathered from Alexa [1], and found that 25% of them do not provide a mobile version of their content. For example, neither bloggers nor blog providers customize their content for mobile devices. Moreover, adaptation at a proxy server or cloudlet [2] (located at the edge of the client's network) still suffers from limitation in processing variant and dynamic changes in the mobile scenario. Clearly, content adaptation at the mobile device is not desirable since transmission of non-adapted content consumes significant resources of the mobile device in terms of energy consumption and wireless bandwidth. As a result, content adaptation at AP should be investigated.

An Access Point (AP) enhanced with context-aware content adaptation schemes, we name it Smart AP, can adapt content more efficiently in several ways. First, it provides more accurate and customized content to the users based on the context while minimizing the delay experienced in accessing the content. It has the advantage of higher computing power, and unlimited access to energy in comparison to mobile device, immediate access about context of mobile device while it has the minimum delay in network communication in comparison to cloud. In other words, it can lessen the overhead of content adaptation through knowledge of context efficiently. Moreover, adapting contents at a Smart AP minimizes the power consumption and traffic bandwidth at the mobile device. It is worthwhile to mention that because of context content adaptation, Smart AP should have more powerful resources such as processing and memory unit in it. We envision that these resources can be embedded simply in the current APs or an adjacent proxy server can provide these resources.

Our contribution in context-aware content adaptation in Smart AP can be described in three parts. First, we introduce context information of the wireless and mobile environment and show how this information can be used to adapt content. Second, we describe how the Smart AP can perform context-aware content adaptation. We also introduce and discuss the advantages and challenges of pushing the content adaptation into the lower layers of the Smart AP (i.e., MAC). In the next section, we review the state of art for context-aware content adaptation. In Section 3, we describe the Smart AP in detail. Finally, we conclude the paper and discuss future work in Section 5.

RELATED WORK

Context content adaptation has been studied in several mobile applications. For example, Weißenberg et al. [3] consider user profile, location, time, and user preferences to deliver adapted and customized content to mobile users in a large sporting event, such as the Olympics. T. Laakko [4] comprehensively surveys context-aware content adaptation for mobile user agents. Unlike schemes that focus on applications and user requirements in content adaptation, our focus in this paper is on context-aware

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content adaptation mechanisms that improve the performance of wireless networks and mobile devices. Also, sophisticated methods such as semantic image adaptation for mobile displays have been proposed recently [5]. The goal of these methods is to adapt the images while keeping the user's satisfaction of received content high. However, our focus in this paper is to show that these methods can be used effectively for power saving.

SMART ACCESS POINT

Because of the special characteristics of the access point (AP) in wireless networks, we believe it is the ideal candidate to support the new requirements of context-aware content adaptation. First, the AP is the last node at the network edge, so it can adapt to context changes faster than any other node in the network. Second, the AP does not have power constraints and thus, it can perform costly content adaptation processes that are not cost-effective to be performed on the mobile device. Third, compared to the mobile device, the AP has larger computation power that can be utilized for compute-intensive tasks in content adaptation such as video format conversion. Finally, the AP has high bandwidth access to the cloud, providing access to the content faster than the mobile device.

Context information

Even though context information has been used for content adaptation in previous studies, there are still two open issues for a comprehensive context-aware content adaptation solution. First, there is some additional context information such as the ambient light and noise that can enhance the efficiency of content adaptation schemes. Second, the context-aware content adaptation schemes have been mainly designed to user experience, not to improve the network and device performance.

The Smart AP can adapt contents using all of the context metrics. Table I shows examples of context information usage in content adaptation. We introduce the environmental context information as a new category of context for content adaptation.

Information about the environment such as light, noise, temperature, pressure, etc. can be used for content adaptation. For example, currently all the sounds for video clips, songs, and advertisements are sent with the same quality and independent of the device capabilities, the environment noise, and the sound volume the user has set. For instance, if the user mutes the audio, it is not required to send audio of a video clip. Thus, power and bandwidth will be saved. Another case is if the surrounding noise is low, audio with a lower quality may satisfy the user's requirements while saving bandwidth and energy.

Category	**Usage** - The star (*) denotes our contribution
Environment[*]- ambient sound, background noise, temperature, pressure, light, magnetic field, …	Content adaptation based on ambient sound, background noise, temperature, pressure, light, magnetic interference (to adapt bit rate and scheduling) [*]
Device- , CPU, OS, browser, network interfaces, battery, ...	Content adaptation based on residual power and screen size and resolution [*]
Person- demographics, job, language, activities, information interest, preferences, browsing history, …	Delivering content based on user preferences [6]
Network- available networks, data plan rate, available bandwidth, …	Delivering adapted video based on type of network[7]
Location- indoor, outdoor, accuracy, logical location (e.g. restaurant, sport club), speed,	Delivering ad content based on user location [3]

Table 1. Context Information Usage of various Context Categories

Furthermore, screen size and resolution vary for different mobile devices, and in many scenarios, small devices do not require high quality content. Almost all smart phones have a range of screen sizes from 3.2-4.7 inches and resolutions from 360x640–480x800 pixels. Likewise, tablets have screen sizes of 7-12 inches and resolutions of 1024x600-1600x1200. This shows the need for multiple individual adaptation schemes to accommodate for the different configurations of current mobile devices in order to have efficient content-adaptation architecture.

Smart AP Architecture

Conventional method of content adaptation is to use content adaptation server in the cloud, as shown in figure 1. We evaluate two new solutions for content adaptation in which the content is adapted at *Smart AP*. The content adaptation functionality of the Smart AP can be performed at either upper layer (i.e., application layer) or lower layer (i.e., MAC layer).

Figure 1. Legacy architecture for content adaptation

In the application layer method a proxy server to Smart AP (figure 2). The main advantage in comparison to legacy method is that content is adapted faster and also content could be adapted fast when context information changes are high. In comparison to MAC layer solution, it has a simpler implementation, but requires additional hardware.

Figure 2. Topology of Smart AP in Application layer method

The next solution adapts the content at the MAC layer of Smart AP (Figure 3). In this scenario, there would be only software modifications at Smart AP and the existing AP hardware could be used. Content Adaptation at the MAC layer is more difficult and needs new-sophisticated schemes. However, the advantages of this approach include the no-requirement for additional hardware as well as the high efficiency of the adaptation performance because of faster operations at the MAC layer.

In the content adaptation at the MAC layer approach, Smart AP needs to modify the MAC layer packets before transmitting them to the client, based on the context metric and decision rules that Smart AP is aware of. For example, in a video-streaming scenario, when Smart AP understands that wireless channel condition is not ideal, it will reduce the quality of video. One possible mechanism is to drop non-key video frames. The challenge here is to do a fast identification of the MAC layer frames that contain the non-key video frames. The same mechanism can be applied for other context information of the device. For example, the Smart AP could apply similar frame dropping scheme when the device battery level becomes low. In summary, content adaptation at the MAC layer of the Smart AP offers near real-time adaptation of content in comparison to adaptation on the server or even at proxy server at AP.

Table 2 summarizes the Smart AP solution versus client and server based solutions. It shows that Smart AP has advantages of both client and server based solution. Not only does Smart AP save bandwidth and energy, but also it can adapt content based on immediate changes in condition such as network available bandwidth.

Figure 3. Topology of Smart AP in MAC layer solution

Content Adaptati on Solution	**Saving Bandwidth and Energy**	**Fast Adaptation Rate based on instant context**	**Unlimited Resources (power, processor, bandwidth, etc.)**
Server-based	Yes	No	Yes
Client-based	No	Yes	No
Smart AP	Yes	Yes	Yes

Table 2. Smart AP solution VS. other solutions

PRELIMINARY RESULTS

Image adaptation is one of the typical applications of content adaption. For example, when browsing a page, many resources are presented to the user such as text, images, sounds, videos, etc. Most of these items have large sizes that are not usually required for mobile devices since the screen size is not as large as PCs. As discussed earlier, there are several mechanisms for content adaptation. Here, we use one simple method; image resizing, to show its impact on the bandwidth and the power saving by utilizing the first solution of Smart AP (i.e., application layer solution).

We randomly select 30 JPEG images with different sizes ranging from 160 KB to 2 MB, with an average size of 700 KB and total size of 23.7 MB. Images are classified to five categories: indoor, outdoor, group, scenery, and news. The user views them on a webpage via an Android Nexus S. An squid3 proxy server is set up for image adaptation at the Smart AP. We choose two adapted sizes; 50% and 30% of original size. This generates images that have a total size of 7.4 MB and 3.2 MB, respectively. Figure 4 shows percentage of reduction in energy consumption of the wireless interface when using WiFi networks. Power consumption has been measured with PowerTutor [8] tool. However, because this tool does not measure the exact power, we only provide the relative power consumption for each setting.

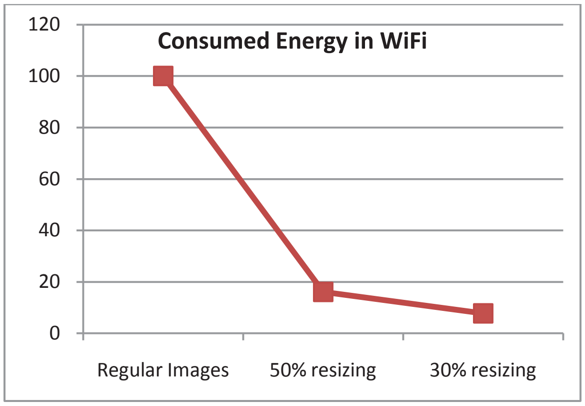

Figure 4. Energy saving for image resizing

Clearly, more features can be added to the resizing schemes, such as changing the image quality based on the size of the image and/or the screen.

CONCLUSION AND FUTURE WORK

In this paper, we introduced the Smart AP as the best candidate for context-aware content adaptation in high dynamic wireless networks consisting of devices with different characteristics. We also introduced new context information (device screen size and resolution, environmental context - noise, light, etc.) as new context parameters that can be used in content adaptation. In addition, we introduced content adaptation at MAC layer of the Smart AP. This technique does not require additional hardware, but more complicated schemes are needed. In summary, context-aware content adaptation can be performed at Smart AP with low delay, low cost and energy constraint free. In future we will further investigate and evaluate the presented techniques for video and image adaptation.

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