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Energy Consumption on Smartphone Web Browsing in 3G Network

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Abstract: - Nowadays usage of smartphone application has been reached great height. Web browsing on a smartphone takes a significant amount of power as it uses the features of 3G radio interface for downloading web pages. In this paper, two techniques are used to resolve this power consumption issue. In leading technologies, process computation sequence while loading a web page. Web browser first runs the computation that will generate new data transmission and put radio interface into low power state and release radio resource. Remaining computation is executed later. In the second technique, prediction of user reading time is performed using data mining techniques.

Keywords: Radio Resource Control (RRC) protocol, DOM tree, Gradient Boosted Regression Tree (GBRT)

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1. Introduction

The smartphone is used by almost everyone as it provides a variety of application to users. Different application on a smartphone requires a different amount of power. So, while handling a smartphone one thing must take into consideration, i.e., battery usage. Power consumption is mainly due to the characteristics of wireless radio interface, power consuming display. In this paper, we concentrate on the power consumption while browsing the web. To resolve power consumption issue research on various interfaces of the smartphone have been done such as a display, WiFi, Bluetooth. However, these have different characteristics than the wireless radio interface or the cellular interface like 3G, 4G LTE. So, here those features will be addressed and the issues on them will be identified.

The current smartphones web browser takes a long time for downloading and processing all objects of a web page. Loading a web page involves different computations such as HTML parsing, execution of JavaScript code, decoding of an image, style formatting, page layout, etc. We separate these computations into two categories based on whether they will create new data transmissions from the web server. Hence the web browser can first execute the computations that will create new data transmissions and get that data after that run the remaining computation.

This energy-aware approach uses two novel techniques to resolve power consumption issue of the smartphone. First, reorganize the computation sequence of the web browser when loading a web page. This approach can also increase the network bandwidth utilization since it releases the radio resource earlier.

Another novel technique is to predict the user reading time on the web page after the page is downloaded. For prediction, Gradient Boosted Regression Trees (GBRT) is used, which is a low overhead algorithm. This prediction is used to decide if the smartphone should switch to IDLE.

2. Literature Review

There are various techniques and ideas are applied to a smartphone to optimize the power consumption. J. Sorber, N. Banerjee, M. D. Corner, S. Rollins M. Dong and L. Zhong optimizing the power usage of smartphones [2], [3], but they only focus on reducing the power consumption of one component such as a display. Although some of them also consider the power consumption of the wireless interface, most of them focus on the WiFi or Bluetooth interface [4], [5], [6], [7], [8].

Bartendr [9] establishes the relationship between signal strength and power consumption, and schedules communication based on the signal strength to save power. A. J. Pyles presented [10] SiFi: Silence prediction based WiFi energy adaptation. SiFi examines audio streams from phone calls and tracks when silence periods start and stop. This data is stored in a prediction model. Using this historical data, predict the length of future silence periods and place the WiFi radio to sleep during these periods.

Qian et al. [11] proposed caching techniques to reduce the power consumption and improve the radio resource utilization for web browsing in 3G networks. Zhao et al. [12] proposed an architecture called virtual-machine based Proxy (VMP), which shifts the computation from smartphones to VMPs to save power and delay for web browsing in 3G networks.

Grouping multiple transmissions in a burst have been used in [13], which groups transmissions by deferring them and hence increases the transmission delay. Many recent smartphones and networks support the fast dormancy feature included in 3GPP [14]. The smartphone can send a message to notify the network that its data transmission is complete, and thus the smartphone can switch to low power level.

Speculative parsing (used in Webkit-based browsers) [15] and Google SPDY [16] are techniques to reduce the webpage loading time. However, none of them considers reducing the power consumption of smartphones, and they are a complement to our proposed technique.

For webpages that have already been opened, Zhang et al. [17] proposed a layout caching approach. It caches the layout results to eliminate redundant computations and achieves more efficient local webpage processing. Additionally, Hu et al. [18] proposed a system to properly schedule web tasks among a group of users to reduce energy and delay.

3. Proposed Work

A Radio Resource Control (RRC) protocol define three states: IDLE, DCH, and FACH to efficiently utilize the limited radio resource of the backbone network.

- **IDLE state:** This state consumes the tiny amount of power. The smartphone cannot send user data as it does not have any signaling connections with the backbone network.
- **DCH state:** In this state, the smartphone can send user data as it has dedicated transmission connection to the smartphone, it requires more power.
- **FACH state:** Smartphone in this state only transmit user data and signaling information through commonly shared transmission channels at low speed (up to a few hundred bytes/second) as it has no dedicated transmission channel. Data transmission in the FACH state requires about half of the power in the DCH state.

To transmit the data smartphone has to be switched from IDLE to the DCH state. It first establishes the signaling channel and then obtains the dedicated channel for the transmission. This process requires many message exchanges. The timer is used to determine when to release the allocated transmission channel to a smartphone by the backbone network.

A. Rearranging the Computation Sequence of the Web Browser.

In loading a web page, a web browser does two tasks, i.e., fetching the web content through the Internet and performing local computations to process the content. At the time of loading web page, there are various computations such as HTML parsing, JavaScript code execution, image decoding, style formatting, page layout, etc. These computations are known as a local computation which has to be performed efficiently.

We classify these computations into two categories such as the data transmission computation (HTML, Javascript code execution, CSS file parsing) and the layout computation (image decoding, style formatting, page layout calculation, page rendering).

This separation allows web browser can first run the computations that will generate new data transmissions and retrieve these data. Then, the web browser can put the wireless radio interface into low power state, release the radio resource, and then run the remaining computations which may take 40–70 percent of the processing time for loading web pages. Thus, a significant amount of power and radio resource can be saved.

Fig 1. shows the general workflow that a Web page is processed by modern Web browsers. After receiving a Web page, either from a remote Web server or a local store, a Web browser parses the page in the form of HTML data and represents the parsed HTML data as a DOM tree in memory. The style properties are then generated for the elements in the DOM tree. These properties determine how the elements are presented on the screen. To render them, the browser must trigger a process to calculate the layout for each element in the DOM tree. It can then render those elements correctly on the screen.

Workflow of Webpage Processing:

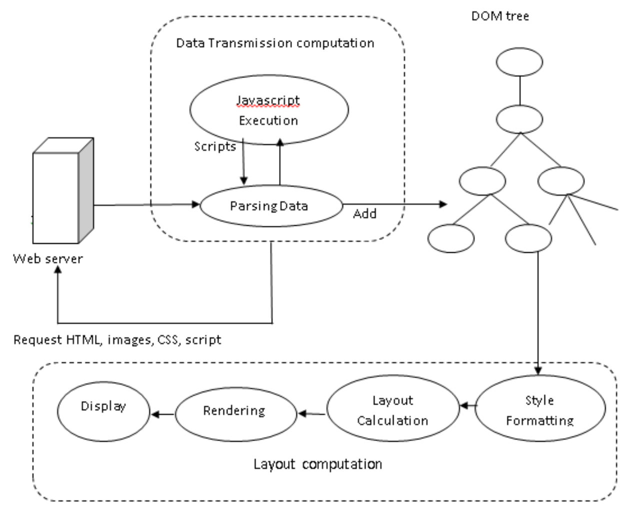

Fig 1. Workflow of web page processing

Fig 2. Compares the computation sequence of our energy-aware approach with that of the original web browser for opening a web page. At time slot 1, the original web browser spends its computation resource on both data transmission and layout computation. It processes one object and adds it to the DOM tree. In energy-aware approach, the browser focuses on data transmission and ignores layout. Thus, our approach can process more objects and add them to the DOM tree at time slot 1.

At time slot 2, our approach processes all the objects and builds the complete DOM tree. At time slot 3, no data transmission will happen, and our approach focuses on computing the page layout. Although the original web browser can display partial web page content on the screen at each time slot, it keeps generating data transmission until time slot 3. Finally, both approaches have the same complete DOM tree and display the same web page although our approach may be a little bit faster in practice.

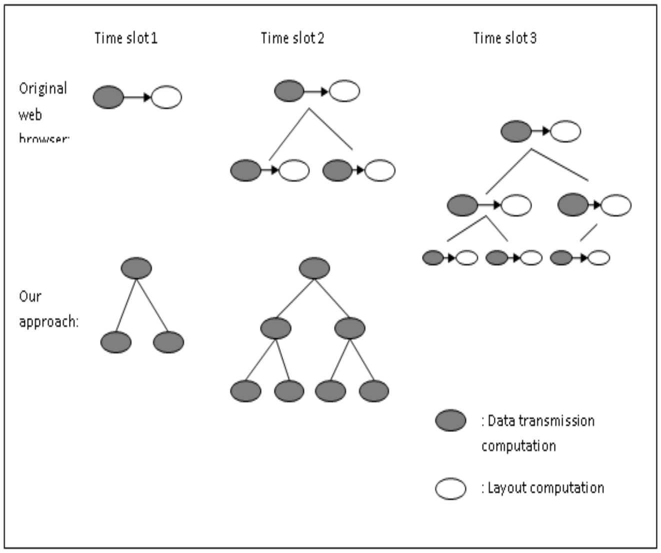

Fig. 2. The computation sequence for the opening web page and building the DOM tree.

B. Intermediate Display

To improve user experience, first web browsers always draw intermediate display and update it frequently when loading webpages. However, this approach has two drawbacks. First, although the web browser already has the web content, it has to wait before displaying the intermediate results. Another drawback is that the browser wastes a lot of computation resource to frequently redraw and reflow the intermediate display before the final display.

By reorganizing the computation sequence, our approach draws the final display at the end of webpage loading, and thus it saves the calculation on redrawing or reflow in the intermediate display. To improve user experience, we present a low-overhead approach to draw intermediate display with little layout computation during the data transmission time.

C. Predicting the User Reading Time of Webpage

When user read the content of web page, we predict the reading time of the user, based on which we can decide if the smartphone should switch to IDLE. Gradient Boosted Regression Tree (GBRT) is a technique of predictive data mining, which is used for prediction. These models are used to predict the value of future data.

Algorithm For Energy Aware Approach

Begin to open web page
Data transmission computation is done
Layout computation is finished
Collect features x={x1,…….,x10} …. Table 1
Webpage is opened
Wait for α seconds
Get T_r from the prediction model with x
if ($T_r > T_d$) or ($T_r > T_p$ AND mode == power)
then
Switch to IDLE state
end if
where,

Parameters	Description
T_r	Predicted reading time (sec)
T_d	Insert threshold (sec)
A	Time duration threshold (T1 + T2) for delay driven mode
T_p	Time duration threshold for power driven mode
Mode	Power driven or delay was driven

Feature	Description
Reading time	The duration from the web page is completely opened to the time when the user clicks to open another web page
Transmission time	Data transmission time
Webpage size	The data size of the web page without considering figures
Download objects	The number of total downloaded objects
Download javascript files	The number of downloaded javascript files
Download figures	The number of downloaded figures
Figure size	Size of the total downloaded figure
Javascript running time	The time for processing all the javascript code
Second URL	The number of secondary URLs
Page height	The height of the web page
Page width	The width of the web page

Table 1: Feature Details

The algorithm shows steps to be carried out in our energy-aware approach. The algorithm has two different modes: the delay drove mode to optimizer delay, and the power driven mode to optimizes power. We know improperly moving to the IDLE state may increase the power consumption and the data transmission delay.

In the delay driven mode, if the predicted reading time (Tr) is shorter than Td, new data transmission arrive during the FACH state, and hence the smartphone will not go to IDLE to avoid increasing the data transmission delay. Here we set Td to 20 seconds which is T1 +T2. In power driven mode, as long as the predicted reading time is longer than Tp, the smartphone will go to IDLE to save power although it may increase the transmission delay in some cases.

4. Conclusion

In this paper, we proposed an energy-aware approach for web browsing in 3G based smartphones. We define a system which first reorganizes computation sequence of a web browser at the time of loading web page by separating the data which generates new data transmission. Web browser first process these data transmission computation put the 3G interface into IDLE and release radio resource. After completion of data transmission computation web browser process remaining layout computation. Secondly, we implement a low overhead prediction algorithm based on Gradient Boosted Regression Trees (GBRT) to predict user reading time when they read the content of web page. The final results show that as radio resource released earlier, it can be used by another smartphone which increases network utilization.Moreover, our approach can minimize power consumption of smartphone during web browsing as well as reduce the web page loading time.

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