Tech-Topic Analysis 7

T. Pering, Y. Agarwal, R. Gupta, and R. Want, "CoolSpots: Reducing the Power Consumption of Wireless Mobile Devices with Multiple Radio Interfaces," ACM Mobisys, Uppsala, Sweden, June 2006.

Overview

Mobile devices are only useful for as long as their batteries are able to hold a charge. One of the main components of mobile devices that drains the battery is the wireless communication subsystem. On most modern mobile devices, the wireless communication subsystem consists of multiple radio interfaces to handle connections such as Bluetooth, WiFi and GPRS. This paper discusses the CoolSpots model. This model takes advantage of switching between the radio interfaces in order to reduce battery consumption. CoolSpots is able to reduce the power consumption of the wireless communication subsystem by up to 50%. CoolSpots is able to reduce the power consumption without needed to modify applications and with only little change to the existing infrastructure.

This paper discusses the switching between two radio interfaces, Bluetooth and WiFi. CoolSpots is able to switch between these two interfaces without affecting applications. There are a variety of applications for mobile devices. CoolSpots is able to reduce power consumption without hindering these applications. This means that applications will be able to function the same in terms of communication range and bandwidth needs. WiFi has a range of 100 meters while Bluetooth's range is only 10 meters. This is a significant difference in range capability. WiFi not only has a larger range of communication but it also has a faster data-rate. WiFi operates at a bandwidth of 11 Mb/s and Bluetooth is only able to offer a bandwidth of 1 Mb/s. The downside to WiFi is its high power consumption. In an active data transfer state, WiFi consumes 890mW and Bluetooth consumes only 120mW. In an idles state, WiFi consumes 250mW and Bluetooth consumes only 1mW. CoolSpots utilizes the advantages of Bluetooth and WiFi. In order to determine the optimal radio configuration, CoolSpots takes into account bandwidth requirement, power, and distances. To reduce power consumption, CoolSpots uses Bluetooth for low-bandwidth activities, and switches to WiFi for high-bandwidth activities. While using Bluetooth, the WiFi radio is turned off.

A CoolSpot consists of an area that is covered by WiFi but also has internal areas that support Bluetooth. This means that normal WiFi hotspots can be easily converted into a CoolSpot by just integrating Bluetooth into the infrastructure. Bluetooth can be added to the WiFi enabled devices or it can be physically separated. Both Bluetooth and WiFi have idle modes. Bluetooth idle mode is called sniff mode. While in sniff mode a Bluetooth device is still discoverable and can easily switch into active mode. The sniff mode consumes very little power. WiFi's idle mode is called Power Save Mode (PSM). PSM consumes approximately 10 times more energy than sniff mode. However, while transferring data at a high-bandwidth WiFi is more energy efficient than Bluetooth. CoolSpots determines when to switch between Bluetooth and WiFi. Switching from Bluetooth to WiFi is known as "switching-up" and switching from WiFi to Bluetooth is known and "switching-down". Instead of entering PSM, the CoolSpots model deactivates WiFi in order to save power. The problem is that a poor switching policy could potentially cause Bluetooth and WiFi to switch too much and consume more energy.

The authors follow by introducing some related work. Researchers have tried to reduce the power consumption of WiFi alone at the application layer, the transport layer, and the MAC layer. There has also been research in using a second-lower-power radio to server as a wake-up channel for the main radio. This method fails to take advantage of low-bandwidth data transfers and also incurs overhead in starting up the main radio. Other research considers controlling multi-radio systems at the application layer.

Next, the paper covers some switching policies. A switching policy is what decides when to "switch-up" and when to "switch-down". In the CoolSpots model, the mobile device is responsible for initiating the switch. It monitors the channel and decides when a switch is necessary. Once the mobile device decides that a switch should take place, it then notifies the base station. WiFi is turned off when Bluetooth is being used to transfer data, however Bluetooth remains active when WiFi is being used to transfer data. The baselines used to measure the performance of the switching policies are wifi-CAM, wifi-fixed, and bluetooth-fixed. In Wifi-CAM, the WiFi radio is always in active mode. In wifi-fixed, the WiFi radio switches between active mode and PSM. In bluetooth-fixed, the Bluetooth radio switches between sniff and active mode. The first policy discussed is the bandwidth policy. This policy simply switches up or down when the bandwidth goes above or below a certain threshold. This threshold is the same for switching up and down. When the threshold is chosen well, the bandwidth policy performs pretty well. However, deciding a good threshold in the real world is hard to do. The second policy discussed is the cap-static policy. This policy switches down in the same way as the bandwidth policy. However, the cap-static policy switches up based of off the round trip time of a ping. When the round trip time increases, this means the channel is becoming saturated and a switch is initiated. The last policy discussed is the cap-dynamic policy. This policy uses the same method as cap-static to switch up, but it switches down at the same bandwidth measured while switching up. The cap-dynamic policy is able to prevent using WiFi when it is unnecessary by using its method of switching down.

After describing the switching policies, the authors go over the benchmarks used in their experiment. In order to see the benefits of each switching policy, the authors used different kinds of traffic to get a real-world representative result. At each benchmark they measured the "Communications Energy" metric. This metric is a product of the completion time and the power consumption. The authors use idle and transfer as their two basic benchmarks. Idle causes no network traffic to be sent and transfer causes a file transfer that consumes all the bandwidth. Along with idle and transfer, they used streaming benchmarks. These streaming benchmarks consisted of a video file transcoded to stream a various bit rates. The last benchmarks used were www benchmarks. These benchmarks where designed to represent a normal web browsing session. The www benchmarks are good because they have content that requires low-bandwidth (text) and high-bandwidth (images or large documents).

Following the benchmarks, the paper depicts the experimental setup. Their setup consisted of four pieces of hardware a Base Station (BS), a Mobile Device (MD), a Test Machine (TM), and a Data Acquisition machine (DA). They tested the MD in three different locations with varying distances. However, they did not move the device while testing.

Their results show that the cap-dynamic policy works best with varying benchmarks. The wifi-fixed policy worked the best with the high-bandwidth benchmarks. The Bluetooth-fixed policy worked the best with the low-bandwidth benchmarks. The bandwidth fixed policy worked the best only with the 128k streaming video benchmark.

Overall, the cap-dynamic policy works the best for real world scenarios. Other policies work good, but only with specific tuning. The cap-dynamic policy does not need any tuning. All it needs is its ping threshold parameter. Using this parameter, it can calculate the bandwidth to switch up and down by using a round trip time measurement.

Analysis

Structurally, I found this paper very easy to read. Someone with little background knowledge in the field can easily understand the content of the paper. However, I think the authors tried a little to hard to get their points across. They repeated over and over again the fact that Bluetooth consumes little energy at low bandwidths and that WiFi consumes a lot of energy and high bandwidths. This repetitiveness made the paper a little dull after a while.

One thing I liked about CoolSpots is that they tried to implement a power saving method requires only a small amount of change to how things work now. Applications would not have to be modified in order for CoolSpots to work. WiFi hotspots would only have to add relatively cheap Bluetooth support to be CoolSpots compatible. These factors make CoolSpots more appealing because people would not want to implement a method that is expensive or one that needs an entire new infrastructure.

I did not like how the failed to include any switching policies that maintain state. It seems that some file transfers may cause an unnecessary amount of switching between Bluetooth and WiFi. If a policy were able to remember how often switching occurs then it could recognize that there has been an suboptimal amount of switching. This policy could then extend the amount of time it is necessary for the bandwidth to be above or below the threshold before it switches. In doing so, it would avoid the energy wasted in switching between Bluetooth and WiFi numerous times.

Lastly, I feel like the authors performed an unrealistic simulation. They moved the mobile devices to three different locations with respect to the Base Station however they did not move the devices while running the benchmarks. The authors justified this by saying the environment could simulate people sitting at their desks in an office or in their homes. This does not make any sense. People who are sitting at their desks probably would have a computer. It is unlikely that they would use a mobile device to download files on the internet. Also, if they were to be sitting at a desk then they are likely near outlets that would allow them to charge their mobile devices making power consumption not an issue.

Research towards extending the battery life of mobile devices is important. Unfortunately, I do not think that the CoolSpots method purposed is realistic. CoolSpots does decrease power consumption of mobile devices, but it only does so in situations where power consumption is not an issue. At home or in the office people are likely to either charge their mobile device or use a computer to download data.