Stratus: Energy-Efficient Mobile Communication using Cloud Support

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ABSTRACT

Cellular radio communication is a significant contributor to battery energy drain on smartphones, in some cases inflating the energy cost by a factor of 5 or more compared to the energy cost of the base device. Stratus is a system to reduce this energy consumption by leveraging cloud resources to make data communication on smartphones more efficient. Using a cloud-based proxy, Stratus employs optimizations that adapt an application's incoming and outgoing traffic to better match the energy characteristics of the radio interface. The optimizations include (a) *aggregation* to bunch up sporadic transmissions, (b) asymmetric dictionary-based *compression* to reduce the number of bits transmitted over the air, and (c) opportunistic *scheduling* to avoid communication during periods of poor signal reception. These optimizations can be used individually, or in combination, subject to an application's delay tolerance. For example, using our Stratus prototype, the aggregation and compression optimizations together achieve up to 50% energy savings for web browsing, while the aggregation and scheduling optimizations together achieve up to 35% energy savings for a media streaming application.

1. TECHNICAL DETAILS

We provide a brief description of the three techniques the comprise Stratus.

1.1 Aggregation

Unlike WiFi, cellular radios incur a significant delay in switching between the low power idle state and the high power active state. Moreover, during the switch, the cellular radio incurs a significant energy overhead. This switching overhead of the cellular radio implies that sending data to the mobile phone in intermittent spurts would incur a far greater energy cost (due to repeated switching) than sending the data in a single, sustained burst. The aggregation component of Stratus merges communication spurts to reduce the number of switches.

In a previous paper [5], we had quantified the energy cost of switching the cellular radio and used this information to optimize wireless tethering. The aggregation technique presented here is adapted from [5] for browsing from a mobile phone.

1.2 Compression

Compression deployed between the cloud-based proxy and the smartphone helps cut the number of bits to be transmitted and hence the energy cost of receiving the bits. However, to achieve overall energy savings, the overhead of decompression must be kept low.[1] To this end, we employ an asymmetric, lossless, dictionary-based redundancy elimination technique, with minimal decompression overhead. Thus bandwidth savings translate into equivalent energy savings.

Our technique for redundancy elimination is inspired by [6], but has been designed for end-to-end operation. In a previous paper [3], we have presented our redundancy elimination technique applied to a general setting. Our demo utilizes the same technique, with some customization to smartphones.

1.3 Scheduling

Cellular radios consume more power and suffer reduced data rate when the signal is weak. Consequently, the energy per bit can, according to our measurements, be as much as 6x higher when the signal is weak than when it is strong [4]. As the signal quality varies, say along a drive, there is an opportunity to save energy by preferentially communicating when the signal is strong. The scheduling component of Stratus helps achieve such energy for applications that are delay-flexible (e.g., on-demand streaming with pre-filling of the playout buffer, email syncing, etc.).

Our technique for scheduling is based on a dynamic programming solver [4] that minimizes energy consumption on a mobile phone while meeting application packet deadlines.

2. DEMO DESCRIPTION

We will demonstrate the Stratus prototype comprising a cloud-based proxy hosted on the Windows Azure platform [2] (a cloud computing service offered by Microsoft) and a lightweight client-side proxy on a Windows Mobile phone. Figure 1 shows a schematic of the demo setup. The cloud-based proxy implements the compression and aggregation optimizations. Users browse the web on the phone, with and without Stratus. Using an external power monitor tool, we show the energy savings provided by Stratus. Figure 2 shows the performance of Stratus compared to the base case,

[1] We concentrate on the common case of data *download*, hence our focus on radio reception and decompression.

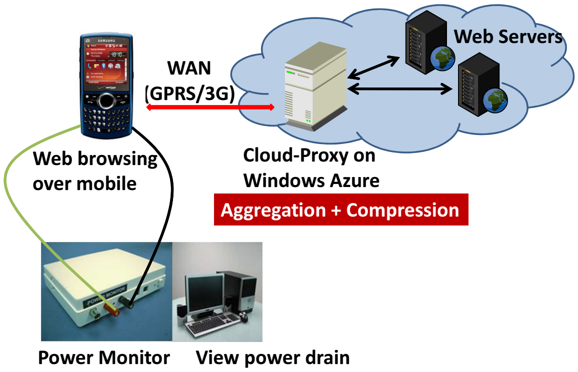

Figure 1: Stratus demo setup.

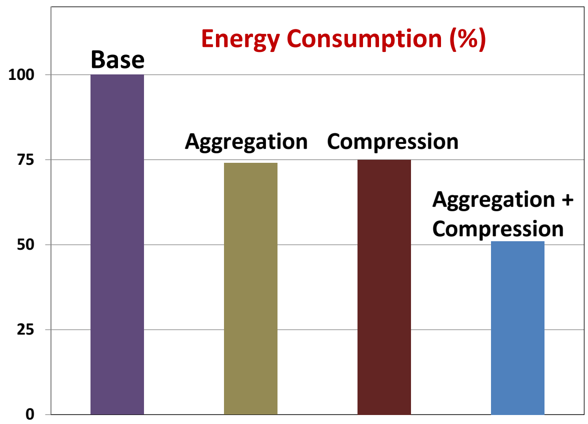

Figure 2: Energy savings with Stratus for web browsing workloads.

which does not include any of our optimizations. A video recording of the demo is available online [1].

We will demonstrate the energy efficient signal-based scheduler with an animated simulation. Based on signal variations observed during an actual commute, the simulator will schedule streaming content for periods of predicted good signal. Figure 3 is a mock-up of the animation. On the right, a map shows the location of the car. Above the map is a video from the dashboard of the car. The video shows the car's surroundings which may have affected the signal strength, and caused variations in the car's speed; variations in speed affect the accuracy of signal predictions. The top-left graph shows the variation in signal strength (white) along with a constantly updated prediction of signal strength based on previous drives (red, dotted). The bottom-left graph shows a running total of energy consumed with (green, lower line) and without (blue, higher line) the scheduler. The middle-left graph shows the amount of buffered data with (green, lower line) and without (blue, higher line) the scheduler.

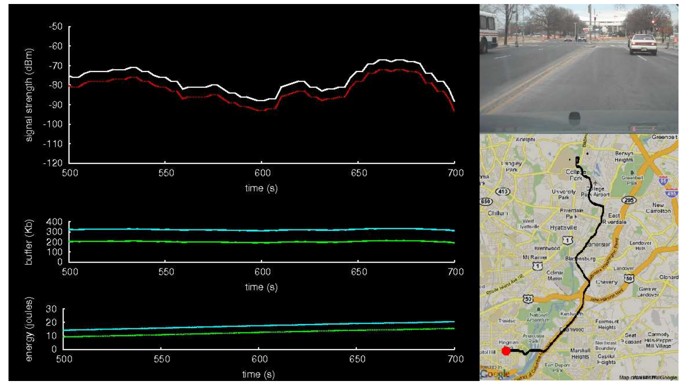

Figure 3: Screenshot of the trace-driven animation showing scheduling in action during a drive.

3. REFERENCES

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