Collaboration out of the box: A framework for enabling large-scale, energy-efficient pervasive computing

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The Vision

The number of mobile phone subscribers is reaching 5 billion. Mobile phones are increasingly used for collaborative applications, such as IM, Facebook, and those for traffic and environmental sensing. As these applications are becoming pervasive and large-scale, much is left to be desired in terms of energy efficiency.

These applications are collaborative and must share information among the participating devices. Basically each device needs to notify peer devices of its latest state and receive new updates from their peers. All the communications must happen in a timely manner. To save energy, they often do not communicate with each other directly. Instead, they are configured to communicate via a conceptually centralized server, or the "cloud" in the modern terminology.

Indeed, offloading communication from mobile devices to the cloud solves part of the energy efficiency problem. However, it is practically expensive to maintain a live connection between a mobile client and the server, especially when the client is hosted in a Web browser. Most existing systems cannot proactively notify a client of updates and rely on mobile clients periodically polling the cloud for updates that may become available at any time, or not exist at all. As a consequence, a mobile client has to compromise between timeliness of information and energy efficiency. Meanwhile, the "cloud" also becomes an energy hog if all clients poll it for updates blindly and frequently.

To fundamentally address this problem, we have to look into the "cloud" to include the network carriers, a critical part that is often missing in many research proposals. Most previous proposals focus on optimizations in the box – how the device hardware and software can be optimized for energy efficiency. They are reasonable for most single-user applications. However, for collaborative applications that are mobile, cloud-based and large-scale, a better strategy would be to collaboratively optimize all the involved parts together, including the server, the network infrastructure, the devices, and the clients. Optimization techniques in-the-box and out-the-box are complementary.

Intuitively, the server and the cellular base stations are connected. The server knows about new updates and the base stations are always connected to the mobile devices as is necessary for uninterrupted service. Hence, theoretically, the server can always push updates to a mobile client's current service station, which in turn can push the updates to the client or suggests the client to fetch the updates from the server.

There are some specific issues to consider: For example, how a mobile client describes interesting updates to the conceptual "cloud", how the "cloud" traces the mobile clients and pushes the updates to them, and how the "cloud" checks corresponding servers for those updates. Between the server and its clients are the carrier network infrastructure. Beyond the mundane systems efficiency issues, it would be necessary to have a well-defined "meta" carrier network service protocol for the server and clients to interact with the infrastructure and also for different carrier networks to interoperate.

Potential Impacts

Specific solutions to fulfill the above vision will involve collaboration across the server, the network infrastructure, and the device levels. We expect impacts in the following areas:

First, significantly more energy will be saved as compared to what traditional optimization techniques in the box could achieve. When all the involved parts are optimized in collaboration, more energy is saved in every part of the loop altogether. As collaborative apps such as Skype and Facebook are becoming the de facto "killers" on mobiles and the Internet today, the aggregate energy savings will be enormous.

Secondly, it will cost much less for users to use mobile services. Not only will they be further freed from worries of battery drainage but also the data charges will be lowered due to reduced net traffic. As a result, more mobile services could be deployed and adopted, which may in turn become a boost to the economy.

Thirdly, the wireless network carriers/operators will gain more incentive to upgrade the network infrastructure, which in turn stimulates the vendors to manufacture more advanced (and greener) network equipment. This will be yet another drive to the economy.

About the Author

Li is a senior researcher at Nokia. Before joining Nokia in 2007, he earned his PhD degree from UCLA in 2000 and was a professor for seven years. He won an NSF CAREER award in 2002 in his faculty job. His interests mainly include collaborative systems, mobile systems, pervasive and context-aware computing.

Li's past work focused on in-box optimization techniques for achieving energy efficiency in mobile collaborative applications. His MaJaB middleware [1] proposes a technique called mooching for Ajax-based collaborative apps, which multiplexes networking activities in a set of Web client components and demonstrated improvements on net, battery, and CPU utilization in the range of 21-99% with real-life workloads. His E-Smalltalker project [2] studies how to achieve energy-efficient and privacy-preserving communications between two smart phones using Bluetooth and Bloom Filters. His current project is developing a always-on mobile system that incrementally learns each user's commute and other activity patterns and makes personalized, context-aware recommendations to users in individual and group.

References

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