MobiCom 2010 Poster: Mobile Data Offloading in Metropolitan Area Networks

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Cellular networks, especially 3G networks, are currently overloaded with mobile data traffic. It is thus imperative to develop novel communication architectures and protocols for this problem. In this paper, we propose to exploit the delay-tolerant nature of non-real-time applications to offload mobile data traffic through opportunistic communications and WiFi networks. We argue that it is necessary for cellular network operators, WiFi service providers, and end-users to cooperate to make the offloading more effective. We also present several preliminary experiment results about the work we have been conducting, which show that it is promising to offload mobile data traffic in metropolitan area networks.

I. Introduction

With the increasing popularity of smartphones and the flat-rate pricing model of cellular networks, 3G networks are currently overloaded with mobile data traffic [1]. For example, AT&T experienced a 5,000\% surge of mobile data traffic over the past three years. Due to this explosion of data traffic, it thus becomes a challenging problem to guarantee the quality of service of diverse applications provided to end-users. To solve these issues, we propose MADNet (Metropolitan Advanced Delivery Network) which leverages cellular networks, opportunistic communications, and WiFi networks to improve the performance of mobile content delivery, as shown in Figure 1.

Mobile data offloading, also referred to as mobile cellular traffic offloading, is the use of complementary network communication technologies to deliver mobile data traffic originally planned for transmission over cellular networks. We focus on the offloading of mobile data traffic in the metropolitan areas due to their high population density. In the traditional delay-tolerant approach [2], it is usually the intermittent connectivity that causes delay. We propose to delay intentionally non-real-time data transmissions until when opportunistic communications are possible or WiFi access points (APs) are available, with the goal of reducing mobile data traffic as much as possible. Note that we do require the intentional delay not to make an application’s completion time go beyond its delay-tolerance threshold\textsuperscript{1}.

\textsuperscript{1}For example, iPhones allow users to specify delay tolerance for applications, mainly for energy conservation [1].

![Figure 1: The MADNet architecture.](image)

We advocate that cellular network operators, WiFi service providers, and end-users cooperate to support mobile data offloading, as it is win-win-win for them. Cellular operators can offer it as a value-added service, which may provide better experience for end-users and thus increase their customer base. For WiFi service providers, it may bring them more users without pre-service contracts. (Cellular operators may also be WiFi service providers, like AT&T and T-Mobile.) Finally, end-users may benefit from the offloading through higher data rate, longer battery life, and reduced overall cost.

II. Related Work

In this section, we review the related work on cellular traffic offloading. There are two major existing solutions to reduce cellular traffic load: offloading to femtocells and WiFi networks. Femtocell was proposed to offer better indoor cellular service, in terms of both coverage and capacity. It works on the same licensed frequency band as the macrocell of...
cellular networks. For indoor users, cellular operators can offload traffic from macrocells to femtocells. Different from femtocells, WiFi works on the unlicensed spectrum and causes no interference with cellular networks. Thus, cellular network operators, such as AT&T, T-Mobile, and Vodafone, have started to deploy WiFi hotspots worldwide. Recently, Balasubramanian et al. [1] proposed the offloading of mobile 3G traffic to WiFi networks for vehicular networks.

MADNet advances the so-called “wireless overlay networks”, which usually consist of multi-technology wireless networks (e.g., cellular, WiFi, WiMax, Bluetooth and ZigBee) with different sizes (e.g., room or building-size, or wide area). The goal of wireless overlay networks is to improve the connectivity for mobile users, for which Stemm and Katz [5] propose mobile-IP based vertical handoffs that occur between different wireless networks. Compared to wireless overlay networks which utilize, for example, higher data rate networks only when they are available, in MADNet we exploit the delay-tolerant nature of non-real-time mobile data traffic and offload it through opportunistic communications and WiFi networks.

III. Opportunistic-Communication Based Offloading

For mobile data offloading through opportunistic communications, we use information delivery as a case study. In this scenario, content service providers first send information through cellular networks to only users in a target set. Then those users further propagate the information among all the subscribed users through opportunistic communications. The service providers will finally send the information to those who cannot receive it before the delay-tolerance threshold (i.e., delivery deadline). We study how to choose the $k$ users in the target set, such that we can reduce the most mobile data traffic.

We propose three algorithms, called Random, Greedy, and Heuristic, for the target-set selection problem. For the Random algorithm, content service providers randomly choose the $k$ users. The Greedy algorithm runs in $k$ rounds and identifies the most suitable user in each round. A major limitation of the Greedy algorithm is that it requires the knowledge of user mobility in the future. To solve this problem, we propose to exploit the regularity of human mobility [3], which results in the Heuristic algorithm. Based on the Greedy algorithm, the Heuristic algorithm identifies the target set through the history of user mobility, and then apply it to future information delivery. We refer interested readers to Han et al. [4] for more details about the proposed algorithms and their performance evaluation.

Different from the existing routing/forwarding protocols in delay-tolerant networks, it is the end-users, not MADNet, who make the decision about whether to share/disseminate the information with/to their peers or not and thus we can protect users’ privacy. We are building a proof-of-concept prototype implementation, called Opp-Off, on Linux-based smartphones (e.g., Nokia N900). In Opp-Off, we use Bluetooth interfaces for device and service discovery, and WiFi interfaces (in ad-hoc mode) for data transfer. Our preliminary experimental results verify the feasibility of opportunistic communications for moving smartphones during their short contact durations.

IV. Offloading to WiFi Networks

Benefiting from the proliferation of smartphones with multiple wireless interfaces, nowadays mobile users are able to request content from the Internet (e.g., YouTube) or generate content to upload to remote cloud services (e.g., Facebook Mobile) with their phones. To offload mobile data traffic to WiFi networks, when end-users request content from the Internet, the MADNet module running on their phones will send several pieces of information to their associated base stations, including the signal strength of both cellular networks and neighboring WiFi APs (if any), the user’s current geographical location, moving speed and direction, etc.

Smartphones can retrieve these information from their wireless interfaces and various sensors (e.g., GPS and accelerometer). To reduce the energy consumption, MADNet will turn the WiFi interface and other sensors on to scan the neighboring APs, measure the channel quality and retrieve other related information only when end-users issue content requests.

We require cellular base stations to know the locations of their neighboring WiFi APs to facilitate the offloading, which is easy to achieve because these locations are fixed and some of the APs (i.e., hotspots) may be deployed by cellular operators. Based on the above information, the base stations will then make the decision about whether to delay the delivery of requested content by offloading it to available WiFi networks. Several factors will affect this decision, including cellular traffic load, WiFi network availability, and the delay that mobile users can tolerate.

Although Wiffler [1] has many attractive characteristics, it has been evaluated for only desktop/laptop
machines on vehicular networks, accessing cellular networks through a 3G data modem. The limited processing power and battery life of smartphones bring more challenges to the protocol design for them and directly applying WiFifier to smartphones may not be suitable. For example, WiFifier uses a history-based predictor to estimate the AP encounters and the offload capacity, which requires the mobile devices to keep scanning the neighboring APs.

We measured battery life with different scanning intervals for two environments, an industrial lab and a residential apartment, and show the results in Figure 2. There are three observations from this figure. First, scanning of WiFi APs reduces the battery life of a fully charged new N900 phone from longer than 300 hours to around only 5 hours. Second, increasing the scanning interval can prolong battery life. Third, the battery life for a residential environment is usually longer than an industrial lab, mainly due to its small number of deployed home APs. This figure indicates that we must take energy consumption into account when designing offloading protocols for smartphones.

We also measured the availability of 3G networks and WiFi APs in Berlin, Germany. The duration of the experiment was 140 minutes, during which we took buses for 80 minutes and walked on streets for 60 minutes. We retrieved 3G signal strength and scanned WiFi APs periodically, with 5-second intervals. We forced our N900 phones (subscribed to T-Mobile and support both GPRS and UMTS) to run in 3G mode. We show the results in Figure 3. The x-axis is the time in seconds. The left y-axis is the number of detected WiFi APs and the right y-axis shows the 3G signal strength in percentage of the maximum value. As we can see from this figure, the 3G signal is almost always 100% on our routes. For the WiFi availability, the maximum interruption we need to tolerate is 432/5 (Bus/Walk) seconds if we can use all the detected APs, and 549/175 (Bus/Walk) seconds if we can utilize only the open ones (those with MAC encryption off). During these long interruptions, the bus was running at the edge of parks in the city.

These results are lower bounds, as in practice we may not be able to access all the detected APs. Even if their encryptions are off, they may use MAC address filter or web-based authentications for access control. However, these results show that it is promising to offload mobile data traffic to WiFi networks, if users are willing to share their home APs and cooperate with cellular operators and WiFi service providers. We are currently measuring the throughput of 3G and WiFi networks and implementing the proposed mobile data offloading solution.

V. Conclusion

In this paper we propose MADNet, a heterogeneous wireless network architecture, to offload mobile data traffic using opportunistic communications and WiFi networks. Our preliminary experimental results show that it is encouraging to offload mobile cellular traffic in MADNet.

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References