mango: Low-Cost, Scalable Delivery of Rich Content On Mobiles

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ABSTRACT

We present mango, a low-cost and highly scalable content-delivery service for mobile phones. The service is targeted at emerging countries such as India where users are highly price sensitive, and there is considerable demand for rich media content. mango is designed as a content "synch-up" service. Users install an app on the phone, and through a simple menu select content for download, upload or sharing. Then, in order to actually transfer content to and from their phones, users visit or opportunistically connect with mango hot-spots. The hot-spots are short-range cells (installed in shops, cafes, or as an app in other users' phones) with a back-haul connection and a wireless interface such as Bluetooth to communicate with the phones. Given a large number of such low-cost, short-range access-points, the mango network delivers content to the very edge of the network, to within a few feet from the user. Such a content delivery architecture is faster, cheaper and can support a much larger number of users than macro-cellular data networks. In this paper we present the mango service architecture, discuss its potential as a substrate for deploying a range of novel applications and present technical challenges for timely, low-cost content-delivery.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

General Terms

Design, Experimentation, Human Factors

Keywords

Mobile applications, CDN

Motivation.

In recent years there has been a remarkable proliferation of cellular services and handsets amongst people in emerging markets. For example, in India alone there are nearly 300 million cellular subscribers, with about 10 million added very month, and projected to rise to 600m by 2012 (in contrast there are only 20m PC users [**?**]). Cell phones are the primary communications interface in the developing world, and clearly, providing access to rich media on people's cell phones is a natural next step. But low-cost delivery of rich content to and from mobile devices has remained an elusive goal (Indian consumers are highly price conscious, operators ARPUs (average revenue per user) are USD $6-7$ [**?**], as compared to USD 51 in the US). There is a lack of easy-to-use applications to search for and access rich media content on mobiles (less than 1-2% of the ARPU is due to data services [**?**]). An important reason is that current-day wireless data networks (especially the generation of networks that are currently available or will be deployed in the next few years) do not have the capacity to support such bandwidth hungry services for millions of users at low price-points. Operators have instead focused on voice networks and low data-rate data applications (emails, ring tones, wall papers etc.).

MobiHeld'09, August 17, 2009, Barcelona, Spain.
ACM 978-1-60558-444-7/09/08.

Architecture.

We describe mango, an application and service that is designed to serve rich content on mobiles, for the masses in emerging countries. Given our target demographic the service is designed to keep the user-experience simple and cost of delivery low. Users download an app on their phones that allows them to browse and select content from a menu and/or mark items to be uploaded or shared with their friends. Then, to transfer content to and from their phones, users visit or opportunistically connect with a mango hot-spot. The hot-spots are a network of inexpensive short-range cells. Each cell has an air-interface to deliver content to and from mobile handsets (Bluetooth, WiFi, short-range cellular), and a back-haul connection (wired broadband, 2.5/3G cellular data). The cells can be physically installed in shops, cafes, bus stops etc., or can have a software manifestation installed in user phones. The basic idea behind mango is a content "synch-up" service, where users select content in an off-line manner (i.e. when the user is not in the vicinity of a mango cell). These selections are sent over a low-capacity channel (such as SMS), or whenever a user visits the mango cell. The actual transfer of the selected content happens when users goes to the cell of a mango hot-spot.

The notion of serving content from short-range "hot-spots" or "infostations" has been explored by various projects, such as Drive-thru-Internet [**?**], Infostations [**?**], CarTel [**?**]. However, we believe such an architecture is not only useful for content-delivery, but that such a distributed network of short-range cells (with content served from the edge of the network) can also act as a substrate for a range of novel applications.

Thus, we view mango as an open platform to bring content and applications to users (independent of providers). Through a set of APIs, we would like to provide access to mango cells for local administrators to install and serve content and applications. In this way, customized services, e.g. that are of particular interest to users of say within a local geographical area, can be deployed. Also, short-range mango cells can be the source of useful information such as proof-of-presence of a user (useful for location-based ads, disbursing coupons and for e-payment solutions in a shop), and can also provide means to form opportunistic social networks (e.g., within a coffee shop). In short, the physical infrastructure and useful information produced by a deployed mango system can be utilized by novel applications. We believe there are interesting architectural issues to be resolved in deploying innovative services in a scalable and secure manner over such an open, distributed system.

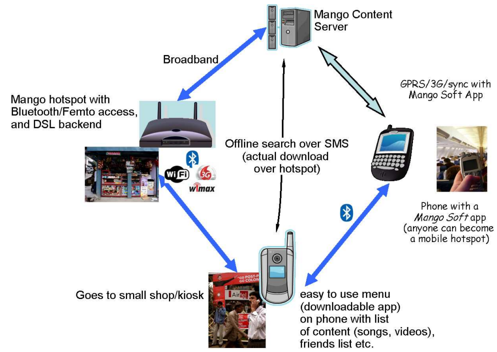

Figure 1: mango system architecture

Value proposition.

We have done quantitative comparisons [**?**] between the mango service and cellular data networks, across metrics such as the capacity of the system, download times and the cost of service, based on assumptions on user behavior (e.g. amount of content downloaded/user/day), network architecture (e.g. number of cells per sq. km, typical size of cells) and the performance of various wireless technologies (Bluetooth, 2.5G Edge, 3G UMTS). We found that the mango system can have an order of of magnitude more capacity and significantly lower download times as compared to 2.5G cellular networks (that are currently deployed in emerging markets such as India). Also, compared to a 3G UMTS network, a mango like small-cell system can have significantly more scale and comparable download-times. Moreover, while 3G services are beginning to be deployed in India, it is widely believed that initially the 3G spectrum will be significantly used to offset the load on voice services - and not to offer low-price, high-bandwidth data services, further lending weight to the arguments made above.[1]

The cost of the mango service is kept low by deploying inexpensive access points (in case of physical deployments), and low bandwidth, carefully managed back-haul links. The mango service does not aim for complete coverage (unlike a cellular service); thus deployment is organic (i.e. users, shops, cafes and other establishments deploy cells as demand grows) and does not require any network planning or management. We envisage mango will be deployed as a "pay-as-you-go" service, and while the exact price of the service will depend on several other factors such as content-licensing costs, hosting costs, profits etc. (that will also be a component of any similar service on cellular networks), given the above points, we strongly believe mango can be offered at much lower costs compared to conventional cellular data services.

Technical challenges.

As discussed, several projects [**?**, **?**, **?**, **?**] have investigated issues emerging from serving content through a network of short-range hot-spots. Perhaps because the common use-case considered is to provide opportunistic Internet access from within moving vehicles, the primary focus of such work has been on the performance of the wireless link between the user and the hot-spots. In the mango service, however, users voluntarily visit and associate with a hot-spot and are willing to spend some time waiting to transfer content. Therefore, enhancing the performance of the last wireless hop and issues around maintaining end-end connectivity are less important.

Instead, a crucial factor in the successful running of a large-scale service such as mango is to reduce the operational costs. Our calculations suggest the single largest component is the cost of the back-haul link at each mango hot-spot[2]. To cope with this, an operational mango system will have to select low-priced broadband access plans at each hot-spot, which e.g. in India, almost always impose limits on the amount of data that can be downloaded per month. Thus, keeping the cost of delivering content low gives rise to some interesting challenges that we outline below.

The mango system has a back-end content server, that is a store of all content served to the mobiles. Whenever a hot-spot or a mobile requires content, a naive implementation would be to retrieve this content directly from the content-server. However this implies that the network link at the content-server has to be an expensive fat-pipe that can scale to serve tens and thousands of mango hot-spots. One natural option (to reduce the cost of a fat pipe to the content server) is to cache or place content on the distributed network of mango hot-spots, and when required, source it from a hot-spot which has spare back-haul capacity. This also helps in offsetting the sunk costs of a back-haul link. Although co-operative content caching has been studied extensively in several contexts e.g. [**?**, **?**] we believe that the limited monthly transfer capacities on the hot-spots pose a novel and practical problem formulation very different from existing literature. To summarize, given a set of current and future user demands, limited storage and monthly back-haul link capacities at mango hot-spots, we are posed with an optimization problem to find efficient content-routing algorithms that will minimize the content-delivery costs.

To minimize the waiting time at hot-spot, user data can be pre-fetched onto the hot-spots. Content may have to be pre-fetched to multiple hot-spots, shared by multiple users. While previous works have considered pre-fetching strategies, doing so given the resource constraints of the back-haul link, and while ensuring fairness across users is another interesting, previously unstudied optimization problem.

In conclusion, we believe the mango system presents a cost-effective, scalable architecture for delivering rich media content and other innovative applications on user mobile phones. We also believe that such short-range cellular architectures will become more common in the future (to account for cost and scalability) and the design and operational lessons that will be learnt from mango service will be invaluable in designing small-cell systems of the future.

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[1] Finally, mango is not restricted to use the Bluetooth air-interface. In time, mango can evolve to a higher-rate 3G-Femto based architecture and hence will continue to far outperform a cellular infrastructure with the same air interface.

[2] Typical basic business broadband (256Kbps) plans start at Rs. 3,000 p.m. (USD 60). Considering that a hot-spot in a small shop can attract only a certain number of paying customers in a day, and that content-transfers will be low-priced to appeal to the target demographic, the cost of broadband access can be a significant percentage of the hot-spot revenues