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Toward a Mobile Digital Wallet

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ABSTRACT
Mobile phones have now made their way into a large fraction of pockets and handbags worldwide. An intriguing question is whether such phones will eventually replace the physical wallets we carry. We believe the answer is in the affirmative, though plenty of challenges abound in overcoming entrenched personal and business practices and processes. In this paper, we explore the changes that need to ripple through the ecosystem to build a vibrant set of digital wallet services that potentially interact with each other to provide users both with increased convenience and a level of functionality hitherto unrealized. We describe our initial mobile wallet prototypes on web-enabled smart phones, designed to explore some of the challenges in creating the architecture and infrastructure necessary to make this vision a reality. Feedback from users and experts across a range of industries such as retail, banking, telecommunications, and healthcare indicate that we have just scratched the surface and a substantial wave of innovation is necessary to make the digital wallet a full-fledged reality.

Keywords
Mobile wallet, mobile applications, mobile computing systems, digital cash, coupons, receipts.

1. Introduction
As the mobile phone continues to take on an ever more central role in our lives, it is increasingly replacing old activities and practices. It is commonly accepted, for example, that the mobile phone is superseding the wrist watch [7], especially among the younger generation. Further, internet-enabled smart phones that also include cameras, music and video players, large storage, and navigation services are reducing the need to carry multiple devices. In response to these significant changes, we have been experimenting with ideas about how the mobile phone might also entirely replace the function of a physical wallet.

One of the first things to come to mind when a mobile digital wallet is mentioned is digital cash. [9] But when we examine our own wallets, we find many other objects there in addition to money. Among the principal functions of a wallet is to carry our identification such as a driver's license, employee badge, and other forms of id. We also carry credit and debit cards, loyalty cards, health insurance cards, and membership cards for the local library or professional association in our wallet. Wallet items are often grouped by function – for example, shopping lists, coupons, and receipts all support shopping. We might carry business cards in our wallet, both our own as well as those we receive from others. We may also use the wallet for purely personal functions – for example, carrying pictures of our children or pets, making the wallet into a miniature photo album.

Beyond the analogy with a physical wallet, a mobile digital wallet provides additional functions and benefits, such as virtually unlimited storage, location awareness, and quick sorting or searching of its contents, making it an even more compelling replacement for the physical wallet. Doing away with paper receipts, business cards and other paper artifacts, and the potential for optimizing or eliminating trips, all have environmental benefits. Note that some of the same security and privacy concerns associated with a physical wallet are also present for the mobile version -- losing either can be enormously disruptive.

We define a *mobile digital wallet* as a heterogeneous managed store of content items related to daily transactions, both electronic and physical, providing secure, automated multi-channel access to the user and other parties. What issues does the research community need to address to make a mobile digital wallet a reality?

This paper positions the emergence of a mobile digital wallet ecosystem as the central need, rather than just the need to build new capabilities into mobile devices. The paper first presents some advanced usage cases that are possible within such an ecosystem. We then analyze the players and roles involved in an ecosystem, and derive some design principles for it. We then outline technical capabilities that will be needed in its enabling software. We then describe a substantial customer pilot and mobile digital wallet prototype that backs our ideas. Additionally we summarize related work others have conducted in this area and outline our conclusions and future directions.

2. Digital Wallet Scenario
Jane is a busy working mother with three demanding young children. In a typical week, Jane visits several grocery stores, "Grocer-o-Rama" near her home, a more upscale "Fresh Foods" closer to her work place, and "Shop A Lot" near her children's day-care center but which usually has long lines on weekday evenings. Frequent trips to the local library, pediatrician's office, and a pharmacy further complicate her life.

But Jane has recently switched to a more advanced mobile phone that includes a futuristic digital wallet on board, and this has helped to simplify her life. The phone receives coupons and promotions, based on her profile and past shopping lists, which relieves her from needing to clip coupons from the Sunday paper and fumbling with them at checkout. She can see the estimated total cost of her current shopping list at the three different stores she patronizes, and pick the one that optimizes cost and travel time. The list itself is proposed, based on past lists and electronic receipts, and is easily modified to exclude or include specific items. Further, it is automatically sorted in aisle order when she enters a particular store, saving time and frustration as she shops. She pays for her purchase by selecting a credit or debit card from

her phone, which suggests a preferred card based on current balances, due dates, promotions, and interest rates. Sometimes she pleasantly finds that several of her expired coupons have been refreshed with valid coupons.

As she checks out by briefly touching her phone to the point of sale terminal while entering her PIN code, the electronic receipt and new promotional offers are automatically sent to her wallet, replacing the old-fashioned offers on a printed receipt, which she never seemed to be able to find again the next time she shopped.

Because Jane's new digital wallet makes use of a variety of services effectively located in the cloud, services that are able to interact with one another to provide intelligent suggestions and choices, she finds that her busy schedule is indeed simplified. Because she is now able to manage the family finances better and to eliminate unnecessary paper and optimize travel time and her own schedule, she feels that her new digital wallet represents a significant advance, an innovation with both ecological and financial benefits.

As we write this today, this scenario is still futuristic, with lots of unresolved questions and issues. However, we believe the vision is an appealing one; the next three sections outline some first steps toward achieving this vision.

3. Building a Mobile Wallet Ecosystem

We believe that a central hurdle for widespread acceptance of the mobile digital wallet concept will be the emergence of a generalized *mobile digital wallet ecosystem*. In this section, we lay out, as shown in Figure 1, what we consider some of the key players and needed capabilities in such an ecosystem.

3.1 Ecosystem Roles and Players

3.1.1 Wallet User. The most fundamental role is that of the wallet user. In this ecosystem, a digital wallet -- pictured at the center in Figure 1 –-- been established on behalf of a user. The digital wallet ecosystem fosters two key perceptions on the part of the user. First, the user has a perception of ownership and control of the digital wallet, even if the maintenance and technical control of the digital wallet is in the hands of another party. Second (assuming that the user generally makes use of a mobile device), the user has a perception that the wallet exists inside that device. The role of the user is essentially to manage the wallet as an item of property similar to an email account. Even though the wallet is conceptually attached to the device, the user should be able to access the wallet through multiple channels (e.g. mobile web, desktop) and use the wallet within transactions conducted both online and in physical settings such as stores.

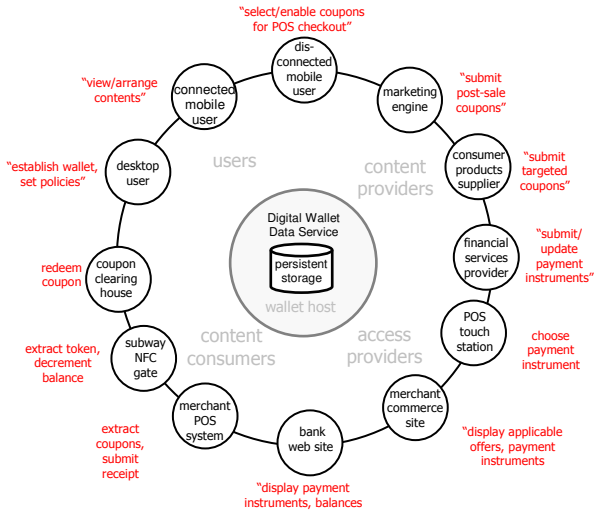

Figure 1: Illustrating elements of a mobile digital wallet ecosystem.

3.1.2 Wallet Content Providers. Entities playing this role wish to provide objects for inclusion in the wallet. For example, a bank or other financial services provider may wish to provide a debit or credit card as a content item for the given user's digital wallet. An online marketing company may wish to provide digital coupons or offers. An advertising company may wish to provide targeted advertisements to the digital wallets of select users. In most cases, wallet content providers operate under the control of the wallet user. In many cases, the user will desire the inclusion of the content provider's wallet items (e.g. the user's bank account should be made available within the wallet) and in many other cases, the user will view the content provider as a spammer. As a result, the wallet should offer a spectrum of access control capabilities that easily incorporate the content items of value to the user, reject those of no value, and provide some intermediate capability for items of possible value.

From the content provider's point of view, there are several key hurdles to overcome. First, there must be a way of identifying the wallet for a particular user. Second, there must be a way of acquiring the necessary credentials for interaction with the wallet of the user. Third, there must be a way of introspection over the wallet so that the rules for accessing the wallet can be determined in advance of dedicating resources to working with the wallet.

3.1.3 Wallet Content Consumers. These are entities that wish to read, update, or extract an item from a wallet. For example, a point of sale (POS) station deployed by a merchant may wish to read the set of payment instruments available in a user's wallet (after authentication of itself to the wallet) and display the available options to the user (e.g. on a touch screen). In some cases the content consumer will disable the wallet item (e.g. a "use once" coupon), mark it (e.g. a multi-use coupon), or decrement it (e.g. a digital cash balance). In other cases the content consumer may be enabled to remove the content item from the wallet altogether.

3.1.4 Wallet Host. In general, someone must implement the wallet and make it available to the other players in the ecosystem. There has been much debate and tension in the industry over this role.

For example, from a mobile usage point of view it would appear to be a natural role for a mobile telco. From the vantage point of classical electronic commerce, it may appear that this role would belong to retailers, banks or financial services providers.

3.1.5 Wallet Access Providers. Beyond the question of who hosts the wallet, arises the question of who provides access to it. One natural role is for the host to the *primary* access provider. For example, the host would provide desktop and web access screens that a user can use to manage their wallet contents, as well as services oriented interfaces. However, within the ecosystem many other players may wish to assume the role of *secondary* access providers within the context of their business function. For example, a merchant may wish to introspect over a user's wallet, read coupons or offers that apply to the merchants product set, and display those applicable items within the shopping or checkout screens of that merchant's online store. As the ecosystem evolves, the roles of various access providers may blend together, and possibly will disappear altogether, with the digital wallet disappearing into the background of everyday commerce.

While we have outlined several distinct roles, in practice, many players in the ecosystem will likely play hybrid roles. A merchant, for example, may be a content provider, content consumer, and access provider.

3.1.6 Standards Organizations. A critical consideration in enabling services from different providers to interoperate is the establishment of industry standards. While some efforts in electronic commerce have been fruitful, there are still many gaps; for example, there is still no accepted standard for the content of a digital coupon.

3.2 Design Considerations

From the analysis of the above roles, we can extract some key design considerations for the digital wallet.

3.2.1 Wallet as a centralized managed service. The wallet should be positioned centrally in any ecosystem, allowing access to a wide field of players. Towards this end, we note that there is increasing attention to the concept of cloud-based services, in which core computational services and business processes are migrated into centrally managed common assets. The wallet ecosystem is ideal for such a service structuring. In particular, a digital wallet is likely not to be an item of licensed software, but a managed service. The players in the ecosystem would become subscribers to a cloud-based wallet service.

3.2.2 Heterogeneity of the digital wallet. The wallet ecosystem should accommodate an arbitrary collection of content types, following a design principle similar to that of the web. Basic access capabilities should be managed in a uniform way that is independent of content type. The ecosystem should provide extensibility mechanisms that accommodate type-specific constructs such as business logic and user interactions. Ecosystem players should agree upon a model for interchange of wallet items and forms of access control.

3.2.3 Wallet as competitive asset. A digital wallet should be managed as a competitive asset. This means that a wide variety of players will need to (1) insert items into particular locations within the wallet, (2) have those items securely managed by the user or by agents that operate on behalf of the user, (3) update (or mark) items in the wallet, and (4) extract or delete wallet items. Digital wallets will need to be managed much like email accounts, and will be vulnerable to an unlimited number of demands for access and equally susceptible to the same motives with regard to spamming.

3.2.4 Wallet Identification. Since the wallet ecosystem virtualizes the wallet, it does not actually reside on the user's physical device. Thus, we cannot identify digital wallets via MAC address, SIM card, or MTN. Another approach may be to identify digital wallets via an email addresses (e.g. user@wallethost.com). However, this has the disadvantage of linking the wallet to a particular provider, and introduces the same problem with email – users typically have multiple accounts. Another approach might be to use a directory mechanism -- however, these approaches tend to be cumbersome and likely beyond the tolerances of end users.

3.2.5 Wallet Lifespan. As the digital wallet incrementally replaces the physical wallet, questions of its lifespan are induced. For example, how long does a digital wallet live? Who owns the contents of a digital wallet? If the user dies, who recovers ownership of the digital wallet contents? Service changes such as switching wireless service providers should be seamless and not dramatically affect the usage of the wallet.

3.2.6 Wallet Automation. Common usage patterns should be managed in a silent, unobtrusive, and automatic fashion. These usage patterns should be driven by a "*hands off*" design point: it should be possible to use your digital wallet in your everyday mobile commerce life with a minimal use of your hands, except for trivial steps such as swiping it at an NFC service point. A digital wallet should allow the attachment of user-preferred agents that execute automated processes in well recognized mobile commerce settings. For example, an agent for the retail POS check out process would automatically carry out scripts which identify the merchant, collect applicable instruments from the wallet (coupons, payment instruments, loyalty cards) and organize a silent, single step transaction with the merchant.

3.2.7 Wallets in Workflows. The emergence of a digital wallet ecosystem may lead to new models of processing transactions. For example, in the payments world a typical payment is viewed as the presentation of a payment instrument by the user to a receiver (e.g. retailer), followed by an opaque process of routing payment transactions through a series of financial providers. With a digital wallet, each of these providers could be modeled by an individual wallet (e.g. your bank has a wallet) and this process may be recast as the successive transfer of content from one wallet to another.

3.2.9 Interacting Wallet Services. Mature mobile wallets will become increasingly heterogeneous, managing diverse individual artifacts and corresponding services. Users will realize multiplicative rather than additive benefits when these services interact with each other. This principle is already emerging in existing mobile device usage – for example, composable functions which link the user's address book to the navigation application on the device allow users to get driving directions by clicking on a contact in the address book. A map in a navigation application in turn can be used to enter an address for a contact. Coupons, promotions, advertisements, receipts, loyalty program, and payment services within wallets must interact with each other and with native device services even when they are provided by multiple service providers.

3.2.10 Monetization of the Ecosystem. Central to the adoption of such an ecosystem is the resolution of issues regarding who pays for and benefits from its functions. An inevitable axiom is that users should perceive value and benefit. Beyond that, a wide variety of monetization schemes could be envisioned. For example, valuations could be attached to each basic operation against an item in a digital wallet. Users may be willing to pay for items as they are added to a wallet (e.g. pay 5 cents for a coupon offering a 50 cent discount), or as they are extracted (e.g. when the user redeems a previously stored coupon). Marketing firms may also receive benefit when the user accepts an item into a wallet – the equivalent of receiving payment for each page view of an advertisement. Wallets could also be monetized based on user access alone in the way that many email providers make money -- either by associating advertising with account access, or through paid subscriptions for advanced accounts. Novel hybrid functions that add value to all parties could be monetized – for example, by attaching coupons to certain payment instruments in a digital wallet, a user may be influenced to use one credit card vs. another.

3.2.11 Client Programming Model. One of the ongoing debates in the mobile application area is whether browser-based web applications or native applications are better [5]. A browser-based digital wallet will work across a wider variety of devices, but is handicapped by different browser implementations and limited access to phone capabilities, such as a camera that can serve as an input device or GPS that can provide user context. Native digital wallet applications are generally better performing and have access to all the device capabilities, but developers face the problem that creating a version of the application for each of the many devices is a huge amount of work, and requires users to download and update applications. Though the advent of HTML 5 [6] within mobile browsers will give an impetus to the web-based approach, we advocate a hybrid approach in which much of the presentation and user interaction is done with browser-based web pages, but in which bridges to native code are defined to give access to device capabilities.

4. Design for Mobile Wallet Service

The preceding section postulated a centralized managed service at the heart of the digital wallet ecosystem. This section outlines the technical capabilities that we view as critical for its success.

4.1.1 Basic User Management Capabilities. As noted above the digital wallet should be a user managed store for a heterogeneous collection of content items, centrally managed and made visible throughout an electronic commerce ecosystem. The wallet should be accessible by users through a variety of access channels, including the desktop web, mobile web, and native mobile applications. The wallet should provide basic user driven operations for searching/sorting and finding wallet items, plus additional operations for user controlled item insertion, modification, and deletion. Key user capabilities should include management of intelligent views across the wallet (the wallet may be a large data space). Views of the wallet should accommodate pluggable presentation modules, which present both previews and detailed views of wallet data types in customized ways. Adding a new type of content item to a wallet should entail no more than plugging in additional display and management modules for that content type.

The wallet should provide versatility in its basic paradigm of organization. We recommend that the wallet offer a naming and organizational model that provides the capabilities of both a directory/folder mechanism and a tag/attribute mechanism. This allows the user to establish the concept of "a place" that a wallet item exists in the wallet (e.g. "my Coupon folder") plus the concept of "properties" within the wallet (e.g. "my expired coupons"). Possible enhancements for mobile commerce could include the ability to manage wallet items by geo-coded locations.

In many cases the wallet is used in settings which have space limitations (e.g. displayed on a small device screen) and or constraints about the complexity and timing of user operations. For example, the user needs to quickly access the digital wallet while standing in a checkout line at a point of sale station. Therefore, the wallet should offer organizational capabilities such as filtering and prioritization of wallet items. To address a wide variety of unpredictable needs, these organizational capabilities should be structured as pluggable modules. For example, a merchant may wish to offer a pluggable wallet organizer which automatically sorts the user's coupons by aisle when the user enters that merchant's store.

4.1.2 Access Control Capabilities. Access to the wallet should be governed by a set of access rules which determine who can carry out operations (find/add/delete/update) on wallet items. These rules should be customized by data type. A simple conceptual model for such an access control rule would be a tuple: *(operation, location, content type name, content type namespace, credential type, credential)*. The operation member would be one of the values `{find,add,delete,update}`, the location member would be a folder name, the content type and namespace member would identify which type of item can be manipulated by the operation, and the credential type and value members would specify which actors can carry out the operation. For example, the rule `("Add", "/Coupons/Inbox", "Coupon", "http://coupons.org", "certificate", …)` would specify that only callers which present a given certificate can add coupons to the wallet.

4.1.3 Work processes. In addition to access control capabilities, which determine what content gets into the wallet in the first place, additional work processes should be in place to manage wallet contents. For example, the wallet should have basic management capabilities that automatically recognize and remove expired artifacts (old coupons, unused offers, etc.). Another work process should also be in place to limit the maximum size of the wallet contents.

4.1.4 Event and Notifications. The wallet implementation should be capable of generating and managing events related to wallet operations. In a simplified form, a wallet can be viewed as the source component of an event stream tied to the four basic operations (find/add/delete/update). This allows logical software components to be attached to event streams flowing from a wallet, for example, summary notifications may be sent to the wallet user whenever certain artifacts are added (e.g. "you have three new coupons from Manufacturer X").

4.1.5 Replication and Content Transfer. As noted in the ecosystem model, a wallet would be managed in a central location and accessed through various channels and devices. In some cases local copies of a wallet view would need to be maintained outside of the central wallet. For example, native wallet applications on

mobile devices could operate against replicated snapshots of the user's wallet, enabling usage in situations where network connectivity to the central wallet service is unavailable or unreliable. The wallet service should support replication strategies where localized copies are synchronized at opportune times. Entities that accept replicated artifacts from mobile wallets should have the opportunity to verify the artifact before finalizing its acceptance. For example, a coupon presented from a replicated wallet would essentially be *a claim* about the true artifact stored at the central wallet. In such a scenario, the user's wallet may be disconnected but the receiving merchant may be connected and can verify the coupon. It should also be possible to transfer items from one wallet to another. Transfer capabilities should be in effect even if the two wallets are not managed by the same wallet host.

4.1.6 Sharing. In many usages, the contents of a wallet could be shared among users – for example, family members may wish to share payment instruments or virtual cash. This can be realized in two ways: replication of the shared items from a base wallet, with periodic synchronization, or via virtualized views on a base wallet. Operations carried out on a virtualized wallet view would be transferred to the base wallet. Virtualization storage schemes would induce the need for virtualized access control policies, for example, a conservative scheme that computes and enforces the maximum access requirements among the base and virtualized wallets.

4.1.7 Staged import and export. The combination of the above wallet storage, access control, and replication and transfer capabilities can be combined in useful ways that yield higher level policies about wallet usage. For example, access rules could be arranged to allow artifacts to be imported only into special staging folders (e.g. "`/Coupons/Inbox` These can subsequently be accepted into production folders (e.g., "`/Coupons/Groceries`") either manually or by an automated agent. The same staging approach could be used for exports, with relevant artifacts moved into special export folders depending upon the user's activities. This could be especially useful for speeding wallet usage at critical times such as point of sale. For example, a retail workflow agent could recognize which store the user is shopping in, establish a transient folder (e.g. "`Exports/XYZStore.Nov212010`") for staging exports, then move applicable coupons into the "`Coupons`" subfolder, applicable payment instruments into the "`Payments`" subfolder and the retailers loyalty card into the "`LoyaltyCards`" subfolder. The user could then quickly review the items and approve the items before approaching the point of sale station, allowing the transaction to be completed in a single step. The staging folder could be referenced via a generated short code (e.g. "`ABC123`") and presented to the POS operator or, in the presence of NFC, a ticket datum referencing the export folder could be exchanged with the POS.

4.1.8 Self description and semantic linkage. A heterogeneous wallet requires that content items within be self-describing, at both the schematic level (fields and values) and semantic level (meaning). This capability is particularly important in enabling the hybridized business functions envisioned in the ecosystem such as an agent suggesting shopping strategies based on receipts and coupons in the wallet) and also in enabling ad-hoc operating modes. For example, a self describing wallet can be presented to a merchant with no prior administration. Such cooperating services are at the core of the semantic web and will likely gain equal importance in a mobile digital wallet ecosystem.

5. Prototype and Customer Pilot

As a test of the concepts described above, we developed a substantial prototype implementation of a mobile digital wallet and recently conducted a customer pilot with a major U.S. retailer. The customer pilot involved a digital wallet scenario that combined the function of two wallet artifacts: (1) loyalty cards and (2) store promotions (e.g. coupons and offers). Using this solution, loyalty program customers may use their mobile devices when they visit a pilot store to receive price promotions.

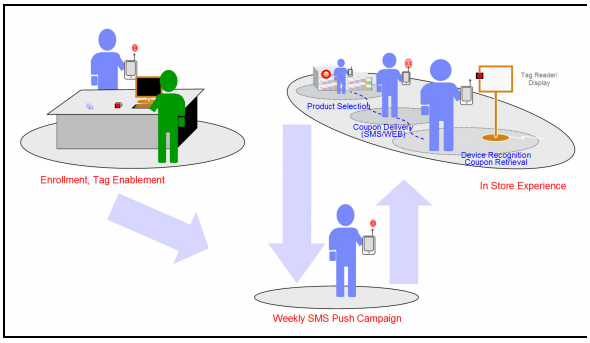

Figure 2: Illustrating three phases of the customer workflow for in-store mobile digital wallet pilot.

The pilot involved three phases of usage, seen clockwise in Figure 2. The first phase is an enrollment phase in which a mobile digital wallet is established for a user and linked to their existing loyalty card. A wafer-sized RFID tag, used for customer recognition, is attached to their mobile phone. The mobile digital wallet is stored on a server, consistent with the "wallet-as-service" principle outlined above. The second phase is the in-store visit: the customer enters the pilot store, swipes the mobile device at an RFID reader station, receives in-store offers into the digital wallet, and is notified of new offers via SMS messages. Additionally the user can access their digital wallet from their device using a mobile web application. Discounts are automatically applied at the point of sale when the user presents their loyalty card. The device is not involved at the point of sale. The third phase is an opt-in reminder campaign in which weekly text messages remind users of the week's promotions.

Figure 3: Prototype of general purpose wallet running on Android phone.

The pilot was motivated by the retailer's desire to find new ways to strengthen their relationship with loyalty cardholders. We tracked user participation and offer redemption rates during the pilot. We found coupling business processes such as marketing campaigns with the on-device wallet led to significant business

advantage. Though confidentiality agreements prevent us from releasing detailed results, we found that (1) the frequency of in-store visits was greater than the visit rate of the baseline loyalty program, and (2) the electronic coupon redemption rate was several times higher than traditional paper coupon redemption rates.

The success of the pilot motivated us to broaden the digital wallet concept and forms the basis for many of the assertions described in this paper. Specifically, we generalized the prototype to support an arbitrary set of content types, rather than the special purpose ones used in the pilot. Figure 3 illustrates this prototype configured for mobile coupons and electronic receipts. At present our prototype supports pluggable organizational modules which arrange wallet artifacts by a variety of parameters. In addition to the ability to arrange the wallet by simple sorting and searching on fields such as amount or expiration date, pluggable modules provide the ability to arrange artifacts based on complex concepts (e.g. order coupons by store aisle or display receipts by geocoded locations). Pluggable display elements induce custom visuals for content types. Our current client model is browser-based, however we are working towards integration of the wallet client with native capabilites on the device such as camera (facilitating in-store barcode scanning, which can be used to correlate wallet items to products) and GPS (facilitating the correlation of wallet items to location). In each of these versions, we have used a centralized managed service model for the wallet (following many of the capabilities described in Section 4), built on our testbed system called Celadon [10].

6. Related Work

Much of the previous work in this area has been concerned with mobile payments—the use of the mobile phone as a surrogate for a credit card or smart card. The device is linked to a bank account or credit card or phone account; alternatively, it may be supplied with a fixed amount of digital cash, which may then be spent anonymously [4]. In some regions, this use of mobile phones for payment is already well established. In Japan, Hong Kong, and Singapore, for example, the FeliCa contactless RFID chip is included in many mobile phones, enabling mobile payments. In South Korea, mobile payments are well established; contactless RFID chips or SIM-sized cards inserted into the phone enable mobile payments, with charges showing up on the customer's phone bill [3]. Taking a somewhat different approach, PayPal Mobile allows certain types of transactions from a mobile phone. However, mobile payments alone do not constitute a mobile wallet, as evidenced by the personal observation that consumers in South Korea and Japan still carry the old-fashioned kind of wallets. A somewhat broader approach is demonstrated by prototypes that combine mobile payments with organization of credit and loyalty cards, based on an NFC phone [1][2]. In other efforts, there are now numerous commercial or free mobile applications to store and organize various individual content types, for example passwords, loyalty cards, shopping lists, business cards, coupons, and so on [8]. But a series of applications, each dealing with one or two different content types, each with a different user interface, each possibly requiring a separate login, falls far short of what we believe is required to make the mobile phone a viable replacement for the physical wallet. We believe that to accomplish this goal requires a unified architecture, able to accommodate an open set of content types. Standards will also be an important aspect of this work, enabling independently-developed services from multiple providers to interoperate with one another.

7. Conclusions and Future Work

We have described the opportunities and challenges that arise in designing a mobile wallet that could potentially replace a physical wallet. Challenges abound in user interfaces, business models, standards, interactions among wallet contents and services, exploiting user context, identifying user intent, lifecycle management, etc. Our initial implementation of a digital wallet holds coupons, loyalty cards and electronic receipts. In the future, we plan to expand our repertoire of services to include a larger catalog of content types, refine the user interface, and expand it to a wider variety of user pilots.

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