A TAXONOMY OF MOBILE LOCATION-BASED SERVICES

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Abstract: This contribution aims at identifying classes of differential features of mobile location services, as a framework to understand their value chain and business models. With the purpose of recognizing LBS horizontal common features, we conceptualize a functional taxonomy from an empirical analysis of current commercial mobile location applications. Afterwards, we propose and use an evaluation model to describe mobile location services considering their technological aspects (network technology, accuracy needs, location techniques, etc.), but also the user experience (value proposal, user interaction methods and type of delivered contents or privacy management) and some related business issues (involved stakeholders, value chain and revenue model). To exemplify the proposed model, a number of in-market services are reviewed.

1 INTRODUCTION

Location based services (LBS) have now a place in the wireless world market. In 2001 an unbounded optimism hyped what finally was a slow and limited adoption of a number of these services. Since then, positioning technologies, applications, and business models have been evolving: at this moment, most mobile operators offer in their portfolio some location based services and a number of companies focus their business on location based products for niche markets (such as health, logistics or manufacturing). Thus LBS seem to reappear in the scene and a significant market growth is again estimated: for example, ABI Research expects the US market to rise from 981 million USD in 2005 to 8 billion USD in 2010 and Berg Insight forecasts that mobile LBS revenues will reach 622 million euros in Europe by 2010, when 60% of WCDMA handsets will be GPS/Galileo enabled (Berg Insight, 2006).

Due to legislative and cultural differences, location based services have been unequally deployed worldwide. In the US, December 31st 2005 was the deadline to fulfil the Federal Communications Commission E911 directive (E-911 Requirements, 1995), that established the mandate for locating the emergency calls made through a mobile network; during the last years, this circumstance has compelled the operators to update their infrastructures and mobile devices in order to reach the accuracy requirements, that range from 50 to 300 meters depending on the technology (terminal-based or network-based approaches).

A similar demand for location accuracy has not been legislated in Europe; all the operators are recommended to provide a best-effort service when locating an emergency call (CGalies, 2002). Operators have not been then pressed for introducing accurate location systems, so market has been the only tractor of most part of the deployed applications (mostly based on cell identification positioning). The greatest acceptance of location based services is in the Asia-Pacific area, which gathers 55% of LBS subscribers all over the world: in Japan, KDDI has 6 millions of users for 130 location based services and in South Korea, SK Telecom is estimated to have 12-15 millions of assisted GPS (A-GPS) phones and 150 services (RedHerring, 2005).

The deployment of LBS to the market follows a relative complex business model where, besides the mobile operators, third-parties occupy a significant place in the value chain as application designers or even service providers; in fact, the fraction of the potential LBS European market attributable to telcos in terms of value chain covering is only reported to be 5% (Eurescom, 2004)

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Table 1: Value chain for A-GPS based services.

Stakeholder	Role
Location data providers	GPS data providers. E.g. US DoD, future EU Galileo.
Cellular infrastructure and middleware providers	Providers of mobile operator point to point solutions that include infrastructure (SMLC, GMLC), positioning techniques implementation and location management software. E.g. Openwave, Trueposition, NEC or Ericsson.
User device middleware platforms suppliers	Providers of software to develop applications without coding for the system interface. E.g. Qualcomm BREW for CDMA.
Suppliers of platforms for developers	Platforms with simulators, white brand basic location services and interfaces, service creation environments or particular APIs. E.g. Autodesk.
A-GPS chips makers	Eg. Texas Instruments, SiRF, Global Locate, etc.
Handsets suppliers	Manufacturers that integrates A-GPS chips in their user devices. Eg. Kyocera, NEC, Samsung, etc.
Content providers	Content owners and makers. Eg. Google Maps, Yellow Pages.
GIS and maps providers	Eg. NavTeq, TeleAtlas, etc.
Applications providers	Markets observers that design applications and acts as integrators to deliver a final application. Eg. Bimactive, Google Maps.
Mobile operators	While acting as carriers and interface with customer, they can negotiate the terms of profit share with applications providers while maintaining customer control.

As an example, Table 1 gathers the main stakeholders of an A-GPS (assisted GPS) based location service provided by the mobile operator.

Furthermore, technologies such as Bluetooth, Wi-Fi, UWB or RFID have specific location capabilities and value chains that may include, e.g. specific hardware manufacturers (such as RFID chips providers) or Wi-Fi location engine makers (that finally commercialize complete hardware and software solutions).

This increasing complexity and variety in technologies, services and business rules makes challenging the design of a taxonomy to help to consistently foresight how these services will evolve in a middle term horizon (see, e.g. Arbanowski et al., 2004; and Karlson, 2003) towards the advanced deployment of user-centric ubiservices.

In this context, this paper intends to contribute to the understanding of the essential characteristics of the actual LBS services. A preliminary framework is described; it will ultimately allow us to classify and contextualize existing and new applications.

In the following section (Section 2), we review the current situation of commercial or pre-commercial location based services, classifying them into a number of categories. Section 3 states the factors which can be considered in a model to describe the main features of LBS, essentially those considered in terms of user experience, technological aspects and business structure. In Section 4, the model is used to evaluate a number of current commercial LBS. Section 5 concludes with some open issues to be considered.

2 A CLASSIFICATION OF COMMERCIAL MOBILE LOCATION SERVICES

In the last years, a number of authors have proposed different schemes to categorize mobile location services. Among them, Giaglis et al. (2003) identify six types of mobile location services (emergency, navigation, information, advertising, tracking and billing). D'Roza and Bilchev (2003) recognize five areas of application (communication, fleet management, routing, safety and security and entertainment) and Steinfield (2004) also includes mobile office applications or proximity information services.

Our classification is made from the analysis of the commercial current situation of mobile location services; to a certain extent it re-elaborates previous taxonomies in order to add particular services that are being commercialized or in a pre-commercial state. We mainly aim at identifying "horizontal functionalities" (not areas), services' functional features that can be customized and combined to profile complex applications or suitable proposals for niche or particular market segments.

The obtained categories are explained below together with some inspiring examples in the state-of-the-art of commercial LBS:

- *Navigation*. The goal of these services is helping in the process of route discovery and providing guidance in the way to a given destination. Maybe being the most popular application, thanks to car navigators, navigation service is also offered by the mobile operators, mostly to those users with a

GPS enabled phone. For example, KDDI pioneered the mobile phone service launching in 2003 EZ Navi Walk, a full-scale navigation service for pedestrians.

- *Tracking.* Tracking applications are based on tracing a person, pet, vehicle or specific tagged asset. Two examples of tracking applications, supported on different technologies, are a system for sport practice monitoring that tracks the sportsman to obtain data of performance (commercialized by Bimactive for GPS enabled phones) or the WiFi solution to track miners when working (from Ekahau).

- *Group management.* In this category, where resource finding and tracking functionalities are evidently needed, we include all those applications conceived to locate a collection of distributed nodes (workforce, assets, vehicles…) in order to manage them efficiently. Although most commercial applications provided or not by mobile operators, use GPS to locate, indoor services are coming to be implemented with technologies such as UWB or WiFi. An example of the latter group of solutions is an application to track patients, staff and critical assets in hospitals, provided by Aeroscout.

- *Finder.* The purpose of the finder service is to locate oneself, another person, place or tagged object. There are many solutions provided through cellular networks (e.g. TeensArriveAlive, an A-GPS based finder provided by Nextel) or using WiFi (school children in Yokohama City may use a Wi-Fi based system to be located in their way home, by NTTDoCoMo). People finders are to be one of the most successfully accepted LBS applications.

- *Location based content delivery.* We refer in this point to those services that provide some kind of content, based on the user's location:

a) Directory search. When a service or information is looked up following a real time user request, we consider that a search in directory is being done. For example, most mobile operators offer the possibility of consulting nearby facilities (restaurants, gas stations, pharmacies, etc.). Other companies, such as Geovector or iST iPOINTER use GPS and digital compass information to make the user receiving information only by pointing towards the object or the place they want to have information.

b) Push based delivery. Opposite to directory search, location aware contents can also be delivered through raw push, programmed delivery or subscription formulas, depending on the application and/or business model. The best known application is probably location based advertising, which delivers ads or coupons to potential customers positioned in a particular place, under request or pushing them into the phone (e.g., Peekablue, Kameleon or FutureLink are bluetooth systems focused on location based m-marketing). Anyway, many other applications (such as location aware self-made reminders) are possible.

- *Geotagged content making.* New business models can be focused on profiting from managing location aware content authored by the users themselves. For example, updating a mobile blog (mblog) is a widely offered service (e.g. Orange Blog or i-shot service by NTT DoCoMo) that can be improved with geotagged content (e.g. Geotagged photos can be sent to popular websites such as *Flickr,* to share and publish them), and niche applications (e.g., a mobile tourist guide in a wiki format enhanced through geotagged content sent by its users) are also feasible.

- *Social networking.* LBS are beginning to support the mobile concept of community that so successfully has spread in Internet. Wireless social networking services can schedule appointments based on proximity, interest matching and availability. They allow content sharing, finding friends and communication. Some recent examples of incipient initiatives in mobile social software are Pantopic or Mobiluck (both using Bluetooth) and others such as Dodgeball (bought by Google in 2005) or AreYouHere (on cellular). In a certain way, multi-user games can be also considered as part of this group of applications (i.e. Mogi-Mogi from Newt Games is a successful location and presence pervasive game).

- *Location enhanced communications.* Extended ways of interacting among individuals are possible by adding location aware capabilities to common services as instant messaging or push-to-talk. For instance, Clarity Communications commercializes Where2Talk, a location-enabled Push-To-Talk (LEPTT) application.

- *Location based billing*. Different charging systems may be created depending on user's location. E.g. O2 has been offering a 'home zone' plan, which allows calling with fixed-line tariffs when in an area of about 500 meters around home.

- *Proximity applications activation*. In this group we consider applications enabled by Near Field Communications or RFID technologies (that can be embedded in mobile devices) or 2D matrix codes (e.g. QR or Datamatrix codes); both approaches make possible proximity services activation. Some applications based on this concept are being currently commercialized in Japan. For example NTTDoCoMo provides, by waving a phone with a

NFC Sony card near a tag reader, commercial information and discount coupons (ToruCa service) or purchasing from a machine (M2M vending applications).

In most cases, the horizontal services above are adapted and combined to offer ad-hoc solutions in niche areas such as logistics (fleet management or asset tracking), business (workforce communications and adapted social networks), transportation (vehicle navigation, traffic information and law enforcement), tourism and travelling (ubiguides, tourist social networks), leisure (pervasive games, nearby entertainments, friend finder, dating networks), emergencies and disaster management (emergency positioning, roadside emergency, fire fighting applications), U-commerce (M2M and U-advertising) or security (children and senior finders and trackers, animal finder, theft vehicles finder).

Among all these services, there are divergences about which of them will be real market demand pullers, but some analysts bet for navigation (Berg Insight, 2006), family trackers (inCode Wireless, 2005) and location aware billing. Apart from those, multimedia downloads (music, audio and video) with location related reproduction rights, information in mass entertainment shows (live statistics or sport replays) or pervasive games seem to be other valuable proposals for final users (McMahon, 2006).

3 TOWARDS A MODEL TO CHARACTERIZE MLS

As noticed in the previous section, conceptualizing a complete taxonomy to support the analysis of mobile location services' features is a difficult task due to the variety and complexity of the applications. In order to elucidate which the relevant features to describe mobile location services are, technical requirements have been usually (and correctly) considered. For example, Giaglis et al. (2003) describe LBS mainly in view of technological factors (accuracy needs, application environment and facilitating technologies) although also point at taking into account pricing schemes. Stein et al. (2005) applies Giaglis' taxonomy to ubiquitous commerce for tourism, choosing a number of tourism applications and classifying them regarding their access technology, location technology, information access and whether there is an online component. On the other hand, Tsalgatidou et al. (2003) remark the particular requirements of mobile location services in terms of functionality, usability, reliability, privacy, location infrastructure and interoperability.

Capitalizing on the categorization of services made in Section 2, we propose to identify similarities and differential features among mobile location services not only from a necessary technological perspective, but in a framework to understand LBS business and to evaluate new services.

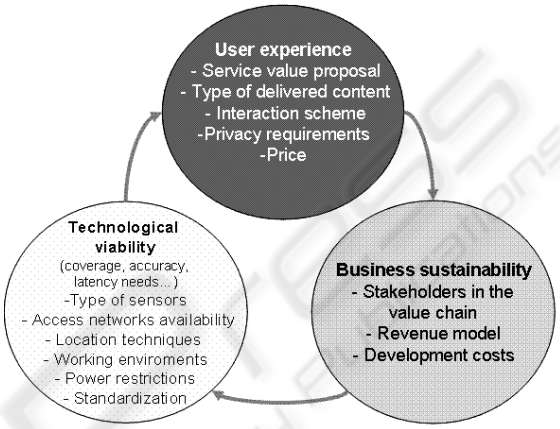

Figure 1: Towards a model to evaluate location based services.

Then, we propose an analysis model for mobile location services based on three pillars a) user experience, b) technological viability and c) business sustainability, to describe the user perception of value and to consider, at the same time, technological needs fulfilment and business aspects (Figure 1).

The user experience

There are different factors that may be considered to describe how the user feels when using a service:

- *The perceived service value proposal.* The killer LBS has not been found yet (McMahon, 2006); in general services such as navigation or children finders are being accepted, how to increase their use is the next challenge. In order to describe the value proposal, we will use the classification in Section 2, as it is possible to frame most current location services regarding their main features; as stated before, many services are a combination of "primary" features that can be particularized for particular areas.

- *The type of delivered content.* Text, voice, multimedia (maps, graphs, photographs, videos, etc.) compose mobile location delivered content. The need for contents usually describes the service complexity, they have to be combined and adapted

for the capabilities of small and very diverse mobile devices (with different hardware and software performance) and to the access network possible restrictions.

- *The service interaction scheme.* A friend-finder service can need six clicks and one minute for the client to get the response. To provide an enhanced user experience, minimizing and making easier the user interaction and fulfilling user's expectations in terms of performance is a must. That is why aspects such as 1) the easiness of download, installation or setting-up processes, 2) the implementation of direct service triggering methods or 3) the usability and adequacy of interaction mechanisms are relevant. For example, when considering the service trigger, LBS can be provided on demand (pull) or spontaneously (push). On the other hand, as in other mobile services, multimodality -the combination of different physical interaction methods (voice, keyboard, movement or pointing…) in the same device and for the same application- are needed. The system reaction to the user's demand can be configured e.g. using voice, SMS/MMS, USSD codes or direct data downloads.

- *Privacy requirements*. Privacy issues (Gratton, 2002) regarding LBS are related to the collection, storing and exchange of historical location data gathered in databases, to the misuse of real time positioning data (e.g. sending unsolicited information may convert mobile devices in spam receivers) or to the user losing control of the location process (EU regulations offer some protection through Directives 95/46/EC and 2002/58/EC, but technical and legal aspects have slightly advanced) (Ackerman, 2003). Obviously, privacy is a crucial issue for LBS (it continues being a major roadblock towards their adoption): for example operators try to mitigate adverse feelings through mechanisms of usable privacy-level options and appealing to their experience in gathering relevant data and managing sensitive information. Anyway, privacy requirements vary from service to service; in fact, being less controversial, operators' application portfolio is frequently focused on business services. Privacy enhancing technologies (such as policy management and pseudonym use, camouflage methods -temporal or spatial cloaking or mix zones) are a complement for well built legal and social frameworks (Fritsch, 2005).

Apart from the stated issues, many other aspects can also describe the user opinion towards a service. Among them, balance between offered value and cost is critical in most of cases.

Technological viability

In brief, technical issues are about satisfying service coverage, accuracy or latency requirements with appropriate location techniques while dealing with network restrictions. Hightower and Borriello (2001) give a wide explanation of the performance characteristics of different location systems. To face the services' description we will evaluate:

- *The technological enablers.* GPS and GPRS, Wi-Fi, Bluetooth and UMTS, NFC... There are multiple technologies that can be combined to provide mobile location services, to enhance location process and to balance the network load. In a future, efficient network heterogeneity management will use data fusion (profiting from data from different sensors) to obtain high accuracy and seamless location capabilities.

- *The location technique.* For a review on location techniques consult for example Raja et al. (2005), Laitinen et al. (2001) or Sun et al. (2005). In summary, location techniques are based on cell identification, angle of arrival (AOA), triangulation based on received signal strength or on time methods (time of arrival and differences of times of arrival) and GPS (usually network or terminal assisted). In cellular networks, A-GPS and Cell-ID are the preferred techniques. Positioning with Wi-Fi is normally accomplished using the received signal strength. For Near Field Communications technologies, proximity (cm) detection triggers the service.

- *The required accuracy.* Evidently, not all the applications have the same accuracy requirements. Accuracy is an attribute directly linked to the technological enablers and location techniques. For example, Cell-ID, the simplest technique available in cellular networks, provides from a few hundred meters of accuracy to several kilometres for GSM. Its enhanced version (with timing advance) achieves 500 m., AOA gets 100-200 m., while the accuracy with E-OTD ranges between 50 and 200 m. A-GPS can achieve 10-50 m. outdoors, but complements for indoor coverage are usually needed. On the other hand, positioning systems based in Wi-Fi have an accuracy of some meters.

Business sustainability

The considered business aspects are related to the value chain composition and the revenue models.

As explained in the introduction (Table 1), the stakeholders in the value chain are highly dependent on technological issues and on the complexity of the necessary contents needed to implement the service.

Usually, the common LBS complex value chains ends in complex revenue models. For example, some children trackers are currently commercialized through a subscription scheme that includes the

access to the service and a fixed number of location requests. Then, each additional request surpassing the included number is also charged. On the other hand, some commercial mobile guides have a revenue scheme composed by a fixed subscription cost to the service (usually paid once) combined with a two or three day flat rate of use. This flat rate does not always include data traffic.

In consequence, it is possible to identify very different charging options: subscription, time of connection (GSM networks), downloaded data (2,5G-3G) costs, premium SMS or MMS pay, application hosting, developers' membership fees and advertising. These alternatives may be combined depending on the service and the value chain composition.

4 AN APPLIED ANALYSIS OF REPRESENTATIVE LBS

In summary, Table 2 at the end of the paper partially illustrates the use of the model for ten commercially available services mentioned in Section 2. From its analysis, we can state the diversity both for technological and business approaches for commercial mobile location services.

Mobile operators come to be key players: cellular technologies together with GPS enable many of the currently available LBS. Due to the high penetration of cellular devices, many application providers usually develop and offer their services by partnering and sharing revenues with mobile operators. Anyway, independent service providers are common in navigation systems and in new Wi-Fi or Bluetooth based LBS.

From the user point of view, pull or authorized push content provision is the most adopted scheme possibly due to privacy concerns.

Regarding technological aspects, we can say that if the statement that a more accurate positioning will enable the deployment of more useful applications is probably true, there is a bundle of applications not requiring accuracy in the range of the centimetre. Of course, extended precise seamless systems able to provide high precision indoors and outdoors (through triangulation mechanisms but also through proximity activation) will enable new services and enhance existing ones.

On the other hand, value chain analysis shows the great amount of partners involved in the development and deployment of location based services: content and GIS makers, hardware providers, operators, software integrators, etc.

On the other hand, fragmented distribution channels can be one of the reasons for non-homogeneous pricing schemes for the final user and sophisticated revenue models among the different stakeholders composing the value chain.

5 CONCLUSIONS

At the beginning of the decade, some factors made hard the take-off of LBS: immature positioning technologies, expensive handsets, short lasting batteries, lack of consumer interest and awareness beyond voice and basic data applications, no catchy services or no standards for developers. After being in the market for some years now, location based services seem to have achieved commercial success in certain niche applications, but they have not been widely accepted yet. Nowadays, location is the engine of a well delimited group of services in which, for the time being, navigation and tracking applications are kings for both customers and business market shares. Nevertheless, a good heap of innovative services are appearing and gaining in interest thanks to the massive deployment of wireless networks based on 802.11 and the consolidation of other technologies such as RFID. Moreover, the transfer and adaptation of services that have succeeded in the Internet (social networks, blogs, etc.) are beginning to be adapted to mobile environments.

In this paper we have proposed a preliminary feature-based model to cope with current mobile location services diversity and to help to prospect their future evolution. The model is basically articulated to evaluate the user experience while considering technological and business issues, and has been partially applied to the analysis of ten currently available location based services.

New positioning technologies with low power consumption, network interoperability standardization, advances in ad-hoc networks that will allow fully decentralized wireless communications and combined location methods (data fusion) are being studied to guarantee seamless positioning indoors and outdoors. On the other hand, the evolution toward solid business models continues; the success of LBS might probably be more attached to profitable business models than to any other factor.

Location based services are only paving the way towards the deployment of context-aware user-centric ubiservices on heterogeneous all-IP networks. These services, based on personalization,

ambient awareness and adaptability will be handle personal descriptors (identity and profile), status parameters (physiological or ambient information – temperature, air quality, light, noise level, etc.), temporal data (date, season, schedule, agenda, etc.), positioning information or relational (social) records altogether. So they will surely manage location data as a commodity context descriptor, but will go further beyond it.

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Table 2: Characterizing some currently deployed location based services. (Brands in brackets represent providers of a particular application exemplifying the niche service).

Niche service	**Functionality** **Example serv.**	**Partners in the value chain**	**Tech. enablers**	**Location technique**	**Accuracy**	**Delivered content**	**User interaction**	**Pricing scheme**
GPS-GPRS personal navigation system	Navigation eg.Wayfinder	- GPS positioning data provider. - GPS handsets provider. - GIS provider (Tele Atlas). - Navigation applications provider (Wayfinder). - Mobile operator.	GPS GPRS	GPS	5 – 50m outdoors	*What:* Maps and voice routes. *How:* Data download.	On demand (pull service)	*App. Provider/ Op.* :Monthly fee that includes application download and route calculation GPRS traffic
Sport monitoring application	Tracking eg. BiMActive	- GPS positioning data provider. - GPS handsets provider (Samsung, LG, Motorola). - GIS provider. - Application provider (Bones in Motion). - Mobile operator (Sprint Nextel, Verizon Wireless).	GPS GPRS	A-GPS	5-50 m outdoors	*What:* Maps, graphs. *How:* On the mobile, through data transfer. On the web, after uploading the received content.	On demand	*App. provider*: Monthly fee. *Operator*: Unlimited data plan (flat rate subscription).
Assets management in hospital	Group management eg.Aeroscout	- Infrastructure provider (Cisco). - Wi-Fi device provider. - Location engine provider (Aeroscout). - Integrator (GTSI).	Wi-Fi	RSS-TDOA	3-4 m indoors	*What:* Custom maps. How: data on the mobile and on the web. SMS alerts.	Authorized	*Location Engine Prov./Integrator:* Cost of infrastructure and system integration
Children finder	Finder eg. Teen Arrive Alive	- GPS positioning data provider. - Handset compatible provider (Motorola). - GIS provider. - Application provider (Teen Arrive Alive). - Mobile operator (Nextel).	GPS WCDMA	GPS and Cell-ID	5-50 m (GPS), 200 m-several km (Cell-ID)	*What:* Location information (on maps) *How:* Mobile data query, voice consult and Internet.	Authorized. Possibility of disabling the service.	*App. Prov.*:One time activation fee plus a monthly fee. *Operator*: unlimited data plan (flat rate subscription).
Nearby facilities information	Directory search eg. I-Area	- Content providers. - Handset providers. - Platform provider (eg. Ericsson). - Mobile operator.	GSM/GPRS/ UMTS	Cell-ID or E Cell-ID	200 m – several km	*What:* Maps, facilities information. *How*: On the phone, SMS, MMS, voice, data.	On demand	*Operator:* Pay per use
Bluetooth location based advertising	Alerts eg Kamaleon	- Content provider. - Hardware providers (Bluetooth points and handsets). - Application provider (Kameleon). - Mobile operator.	Bluetooth and GPRS/3G	Bluetooth AP coverage (~cell-id)	10 m.	*What*: Multimedia, text. *How:* Data download.	On demand / authorized push	*App. Provider:* Application downloading cost. Transferred data cost.
Mobile community	Social networking eg. Mobiluck	- Handset compatible provider (Nokia). - Application provider (Mobiluck).	Bluetooth	Bluetooth handset coverage.	meters	*What-how:* SMS and phone calls.	On demand	Free
Ubiquitous agenda	Geotagged content makin eg. Geominder	- Handset compatible providers (Symbian Series 60 Smartphones). - Application provider (Ludimate Geominder). - Mobile operator.	GSM/GPRS/ UMTS	Cell-ID	Cell size	*What:* Self-made alerts. *How:* voice and text.	Programmed	*App. Provider:* Application purchase.
Home zone tariffs	Zone based billing eg.Home Zone	- Mobile operator (O2).	GSM/GPRS/ UMTS	Cell-ID	500m	NA	Transparent	*Operator:* Fixed-line tariffs for mobile calls at home
Proximity based information delivery	M2M apps. eg. NFC boarding card	- Content provider (Japan domestic air travel groups). - Provider of handsets with specific Sony's chip (various brands for NTT DoCoMo). - Infrastructure provider (includes tag reader). - Mobile operator (NTT DoCoMo).	NFC, UMTS	Contact	cm.	*What:* Multimedia information and coupons *How:* MMS and data download.	On demand	*Operator:* Data traffic charges.