Mobile and Smart Devices in a Human Community – the Challenge of Context-aware Distributed Networking

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Abstract. This paper addresses the new and changing role of mobile devices and services in a dynamic human community, taking individual profiles and the current personal context into account. Binding and interaction are analysed in order to recognise future trends. Considering a community network as a distributed information source, filtering and matching of information tend to become a calculation intensive process. With mobile personalised assistants the way of processing information will be changed. Sample scenarios outlined in this paper show the basic function of such assistants. With the ongoing evolvement of mobile devices and first available frameworks like the Tracy Toolkit an implementation of mobile community supporting systems is possible. The process of contextualisation is defined. Finally, the paper attempts a view in requirements of community support as well as requirements for mobile devices.

1 Pervasive and Personal Communication Services

Buzzwords sell! While Europe focuses on the "social challenge" with the term *Ambient Intelligence* (AmI), America calls the same ideas of their "winner technology" *Pervasive Computing*, which is sometimes adapted to *Pervasive Communication*. Asia recollects their "emperor mentality" when creating the "Invisible Computer". Information technologies are more and more driven by social aspects. While individuals tend to be more independent from each other than ever, networks penetrate all areas of daily life. Moreover, information are taken from the internet considered to be right, just from the fact that they are there. This *network proof phenomena*: "I've seen it on the internet, it's true" leads to unexamined URL citation, even in the scientific community.

Driven by an increasing number of mobile devices using IP inter-communication, fixed network infrastructures are extended by ad-hoc networks, which are established on demand and change all the time. This is a mirror of human communities, where devices represent their users. Furthermore, a user has his/her own personalised assistant which represents him/her in the network, even if the user's device is offline. Fixed links are replaced by autonomous assistants, migrating on a big virtual network when required.

Chapter 2 describes the new role of mobile devices, while chapter 3 takes a look at how context awareness will drive the community aspect by means of mobile personalised agents. A first set of requirements for community mobility is presented, too. A compact vision of the future of contextualisation is provided in chapter 4.

2 Role of Mobile Devices

In the long term past incumbent telecommunication operators always propagated their systems. The most classic example might be the worldwide Plain Old Telephone *System* (POTS). The next era centred the services. Logically, the first complete digital communication network was called Integrated *Services* Digital Network (ISDN). With liberalisation of the telecommunication market the customer came to the fore. The Digital *Subscriber* Line (DSL) stays abreast of changes, being the starting point of all IP networks. A similar evolution holds for the devices' domain.

Looking at framework architectures, the same development leads the design. System middleware like the Common Object Request Broker Architecture (CORBA) was replaced by web services, resulting in the Service-Oriented Architecture (SOA). Today's business cases are based on subscriber bundles. We will call both effects the SSS or "triple S evolution" (S^3), which stands for *System* $\Rightarrow$ *Service* $\Rightarrow$ *Subscriber*, representing the experienced alteration. But what is next: the device, the peering or the Personal Area Networks (PAN) again?

Communication, computing and society grow together, which is reflected in the current European R&D programme [EC02]. Mobile devices bring much more dynamics into established networks, including IP migration. The following seven theses summarise our experience noticed over the resent years:

1. **Communities go mobile.** Smaller and powerful mobile devices allow increasing consumption of seamless services (e.g., mobile weblogs).
2. **Private meets business.** One mobile device with multiple functions is used for both. Private and business databases are merging (e.g., PDA).
3. **Users are ad-hoc involved.** Mobile communities imply short term memberships. The creation of content increases compared with its consumption.
4. **Personal assistants feed individual needs.** Due to a big information flood the selection of relevant content requires intelligent support (profiling, filtering)

5. **Personal data become a value.** Loss of physical device or a system crash become less important than a stolen network identity or lost configuration data.
6. **Security is taken for granted.** The belief in useful and secure configuration data is higher than the active adjustments for personal protection (defaults).
7. **Life cycles speed up.** Mobile devices are replaced in short terms and new services emerging more often, while reliability of both decreases.

2.1 Mobile Device Bindings

End user devices become smaller and portable, accompanying their owners everywhere. While in the past, communication and entertainment devices such as telephones, television sets or personal computers were shared by several persons living together (fig. 1a), universal mobile equipment (laptop, PDA or mobile phone) reflects a first step in social paradigm change towards personal devices and service consumption accessing different networks (fig. 1b). More recently, cheap service specific devices (MP3 player, game consoles, navigators) flood the market. The users' majority owns already a bundle of individual devices (fig. 1c). This enforces the trend of emerging community services to share individual experiences, using new channels of peer-to-peer-communication, while still forming a virtual service grid.

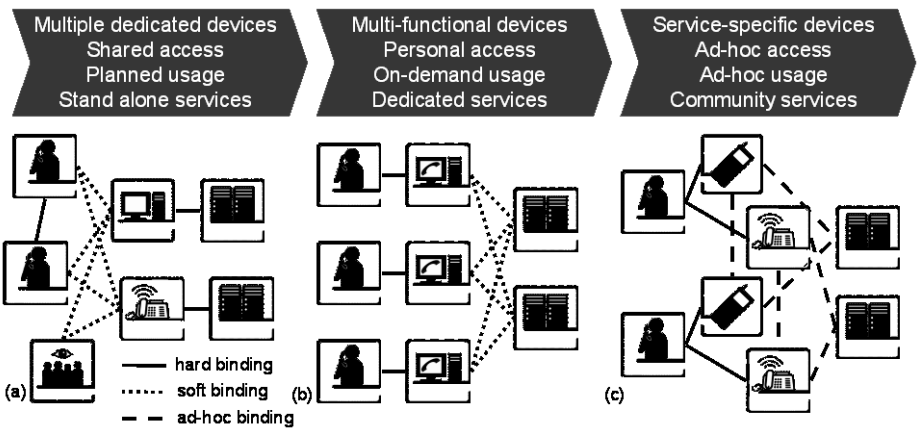

Figure 1: Changed binding of end user devices and services. (a) system binding, (b) user binding, (c) community service binding.

The initial service centered approach did change to a device centered approach, giving the user a new feeling of freedom. The big variety of possible network access technologies hinders easy-going ad-hoc peering, while quasi-standard service specific end user devices like Apple's iPod bring the idea forward.

2.2 User and Environmental Interaction

Today's mobile devices reflect dramatically the short development cycles. First priority is given to *technical features* no matter how easily they can be applied. Second attention is paid on fashionable *design trends* to sell new devices on the market. Unfortunately, *intuitive usability* ranks on very low priority for several reasons e.g., expensive and long development iteration including user group specific testing or difficult sales promotion. The life period of devices becomes even shorter and sales profit is taken from service bundle sales, not from the devices themselves.

An increasing number of features and interfaces leads to an increased power consumption and therefore decreased stand-by time. There are multiple power consuming network access opportunities e.g., GPRS/UMTS, Bluetooth, WLAN, IrDA on the one hand and many new *multi-modal user interfaces* e.g., touch screen, voice control or acceleration & orientation sensors on the other. Even the integrated camera becomes a new environmental interface using visual codes and maps for interaction [RZ05]. Nokia provides special device shells with an RFID reader. Bar code readers are available as SD cards. These are just staring points for new ways of *tag-based* Near Field Communication (NFC) which lead the users from a spamming driven *push* mentality to becoming active by invocation of simple *pull* actions.

2.3 Mobile Community Services

With mobility users become more active. Pure entertainment moves to edutainment [MO05]. Mobile diaries are written, content is created and will be shared within a next step. Social networking as known from the web office application openBC [BC06] will develop to a new level. But currently, the focus is still on the new mobile features.

A survey among 60 users of smart mobile devices, aged from 20 till 60, indicated that still information services are seen as most potential. Surprisingly, there were no significant variations in the results of different target groups divided by age, gender or profession. Within a scale of 1 (low relevance) to 5 (high relevance) travel & leisure information gets a 3.7 closely followed by consumption services, covering personalized advertisement, shopping and product information with a 3.5. Mobile gaming, which has definitely the closest community relation of the evaluated service offers, gets with 2.9 the lowest overall result, because of missing personal interest. In general, private usage of mobile services seems to be more relevant than basic business services, like electronic business card exchange.

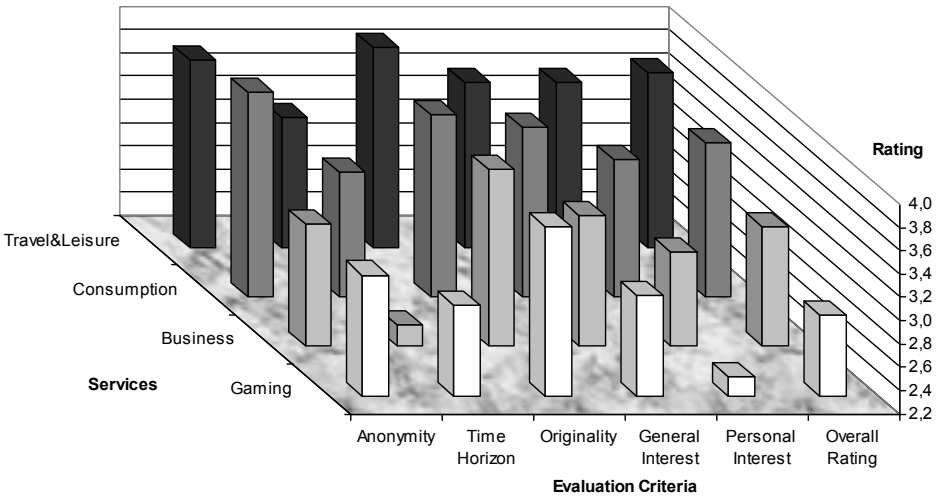

Figure 2: Survey on the acceptance of mobile service domains: travel & leisure, consumption, business and gaming among 60 users of mixed target groups (Nov. 2004 by T-Systems).

A more detailed impression about the survey results on special criteria, i.e. role of user's anonymity, expected time horizon, originality of the idea and general as well as personal interest is given in fig.2. The overall rating is calculated as a balanced average of these five criteria.

2.4 Sample Basic Services

Community applications rely on a set of extensible basic services. Except standard communication services e.g., mail/SMS, phone/video conferencing and application sharing, these are typically services, which help to establish meaningful ad-hoc relationships. Therefore, the current *location* [EB05] and personal *profile* [EW06] are the main sources – more general the *context*.

The *resource finder* assumes that a service provider has a database, where each object (point of interest) is associated with an offering profile. In that setting, the user is able to retrieve an ordered list of interesting resources, ranked by personal relevance, filtered against the user's profile based preferences.

The *contact builder* assumes that each user of the system has an associated pair of profiles (search and offer), describing relevant issues that are weighted positively or negatively. Similar to the resource finder, it is not only possible to find persons, who match a given search profile as opposed to one's own offer profile, but also to look for potentially interesting users by starting with a list of friends and finding out related persons filtered against one's own preferences.

The *annotation service* uses information tags e.g., points at which new content (text, voice message, photo) is instantly created and exchanged between mobile devices and resources. For instance, a discussion forum about a specific location may be directly associated with a hot spot in the vicinity, or a new product may have an information tag where it is possible to leave a rating for the manufacturer or community members.

When considering new ways of communication, such as weblogs or podcasts, this may alter the way of future human-to-human and group communication in an ad-hoc and asynchrony manner.

3 Context Awareness and Communities

The community idea can profit from and be extended by context aware systems. Personalisation as one instrument for context awareness is used to find partners in a community which have similar interests or helps to create value-added community features. The supporting effect of software (and devices) for a user will be improved: the user gets its personal assistant. Furthermore, the complexity of distributed software systems can be reduced if self-organising aspects are taken into account by realising community systems.

3.1 Classification of Context

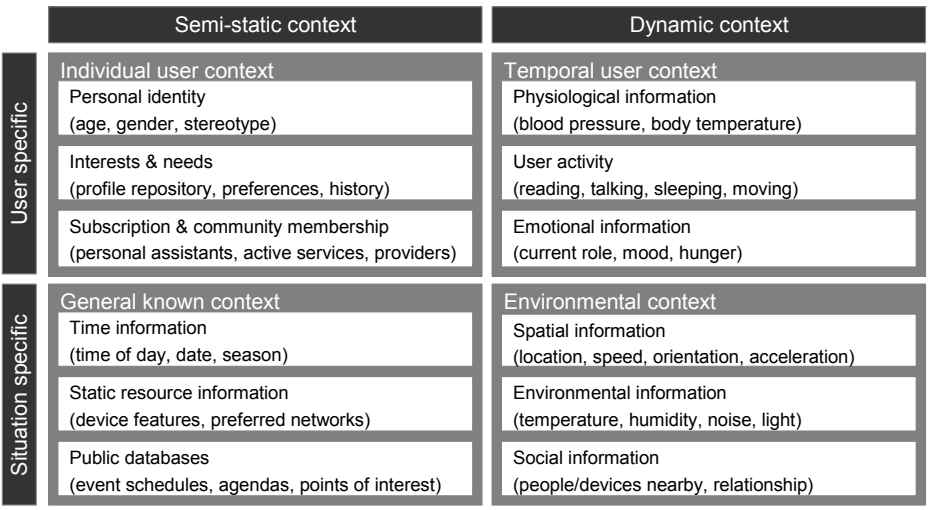

Figure 3: A context classification matrix.

An *event* is defined as a threshold driven change of one or more context elements. The meaning of an event depends always on the surrounding circumstances – the context.

So, one could just ignore an event if it is of no importance in the current situation. In another context the same event would be highly relevant. A challenge of developing context-aware software is to rate the relevance of an event in a given context. First of all, the context needs to be perceived by software. Therefore, the term context has to be defined more precisely.

In [DA99] an explanation can be found in which a context is defined as a set of information that can be used to characterise the current situation. There are also approaches to classify types of contexts [SAW94], [CK00] like computing context, time, user, physical, and history context. Following such approaches a user-centred classification of information is done as shown in fig. 3. The two dimensions show a classification of the context information: horizontally – user specific and situation specific information; vertically – separation of information about context in (semi-)static and dynamic parts.

3.2 Personalisation and Awareness

With *personalisation* the quantity of perceived context information is potentially high. Often only a small subset is of relevance. Through personalisation, information is filtered and individual information's relevance can be weighted according to users' interests and preferences. The process of filtering is tightly connected to matching. For an optimal matching, information are annotated with semantic information or classified in a domain-specific ontology. Languages like the Web Service Modelling Ontology (WSMO), the Resource Description Framework (RDF) or the Web Ontology Language (OWL) can be applied.

For communities personalised information is relevant to get involved. For instance, if one is seeking its surrounding area for people whose interests are common, everybody has to share this piece of information. This leads to the concept to divide personalised information into public and private data. It also makes sense to publish public data actively. The publishing process uses mobile software assistants which are able to migrate from a user's device to a set of reachable devices in its vicinity in a round trip manner. Users will be notified if matching interests are found by the mobile assistant. Therefore, such an assistant needs environmental information like location, orientation, acceleration etc. to be context-aware as well. Looking at fig. 3, information on subscription and community membership are relevant for personalisation of a mobile assistant (user specific, semi-static context).

3.3 Context Discovering Assistants

A user joins a service grid – a community network with services and resources – by just enabling the mobile device or by moving into a certain service grid area. The user wants to get involved by sharing data or services. After joining the network the following two steps will be passed:

1. Other (community) members, respectively their devices, get notified about this new participant and its contribution to the service grid.
2. The new user will receive information on the current situation within the community – its context.

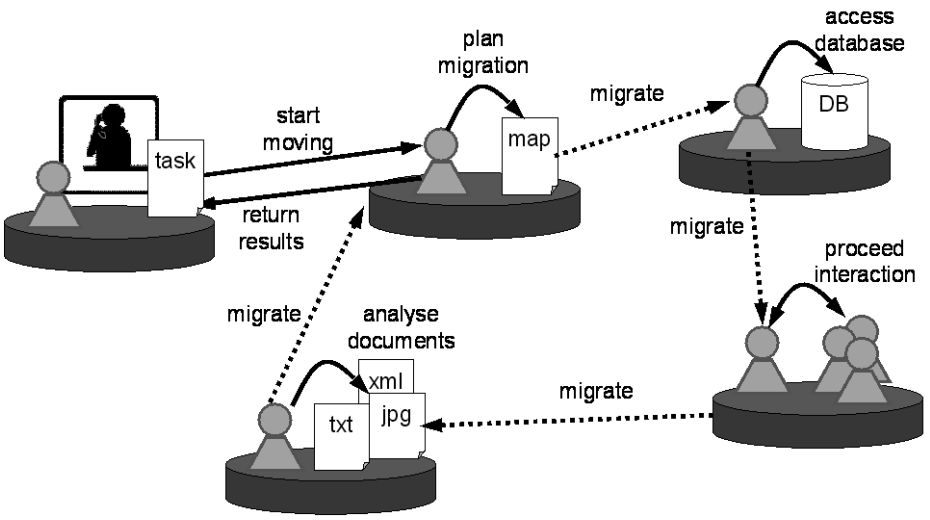

Figure 4: Information seeking personalised assistant.

Now the community has grown. But there are some open questions. In detail:

- Where are interesting services, shared data and other public resources in the community collected and stored?
- What information is passed to an entering user?
- Where does the filtering and matching process happen?

Especially, the last question is interesting in the case, where the user's device is limited within its resources (transmission, storage and computational power) like PDAs or smart phones. Depending on the size of the community the *quantity of information* might be quite high. In worst case a complete transmission of available resources in the community network (step 2 from above) would exceed the device's abilities or the operation duration to parse and filter data would frustrate the user.

A community network can be seen as a distributed information source. Various resources are distributed across the network. Whereby, the content of the information source is changing continuously. For a small community size, say a dozen ad-hoc connected users, it is not worth to create a central instance containing all information of this community. More efficient is the usage of *mobile agents* [BR05] or *assistants* which are seeking for information by *migration* as indicated in fig. 4. An adaptation of that simple scenario "joining a service grid" would be as following: The user's personalised assistant:

1. leaves his/her device and
2. visits all community members (migration),
3. informs them on the new user's contribution,
4. filters obtained information at its origin and
5. returns to its owner with the matching portion of relevant information.

Calculation costs are distributed and in case of a high filtering rate network traffic is reduced too. Updates could be propagated using mobile assistants. Further value-added features are imaginable: Mobile personalised assistants make appointments for their owners or negotiate the exchange of resources. In case of larger communities, a creation of a map with context information, showing the local region (vicinity) around members, will be a suitable solution [Er04], assuming information are fairly stable. Only rough information is stored at the map on far away areas. The maps are built up for orientation purposes: a mobile assistant will use them to gather information on places which are worth looking at by migration.

As an example, a mobile assistant is used to gather information on wines at different online wine stores. The assistant is personalised regarding my preferences on taste, year of harvest, price, etc. In the vicinity of the assistant, at the local map, there are places which have information on wines respectively, which provide a service to gather information on wines. Services are classified at the map by means of ontologies. At the map there is also information on remote services. So the assistant is able to localise promising remote services e.g., beverage shops. Due to reduced information on remote services at the local map the assistant is not able to estimate whether the service could be helpful or not. The assistant has to migrate to these targets.

3.4 Community Scenario Campus.NET

At Friedrich-Schiller-University Jena the research project MobiSoft [MS06] explores the usage of personalised assistants on mobile devices. The publicly funded joint project between two local companies, the GODYO AG (http://www.godyo.de/) and the start-up company 'the agent factory GmbH' (http://www.the-agent-factory.de/), and the university is seeking for future application scenarios and realises necessary improvements of existing technologies for usage of mobile devices. The technical realisation of such a mobile personalised assistant is based upon mobile agent technology. The *Tracy Toolkit* [Tr06] is a result of the university's research activities which has reached product status by 'the agent factory'. This toolkit implemented in Java has a lightweight kernel with minimal basic functions to make it useable on small devices. Additional features are available via plug-ins, as pictured in fig. 5.

A sample scenario called Campus.NET – a community network at the campus – will be prototypically realised as one selected MobiSoft scenario to get a realistic feedback of the technology's abilities and user's acceptance. Various university-related content and services will be accessible with a personalised assistant from a mobile device e.g.,

lesson index and news, library services, information on departments. As an example my personalised assistant could notify me when my favourite meal is available in one of the student canteens. Of course, my assistant knows my courses and can observe them. If new course material is available, my assistant comes back to me with these documents in its luggage. Furthermore, my lecturer can push new information actively by sending his assistant to the students of the course.

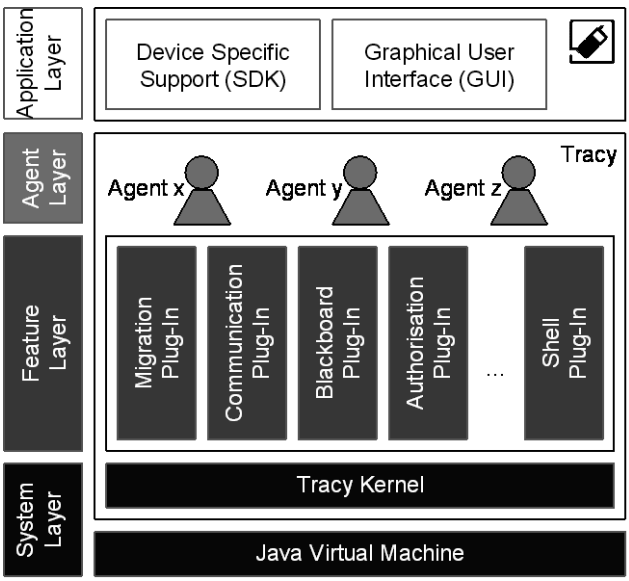

Figure 5: Tracy Toolkit - architectural overview of a typical device implementation.

Exchanges between mobile users are in focus: a bill-board with flat share offers, ride offers, games, learning groups, etc. is planned. But also direct interaction between community users will be implemented. A user can send out its assistant to find friends (contact builder function) or documents (resource finder function) within its surrounding area. NFC over Bluetooth will be possible to make appointments or hand over documents. In such community scenarios social aspects come to the fore, especially when someone could profit from modifying the system software. To counteract such tendencies an evidence based system as proposed by [Ob06] could be used to improve acceptance of the system.

In general mobile agents seem to be a promising concept to support communities. Especially when information or data is distributed over multiple sources, mobile agents can be used to analyse these sources for statistic purposes. For doctors such statistic agents could assist to confirm a diagnose or to investigate a disease: Agents could visit distributed information sources of different hospitals to access and analyse reports or X-ray photographs. It is not necessary to carry away the data itself and even store relations to persons. Extending this scenario, agents could be used to seek and involve experts for a detailed dispute.

3.5 Requirements for Community Mobility

Recent evolutions of mobile devices and device's connectivity allow communities to go mobile. With a tight delay new features are used to implement enhanced value added services. Community members are able to benefit from new, (hopefully) easier to use devices and services. Requirements for mobile communities can be derived in consideration of this evolution (table 1). Especially, the process of contextualisation requires new communication interfaces with the surrounding equipment.

Service Requirements	Hard and Software Requirements
▪ Context-awareness – presence and reachability services ▪ Contact filters for instant group join – short term membership – "social" verification and role support ▪ Appliance of – "contextualisation" – "personalisation" – "communitisation"	▪ Multiple tag receivers – visual codes, RFID, Bluetooth, … ▪ Movement and physical sensors – acceleration, orientation, temperature … ▪ Ad-hoc online/community access ▪ Programming support – communication JSRs ▪ "smart" devices with long uptime ▪ Mobile web performance (Web 2.0)

Table 1: Requirements for mobile community services and devices.

This list of requirements is for sure not a complete one. But from these requirements further work can be derived yet: development of context ontologies, of portable and exchangeable personal profiles, integration of location based services, utilization of new technology approaches (e.g. mobile assistants, self-organising middleware), etc. In addition for a wider acceptance, NFC and the support of various sensors for mobile devices have to be improved as well as the establishment of accepted standards for software development in this area.

4 Next Steps regarding Contextualisation

Many pieces, which will be part of new Context-Aware Services (CAS) are already in place. However, an entire framework for mobile, context aware, distributed services is still missing. [SFB06] proposes context modelling methods, while [DA06] focuses on a modular architecture for mobile personal services.

Multiple steps create a value added process chain to provide users with the right actions in the right place at the right time. Initial trigger events have many faces. Any changing contextual part could be the initiator. Personal assistants will help to unify this diversity. Community requirements are still an open issue. Fig. 6 illustrates the process of *contextualisation*.

The availability of freely accessible, rich up-to-date data bases (critical mass) seems to be an important success factor. This raises the question of ownership of context data.

A clear separation of privacy and non-privacy data is required by law. Certified gateways will act as a mediator focusing on *pseudonymisation* [BLR04].

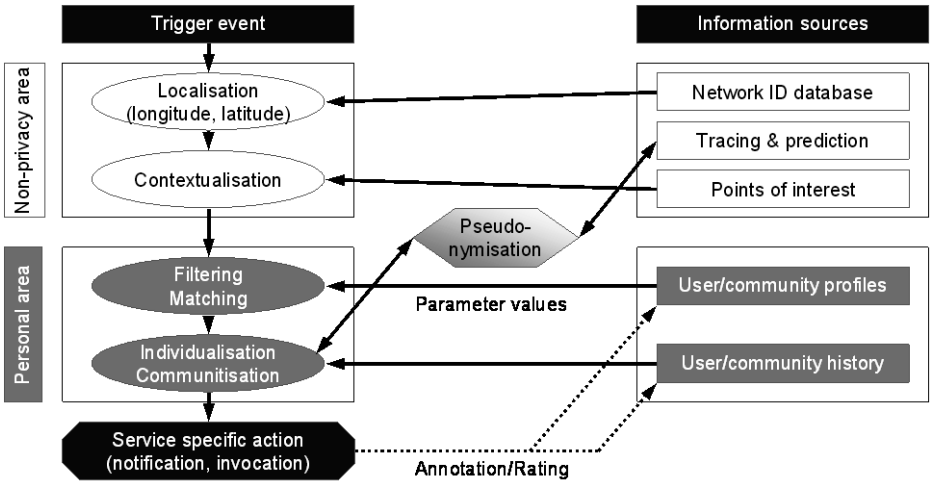

Figure 6: Event triggered recombination of information sources in public and private context using open and protected sources.

Furthermore, security and usability issues in combination with new mobile devices are a big challenge to develop reasonable business models. The mixed processing of public and private data requires several protection levels. So the S^3 evolution will experience a further development onto S^4, becoming an integrated *solution*.

Recent years have shown that device's abilities are getting more comprehensive, but especially, mobile platforms are still different from standard PCs. There are various OS-variants even for a single device. Due to this heterogeneity and restrictions, systems like the Tracy Toolkit need to be adapted and ported. Some features of the toolkit are not yet available for mobile devices. In some cases it is hard to access communication interfaces from Java-side e.g. for Bluetooth a special JSR is necessary. The development process of the Tracy Toolkit will focus on adaptation and porting of features as well as on new features.

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