Service Management Platform for Personal Networks

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***Abstract*— In this paper we propose a service management architecture for Personal Networks. Considering the structure and architecture of personal networks, current existing service discovery and provision protocols does not fulfil the personal network system requirements, therefore the architecture is proposed for resource and service discovery and the prospective service management in such networks.**

***Index Terms*— Service Management, Service Platform, Resource and service Discovery, Personal Area Networks, Personal Networks**

I. Introduction

PERSONAL networks are defined as a set of devices, resources and services, having a personal relationship with the user. These networks are formed around the user, by establishment of a Personal Area Network (PAN), but not limited to the user proximity. The Personal Network (PN) includes all the individual networks formed in all the places which user has interests, such as home, car, office, shopping mall, etc. and can own a network, a single device, a number of services or some resources to use. The IST project MAGNET [1] investigates the formation of personal networks, including PAN formation, interconnectivity with the infrastructure, forming PN and how the user benefits from the personal network to take advantage of the services provided in the network. Fig. 1 illustrates the concept of personal networks.

Personal network is formed by participation of several components [2]. One of the most important concepts in the definition of PNs is **trust relationship,** which technically defines the concept of ownership used in Personal networks.

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Ownership of a device is established by means of a **long term trust** relationship, between all the personal devices. A **personal** entity maintains this relation with other devices/nodes in the personal network. Other entities are categorised as **foreign,** which may establish a **short term trust** with personal entities. A **P-PAN** (Private PAN) is a group of *personal devices* forming a *PAN*. P-PAN itself might use different radio technologies, such as Bluetooth, WLAN, etc.; each of them is used to form smaller PAN constructing networks called **radio domains.** The set of P-PAN and foreign nodes, which are connected to each other on an ad hoc basis, is defined as **PAN**.

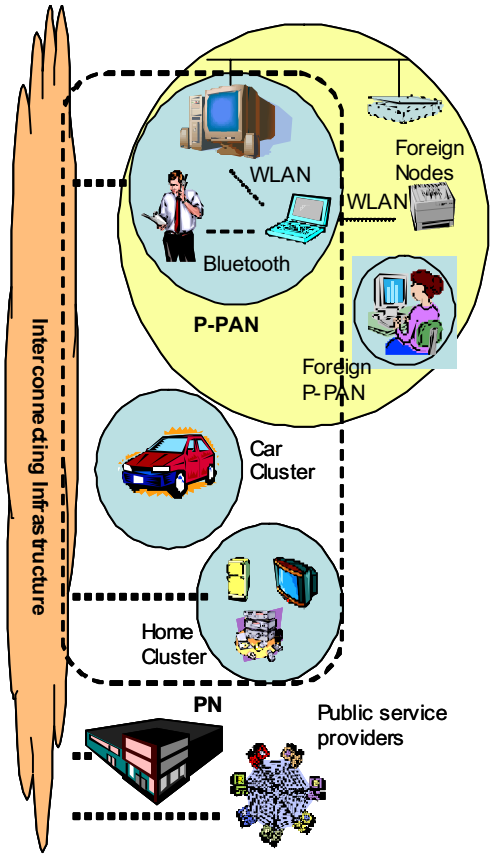

Fig. 1. Personal Network Concept

Every set of *personal devices* at home, car, office, etc. can participate in a local network, called **cluster.** The clusters and the P-PAN, can communicate with each other by means of some foreign networks and interconnecting infrastructure and form a bigger network called **PN (Personal Network).**

Resources in personal networks are the entities being used

directly by the user, network, service or application. CPU, memory, battery power, link capacity, etc. are examples of resources. **Services** include those provided by the devices, e.g. print, display, etc. or the public services such as web services. The main purpose of formation of the personal networks is a proper and secure way of service provision to the users from a personal and private perspective. The availability of resources and services strongly depends on the formation of the underlying network, i.e. personal network. Because of the dynamicity and heterogeneity of the personal networks, services and resources are not offered on a permanent and stationary basis. Additionally the high level and ambiguous demands of the users, security and privacy requirements, context awareness and limitations on resources imply the need for a service management system, to overcome the problems, support the requirements and consider the characteristics of such networks.

Considering the aforementioned facts, we introduce a multi-tier structure for service discovery and management platform for Personal Networks. This paper focuses on the structure and internal architecture of the service discovery platform proposed for the MAGNET project.

II. Service and Resource Discovery Requirements in Personal Networks

Service provision in personal networks, which follows the discovery phase, has some specific characteristics, derived from the dynamic and ad hoc nature of personal area networks, which implies a number of requirements for service discovery process. Some of these requirements are investigated in [4] and [5], which are summarised in Table 1.

Table 1. Personal network characteristics impacting service management

Personal Network Characteristic	*Service Management Requirement*
Heterogeneity - Different access technologies - Different discovery schemes - Different service specification	SD must support interconnectivity to radio technology dependent technologies, proper interfaces to other SDPs such as Bluetooth SDP and UPnP, and probably unified service descriptions and generic service repositories
Mobility - Moving server, client or any 3rd party involved - Remote access problems	Service management platform must support mobility management of the service provision entities.
Ad hoc - Fixed hybrid - Discovery at the P-PAN/ cluster level - Discovery at the PN level	The service management platform should consider the network structure, dynamics, architecture, security, ownership of the network, etc. for selecting the service discovery scheme.
Context Awareness - User preferences - Network conditions/ characteristics - Environment conditions	SDP must support Context Management, i.e. context information gathering and offering to devices performing context aware service discovery, context triggered service discovery mechanism, as e.g. emergency services to be adapted with casualty context; context based service selection mechanism, transferring relevant context information in SD messages to provide the necessary information to service ranking algorithms
User high-level service requests - User makes service request using top level language - User makes fuzzy searches	SDP should translate the request to the system language, regarding the user preferences and context. Fuzzy searches like "find John's home camera" should also be addressed.
Security and data/service privacy Unsecured infrastructure and foreign ad hoc network	Service management platform should support mechanisms like trust relationship, encryption, tunnelling, AAA, on users and services.
Limitations on Resource usage - Limited bandwidth, battery lifetime, memory, CPU - Running the SD platform on most of the PN devices	The service management platform must contain a simple and lightweight structure, minimised running code, use minimum size of data for discovery signalling and consider distribution of the functionalities

III. Service Discovery Hierarchy

Personal networks may contain several networks, ranging from a Bluetooth piconet to a world wide network. The service discovery platform should follow this multi tier hierarchy.

A. Radio Domains within the P-PAN - tier 1

The smallest component in a PN is a network using a specific radio technology, called a Radio Domain (*RD*), in which air interface is implemented, as well as a single and specific service discovery protocol is carried out. In most cases, an RD contains at least one IP-capable node. This node will generally act as the RD bridge towards other RD/networks. For example, a Bluetooth radio domain implementing 802.15.1 radio technology provides the specific Bluetooth SDP for service discovery and contains an IP supported Bluetooth Master.

Depending on the service discovery solutions that will be adopted for a larger scale (*cluster, PN ...*), it would probably be necessary to forward/translate the radio domain discovered services towards more generic service management platform residing in the higher level of hierarchy.

B. Cluster / (P-PAN) - tier 2

A cluster/P-PAN is formed:

- by the interconnection of a number of radio domains, active nodes and devices, and
- by considering a long term trust relation that has to be set up between all the P-PAN components

The only difference between P-PAN and a cluster is the presence of the user in the P-PAN. All the services within the P-PAN should be discovered by using a multi protocol approach, since the different radio domains may use various/heterogeneous legacy discovery protocols and network technologies.

C. Personal Area Network – tier 3

The PAN, in addition to the P-PAN, can also contain all the foreign devices connected directly to the P-PAN, and characterised by a lower level of trust. Service discovery in PAN is performed same as that in P-PAN, subject to a short term trust relationship be provided.

D. Personal Network – tier 4

PN contains the clusters and the P-PAN. It is then formed by a collection of personal nodes and devices that are connected to each other via interconnecting infrastructure. The discovered services in each of the clusters are exposed to other clusters as well as the P-PAN.

E. Global level – tier 5

All the services available to the PN from outside world are categorised in global level, including web services and remote foreign devices connected to the PN using the infrastructure.

IV. Service Management Structure

There are two approaches for service discovery, centralised and decentralised, according to the results obtained in [6], centralised approaches at the cluster/PAN level performs better than decentralised ones. At the PN level, decentralised approaches are preferred.

A. Service Management Node

The SMN is a component that acts as the centralised service discovery and management entity of a cluster in a personal network. SMN also provides the functionality of a repository for storing the descriptions obtained from all the currently available PAN services.

In the PAN and cluster level, a centralised approach is taken. The centralised service management component for any cluster or P-PAN is the SMN. In the PN level, the Peer-to-Peer connectivity is provided between the SMNs. This P2P protocol enables SMNs to advertise their registered services to other SMNs and hence other clusters within the PN.

B. Security and privacy

Most of the exchanging data within a given PN, as well as service management and discovery operations, are related to a particular user, i.e. are personal, maybe confidential and must be strongly protected from unexpected and undesired discovery, access and use by any foreign and non-trusted user or entities.

- *PN networking*

The first step in securing the service management system is providing secure links between the active nodes in the system, i.e. between the clients, servers and the SMNs. This is performed at the P-PAN/PN formation stage. At the PN level, long and short term trust is established beforehand [2], hence establishing a secure relationship between the active nodes in the service discovery process, is not critical from the point of view of service management system.

- *P-PAN/cluster service management*

Concerning P-PAN/cluster service management, the considered solution consists in protecting the access (or the use) to services and their related information, i.e. the service description, repository, discovery and advertisement. This mainly carries out access rights to the cluster/P-PAN services and devices, combined with the list of authorised services and service authorisation.

- *PN and global level service management*

At the PN and the global level, an SMN peer to peer overlay network is adapted for the service discovery and management. In this way the security is mainly related to the one that is needed within the peer to peer overlay network. Depending on the retain P2P protocol, e.g. JXTA [7], standards and available mechanisms will be carried out.

C. Overall Service discovery structure

Among those PN entities, active SMNs are responsible for the service management and discovery for their entire local domain, i.e. the cluster they belong to. In that context, the considered approach for SD in PNs is to use the overlay network of interconnected SMNs to propagate/disseminate the service discovery and advertisement data. This implies that a communication module within the SMN must be defined and implemented and be dedicated to inter-SMN communications.

V. Service Management Architecture

The most important component of Service Management System is the SMN, which runs the functionalities of the system. All the functional entities within the architecture are running in this system. Since the functionalities are to support service provision, we introduce the service platform of the MAGNET, which is called Service Management Layer (SML). The specification of SML is as follow.

A. Components incorporated in the SML

The internal architecture of the SMN, including the SML is depicted in Fig. 2. SML, acting as the MAGNET service platform, contains all the software modules to perform service and context discovery needed functionalities.

1) Service Discovery Module (SDM)

This module acts as the core of the service discovery system. This module is responsible for all the discovery

process operations, such as advertising the presence of SMN, accepting registration of the advertised services, replying the service discovery requests made by the clients, and interacting with other SMNs within the P-PAN/cluster (e.g. individual SMN of radio domains) to compile all the available services in the corresponding network.

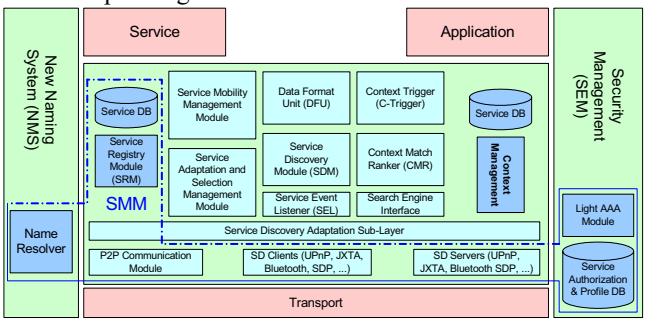

Fig. 2. Internal architecture of SMN

2) Service Registry Module (SRM)

This module manages the service cache, which holds the specification of the discovered services within the P-PAN/cluster. Also this module performs service record comparisons for checking the availability of a requested service.

3) Data Format Unit (DFU)

The purpose and functionality of the DFU is to parse and react properly on user's service request. This means, it basically converts the user's fuzzy input string, to the machine comprehensible service request. As such string potentially contains key words originating from a personal name space, context information or other key words, the input string must be parsed before the service discovery mechanism can be enacted. An example could be a request for service discovery using the following string:

my_home.kitchen.nearbyPrinter

To parse this string, the DFU needs to interact mainly with the Naming system and Context Manager.

4) Context Trigger

It is the purpose of the context trigger to initiate a service discovery request under certain given conditions. The idea behind this functionality is to assist applications in monitoring and reacting on context changes. Such things could be user's health state, i.e. when blood pressure, pulse or temperature raises to dangerous levels the system could automatically initiate a service discovery request for a nearby ambulance for a given location.

5) Context Match Ranker (CMR)

The task of the CMR is to give each service discovery a score based on relevance to the user under given circumstances. This requires a set of functions ($f_1..f_n$) in (Eq.1) for a given service (s) to map relevant context (given in the vector x) information to a comparable score.

$$Score_{service} = w_1 f_1(s,\bar{x}) + w_2 f_2(s,\bar{x}) + .. + w_n f_n(s,\bar{x})$$

(Eq.1)

Output from each function is weighted with a weight (*w*) to achieve a weighted sum of outputs. Based on this, the list of services found are sorted and finally presented to the user.

6) Service event listener (SEL)

This module listens to the service event notifications made by the services and updates the latest status of the service. These events include the service creation, deletion, alteration, suspension, etc.

7) Search Engine Interface (SEI)

This module discovers the available web services by searching the web on the available services. Adaptation of the web services to the personal network context (e.g. finding a nearby shop by using the context information including post code or coordinates, by using the web services) is performed by this module as well as constructing the interfaces to the web search engines.

8) Service Mobility Management Module

This module manages the mobility of the services and clients. Although the mobility is usually handled by the network level, but at the service level mobility of the service to a proper service provider, mobility of a client and how the service continuity must be provided, and even handling the mobility of the SMN, and handing over of the SMN to another SMN are the issues being handled by this module.

9) Service Adaptation and Selection Management Module

This module performs the service adaptation and selection functionalities. Service selection is the choosing the most proper service regarding the context. Service adaptation is adapting the service to the context in which it is provided.

Although this is performed within the service provision phase, but at the service discovery phase, these capabilities must be explicitly identified.

B. Service Management Module

The Service Management Module (SMM) is incorporated in the lower part of the SML (Service Management Layer) and acts as the central service management entity of a cluster or a P-PAN. It therefore resides in the SMN and is mainly responsible for:

- interacting and communicating with the common service discovery frameworks that are used in the heterogeneous and specific RDs (Radio Domains) forming a cluster or a P-PAN,
- centralising the information/descriptions of all the available and active services,
- carrying out the peer to peer external/remote service discovery and management,
- providing a secure service discovery and management,

at the cluster level, i.e. for a whole given cluster or P-PAN.

In order to support context awareness and provide the best suitable form of discovered services, the SMM is interfaced with the Context Manager, through the service discovery adaptation sub-layer.

For security and privacy purposes, a light AAA server, with the associated user profile ad service authorisation database, is implemented within the SMM. These mechanisms are focussed on both services and their potential users.

The SMM is therefore one of the key components of the

cluster/P-PAN centralised service discovery framework as it performs both the functionality of service repository and service interworking. Because of its P2P communication components and its role of Super-Peer, the SMM is also the key SMN module involved in the PN and global level service discovery and management architecture.

The common SMM architecture for both local (*cluster/P-PAN*) and remote (*PN and global level*), is summarised in Fig. 3 and Fig. 4.

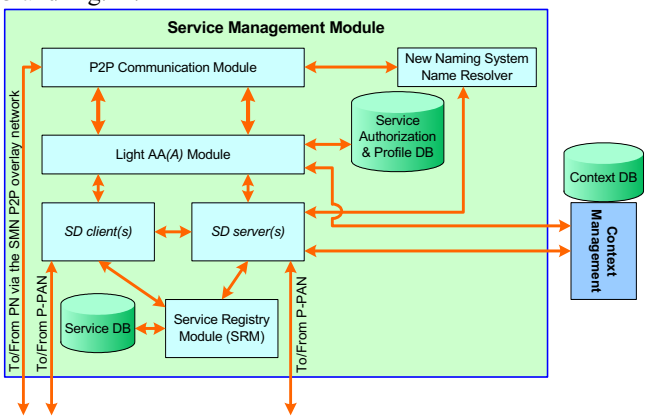

Fig. 3. SMM internal architecture

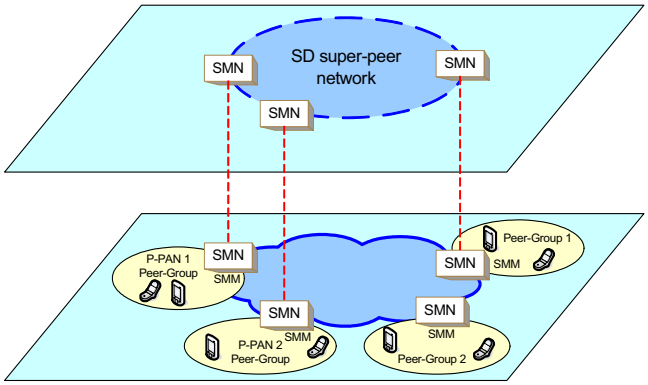

Fig. 4. SMM remote service discovery architecture

1) SMM implementation clues

For the service discovery interworking part of the SMM, a service discovery client and server component is added for each of the specific and common SD framework that can be encountered within P-PANs and Radio Domains. Therefore, growing successfully protocols with a great momentum from the industry like Universal Plug and Play [8] (for IP-based LANs) and Bluetooth SDP [9] (for Bluetooth WPANs) have to be implemented within the SMM, as well as other components being specific to Low Data Rate (LDR) technologies and sensor networks.

For the SMM P2P communication module, any P2P protocols or any frameworks providing the necessary functionality for carrying out a Super-Peer overlay network can potentially be used. Obviously they must be of carefully analysed, evaluated, compared, and eventually combined in order to come up with an optimised implementation of the SMM P2P communication module.

Among all those protocols, JXTA [7] and INS/Twine [10] appear as good potential candidates and are under investigation.

Finally, the SMM must also be designed in order to be platform independent and be as light as possible, in terms of required computational power in order to function in all the cluster or P-PAN nodes that have the SMN capability.

VI. Conclusion

In this paper we presented the service discovery platform proposed in the project MAGNET. The requirements of the service discovery in such a system were provided and how the system is designed to fulfil the requirements.

At current state, the work presented in this paper provides the framework for a system that allows service discovery in PN like networks. Next step in this work will be to specify interfaces and clearly state functions and interactions between components. Research in terms of scalability and discovery time will also be a part of coming work.

Acknowledgement

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