P2P-based M2M Community Applications

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***Abstract*—This publication presents a novel concept for decentralised service and application provision in a Peer-to-Peer (P2P) connected Machine-To-Machine (M2M) network based on community mechanisms. Several execution environments are introduced and evaluated. Requirements are defined to achieve application/ service provision in M2M application fields. This publication also introduces an application, consisting of several services, for building surveillance, realised via the presented concept of P2P based application provision in M2M networks.**

Keywords—Service/Application Provision; P2P; M2M

I. INTRODUCTION

In previous publication a concept for decentralised service provision by end-users has been presented.[4] The aim of the concept described in that publication is to enable end-users (previous service consumer) to take the role of a service provider and offer services for other end-users and corporations. The end-users can be networked to provide cooperative services, consisting of several identical or different services, realised by individual end-users. These services can be aggregated/ composed and can be consumed by central corporations or other customers. The approach of provision services by end-users and consummation of these services by end-users is defined as "horizontal service provision" (illustrated in Fig. 1). The approaches of service provision by end-users (individual or cooperative) which are consumed by central corporations or other end-users are defined as "bottom-up service provision" (illustrated in Fig. 2).

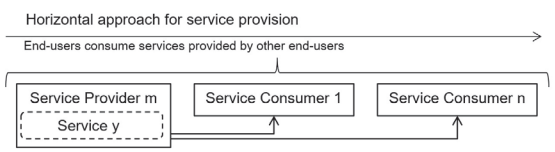

Fig. 1. Horizontal approach for service provisioning

Until now, service provision followed the centralised approach (central service provider which provides services to the end-user). The presented concept changes the relationship from service provider to service consumer which can be described as bottom-up service relationship (end-user jointly offers a service that can be used by central corporation) or as a horizontal service relationship (end-user offer services to other end-users). The described concept is realised by M2M. For this a framework has been defined, that realises service/ application provision using SIP-based P2P networking, so that no central appliances for realisation are required. Furthermore the concept includes social networking approaches, by forming communities and sub-communities for establishing the P2P network and networking the participants corresponding to their interests, geographical locations as well as different application field etc. Through the described concept, in addition of service/ application provision in end-user domain, also service/ application provision in M2M application field becomes possible, whereby M2M devices also are considered as peers.

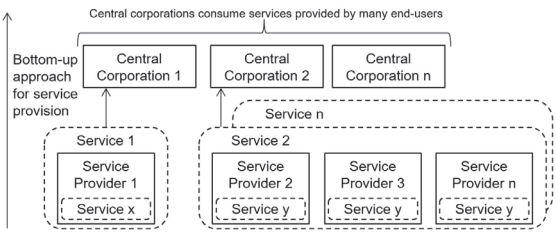

Fig. 2. Bottom-up approach for service provisioning

This publication specifies the concept more detailed to provide community applications which are not covered (and not focused) by the ETSI M2M standard. The presented concept defines a novel framework for application provision, based on M2M Systems.

The service/ application provision in M2M, according to the presented concept, can be separated in two main categories: 1. Autonomous service provision (compare Fig. 1). Here peers provide a service which is consumed by other peers on the same hierarchical level. 2. Cooperative service provision (illustrated in Fig. 3). Here many peers provide a service which is consumed by other peers on same or higher hierarchical level. In case of service aggregation peers e.g. provide a joint service by simultaneously offering the same service. In case of service composition, peers provide a joint service by offering different services.

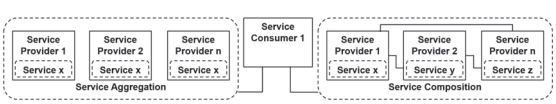

Fig. 3. Cooperative service Provisioning

II. Terms and Definitions of Service Provision in M2M

In order to clarify how an application in M2M context is structured, definitions of [5, 6, 7] are used to classify and separate service and application in context of application/ service provision in M2M (illustrated in Fig. 4). It illustrates that an application consists of one or more underlying services that are combined (i.e. aggregated or composed) and, if required, exchange information. The services are realised by one or more service components, which form the building blocks of services. The service components itself are realised via several software applications executed on several execution environments.

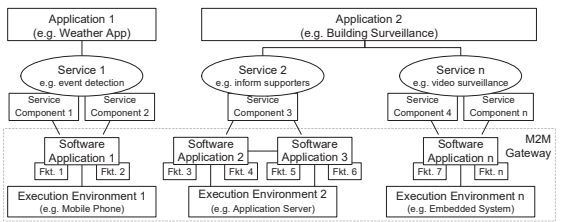

Fig. 4. Classification of Service and Application

A service as well as an application can be realised on technical or non-technical principles (i.e. it can be provided using technical devices, e.g. computers, or by a human, e.g. personal assistance services). To distinguish the kind of services and applications, if necessary they are indicated as technical service/ application or non-technical service/ application. General indication of both is service/ application.

In the presented concept of P2P based application provision in M2M, definition of service and application follows the definition illustrated in Fig. 4. Same as for service and application, peers can be technical devices or humans (if applicable supported by technical devices). To distinguish the kind of peer, if necessary, it is indicated as technical peer or non-technical peer. General indication of both is peer. Peers are able to provide services. The service is executed on the execution environment of the specific device or, in case of a non-technical service, provided by the personal execution of the human service provider (if applicable supported by a device providing a technical service, e.g. a Smartphone).

Based on references [8, 9, 10, 11] M2M is defined as follows: Machine-to-Machine communications (M2M) "refer to physical telecommunication based interconnection for data exchange between two ETSI M2M compliant entities, like: device, gateways and network infrastructure"[8] M2M area network provides "physically and MAC layer connectivity between different M2M devices connected to the same M2M area network or allowing an M2M device to gain access to a public network via […] a gateway."[10] "M2M Applications: are respectively Device Application (DA), Gateway Application (GA) and Network Application (NA)."[9] "M2M Applications […] run the service logic […]."[8] In general [8] defines an application as an "entity (typically in software) designed to perform specific tasks on behalf of /in order to help a user to operate for a specific goal." "M2M Application Service Provider: is an entity (e.g. a company) that provides M2M Application Services in the M2M System to the end user."[8] „M2M value-added services are not services at the M2M application level. The M2M value-added services relate to the data communication services themselves, not to the application in the M2M device and M2M server. Examples of M2M value-added services are: QoS and priority differentiation; charging and subscription management; device management; connection monitoring; fraud control; secure connections."[10] This statement is substantiated by [11] who summarises that despite all networking and communication abilities all M2M applications focus on optimisation of collaboration of M2M devices based on M2M applications within a defined, separated overall process, often using a M2M service platform.[11] According to ETSI the end user operates M2M Application Services (provided by M2M Application Service Provider, i.e. companies). This especially means that the end user (according to the ETSI standard of M2M) does not create and provide services as well as is a different role separated from the M2M Application Service Provider. In summary this means that up to this point only a framework is defined for provision of M2M Network Applications and no framework for application provision on end users domain has been defined yet.

III. Execution Environments for Services/ Applications

Currently several concepts for hosting services/ applications exists. Well-known approaches of service/ application provision are central server approach (using servers, hosting the applications on central locations in the network) and Cloud Computing approach. Next to this approaches two new architectural approaches for hosting services and applications came up: Edge and Fog Computing.

"Edge computing is all about pushing processing for certain data intensive, remotely isolated applications away from the core of the data center to the outer edges of the network where all the interactions are happening and the actual processing needs to take place."[12] Mobile-edge Computing is a part of Edge Computing which "provides IT and cloud-computing capabilities within the Radio Access Network (RAN) in close proximity to mobile subscribers."[13] "Mobile-edge Computing can be seen as a cloud server running at the edge of a mobile network and performing specific tasks that could not be achieved with traditional network infrastructure. Machine-to-Machine gateway and control functions are one example […]."[13] The second new approach of hosting services and applications is Fog Computing, which "is a highly virtualized platform that provides compute, storage, and networking services between end devices […], typically, but not exclusively located at the edge of network."[14] Also [15] describes, that virtualisation plays a big role in Fog Computing and „the Fog enables user devices to become the virtualisation platform themselves". "In the fog, both the network and the services running on top of it can be deployed on demand in a fog of [..] devices."[15] In [15] Fog Computing is defined as „a scenario where a huge number of heterogeneous (wireless and sometimes autonomous) ubiquitous and decentralised devices communicate and potentially cooperate among them and with

the network to perform storage and processing tasks without the intervention of third parties. These tasks can be for supporting basic network functions or new services and applications that run in a sandboxed environment. Users leasing part of their devices to host these services get incentives for doing so“. Fog Computing is defined according to [14] as ”a platform to deliver […] services and applications at the edge of the network”.

The main intention of Edge and Fog Computing is to support network services, reduce the load in the core network, enlarge the Quality of Service for the customers, provide storage as well as perform distributed computing tasks. Considering the definition of Cloud Computing and application provision using centralised server approach as well as the definitions of Edge and Fog Computing acc. to [12, 13, 14, 15], Fig. 5 illustrates the execution environments of services/ applications according to the several approaches.

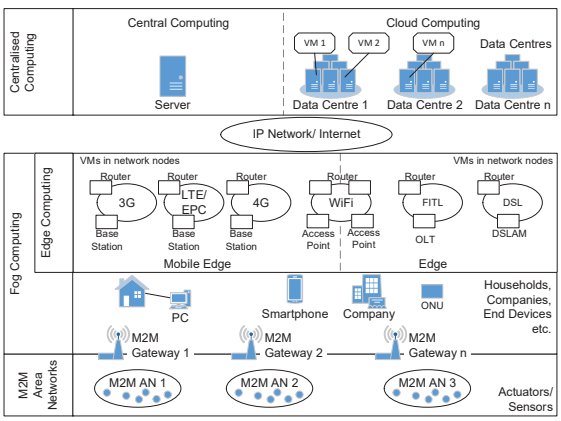

Fig. 5. Execution Environments of Services and Applications

Edge Computing is realised in the infrastructure provided by the network operator (i.e. access networks or devices located close to the customers, e.g. services executed in base stations). This eliminates service provision by end-users in the edge. Fog computing also is executed in same infrastructure and, in addition, more close to the customer (e.g. in IADs) and extended by virtualisation concepts. Edge computing can only be operated by the network operators because no one else has access to the network equipment located in the access network. Fog computing also requires the existence of central corporations for coordination of the distributed computing tasks as well as the management and arrangement of the virtualised services executed in devices next to the customers. Despite Fog Computing offers the possibility for service execution next to the customer, end-users service provision is still not integrated due to missing access to the infrastructure of the Fog Computing provider.

Combining the concept of P2P based service/ application provision by end-users with Fog Computing aspects of virtualisation and service execution next to end-users, by enabling the platforms next to the end-users for execution of services provided by the end-users, with possibility of information exchange between end-users devices, forms a novel concept for provision of M2M services and enables end-users to participate in application provision on end-users domain.

IV. P2P BASED SERVICE/ APPLICATION PROVISION IN M2M

The following chapter describes a solution for P2P based service provision in M2M. First a framework is introduced to provide a solution for service provision in M2M networks. Afterwards the requirements are defined to achieve application/ service provisioning in M2M application fields. This chapter closes with a description of the communication between the involved parties and an evaluation of the presented approach regarding existing execution environments (described in chapter III).

Previous publications, e.g. [1, 2, 3] describe that existing research and development activities for optimisation of Smart Homes and Smart Grids do not consider service provisioning, networking and decentralised optimisation via information exchange. Therefore, a solution is presented in [1, 2, 3], oriented at the personal needs of users, to offer cost-efficient energy management, according to users personal needs, and integration within their house automation as well as combined with multimedia communication. Also the interaction between households is included to exchange information regarding the local energy production and consumption. This information is used for joint, independent and decentralised energy optimisation. The principles and architectures of the proposed framework for provision of services and optimisation possibilities in Smart Grids are presented in [1, 2]. The Concept is mainly based on a Service Management Framework (SMF), consisting of a Service Delivery Platform (SDP) and a Service Creation Environment (SCE), see [3], which is installed in the local households. The SCE brings the functionality to design and configure value-added services graphically, according to the personal needs of the users, to monitor and control actuators, sensors and devices in user households. The SDP is used to provide a solution for service provision, service control and service management and serves as a runtime environment for the generated services. SCE and SDP in combination allow easy service design by the customer, as well as local controlling/ management of energy producers and devices (energy consumer) in Smart Homes. With that solution the optimisation of energy consumption e.g. by optimal load distribution is possible.

The presented concept include the clustering of households for more effective optimisation because of independent optimisation of individual households does not automatically lead to optimisation of the local or distribution grid. The concept is totally based on decentralised approaches to avoid central instances in the infrastructure. In order to provide the aggregation of households, the SMFs of individual households are connected using a SIP-based peer-to-peer (P2P) network as introduced in [16]. To solve issues for networking, avoid legal restrictions, optimisation, missing mechanisms to form the P2P network or the fact that user aim different goals for optimisation (e.g. cost reduction, obtain only “green energy”, most benefit for energy supply) the P2P networking approach

was extended by community mechanism (see [1, 2, 3]). The community-based approach forms a new comfortable way to join a network of peers, whereby the connection of peers is done by joining the users to a social network. Using IP-based information exchange guarantees the applicability by everyone that has access to the Internet. Therefore the realisation is possible with minimal costs. Inside that Energy-Community not only the single customer goals are considered, the goal is to reach a benefit for every participant in the community. In addition the participants can form sub-communities to address common shared interests (e.g. energy saving, cost reduction, obtain only "green energy").

References [1, 2, 3] present the principles of the proposed framework for creation, provisioning and optimisation of services in Smart Homes and Smart Grids. Also the architecture of the implementation of the proposed solution is described. As exemplary service the optimisation of the energy consumption in single and clustered Smart Homes is outlined that forms a novel solution for optimisation in Smart Grids. This described framework demonstrates that service provisioning and joint optimisation by end-users can be implemented in an application field that hadn't addressed those topics yet.

The novel concept of a P2P-connected community offers many advantages and can be applied in various sectors of M2M to form intelligent environments. The SMF is the main component of the solution in provision and consummation of M2M services by connecting service providers and service consumers, using an overall solution for information exchange. All peers, providing services and applications, are associated in a M2M community. The M2M community is the mechanism to form the P2P network and avoid legal restrictions. The M2M community forms a social network of peers. Various sub-communities are used to address different application fields, interests, geographical locations etc. Fig. 6 illustrates the collocation of M2M Community, sub-communities and applications based on the classification of service and application illustrated in Fig. 4. Existing infrastructure (IP network and devices, e.g. IAD or smartphone) can be used to provide different kind of services in different application field with same and cost efficient hardware (e.g. Smartphone). Fig. 6 illustrates the overall architecture of execution environments for applications/ services, where the community and the sub-communities are integrated. The overall goal is to provide a concept for application/ service provisioning in M2M application field and to provide this applications/ services using P2P mechanisms without central instances.

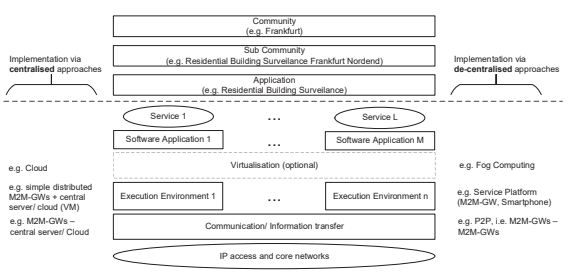

Fig. 6. Collocation of M2M Community, Sub-Communities, Applications

The networking enables the participating peers to provide a service that can be consumed by others. Especially the cooperative service provisioning is considered in the concept (e.g. to provide services consumed by central corporations).

The overall goal can be separated in the goals "joint service provisioning" and "autonomous service provisioning". Joint service provision is separated into service aggregation (provide a joint service by simultaneously offering the same service) and service composition (provide a joint service by offering different services).

M2M is a special field of networked devices with special requirements and limitation for available data storage, processing power, bandwidth etc. For application/ service provision and consummation in M2M, according to the presented concept, following requirements have been defined: Possibility for service provision (incl. cooperative service provision) by end-users using existing resources (e.g. IAD or mobile phone); autonomous service provision; decentralised mechanism for service description/ registration by devices and people; unified communication of service provider and consumer; management of constraints for services (e.g. temporal and local availability). Requirements according networking and resources: Integrated multimedia communication (and other IT services) to services and service platform; minimal hardware requirements for decentralised service execution; networking of service provider and service consumer for decentralised communication and cooperative service provision; estimable Quality of Service (QoS) in dependence of service; avoidance of central instances for (joint) service provision; efficient usage of limited resources (available data storage, processing power, network connectivity); determinability and predictability of network capabilities (bandwidth, availability, latency); flexible, scalable, and robust self-organised network; solutions must address scalability, robustness, openness, and flexibility.

For satisfying the requirement of integrated multimedia communication, the communication unit of the SMF provides an interface for Next Generation Network conform multimedia communication which also offers total communication possibility between the peers. The communication between the peers is realised based on IP-technology (via Internet/ NGNs) which is todays and future standard in network communication. Also IPv6 offers a large scalability for addressing devices. The information exchange between the peers and the connection of the peers is based on the Session Initiation Protocol (SIP)[17]. The communication protocol SIP is a standardised, widely adopted communication protocol for signalling in Internet/ NGNs. SIP provides standardised functionality for information exchanged based on the subscribe/ notify principle. In addition for messages exchange between the peers, SIP is also used for further communication e.g. via audio/ video call, IM. This allows the communication of service consumers and service providers for detailed coordination of service usage (e.g. personal consultations, etc.). Also SIP has standardised functionality for transport of XML-data and mechanisms for reliable communication, realised in OSI Application Layer that offers the functionality to act in heterogeneous networks. SIP has already integrated control functionalities for point-to-point/ multicast connections and provides many features that can be

advantageously used for the connection of peers and the exchange of information. Advantageous functionalities of SIP are: The globally defined SIP address (SIP URI) for users that allows location-independent availability via unique identifiers; Location Service functionality for worldwide localisation of users over the Internet (including mobile users); Presence functionality to request information regarding the availability of users; Event Notification Framework[19] that "enables SIP entities to subscribe to specific events occurring on other SIP entities."[11] and Instant Messaging[20] that can be used "to carry short text messages in a simple way from one SIP entity to another."[11] In addition SIP provides existing security functionalities, described in [17]. Furthermore Interactive Connectivity Establishment (ICE)[18] can be used to traverse a Network Address and Port Translation (NAPT) gateway or a Firewall.

TABLE I. EVALUATION OF EXECUTION ENVIRONMENTS

Advantages/ Dis-advantages reg. single M2M Application	**Centr.**	**Cloud**	**Fog Computing**		**P2P**
			Edge		
Costs	-	o	+	+	+
Short time to market	-	+	+	+	+
Demand for energy	-	+	+	+	+
Large flexibility	-	+	-	+	+
High availability reg. platform breakdown	o	+	o	o	+
Privacy	-	-	-	+	+
Ability of end-users for service provision	o	o	-	+	+
Scalability	-	+	o	+	+
M2M Gateway integrated	-	-	-	+	+
Support of sensor networks with high amount of nodes	-	-	o	+	+
Virtualisation possible	-	+	+	+	-
Distributed data storage	-	o	-	+	+
Independence of network/ platform operator	-	-	-	-	+
Avoidance of central instances	-	-	-	+	+
Automated (optimised) networking	-	o	-	o	+
Corporate application provision by cooperation of end-users	+	+	-	-	+
Community approach is realisable	+	+	-	-	+

V. EVALUATION OF APPROACHES FOR APPLICATION PROVISION

TABLE I illustrates an extract of an evaluation for M2M application provision regarding the approaches introduced in chapter III (central server approach, Cloud Computing, Edge/ Fog Computing and application provision according to the proposed P2P approach). Especially the topics "Independence of network/ platform operator", "Automated (optimised) networking", "Corporate application provision by cooperation of end-users" and "Community approach is realisable" shows the advantages of P2P based application provision as. The positive evaluation of the P2P approach is illustrated once more when evaluations are not carried out respect a single M2M application, but considers multiple applications.

VI. APPLICATION EXAMPLE

In the following the application "P2P Building Surveillance" is described with the basic functionality of building surveillance. The application observes certain buildings if defined events occur in the building (e.g. fire or intrusion detection) and informs the corresponding supporter (peers) about this event. The application is realised by a sub-community for building surveillance with P2P interconnected participants. The aim of that sub-community is to assist each other for surveillance of certain buildings. The specialty of this application, as same as for the complete approach, is that no central corporation for application provision are required.The application consists of in total seven different services which are composed to realise the application and provided by the different peers (e.g. executed inside of a Smart Home platform or a mobile phone). All services can be executed independently and in particular provided directly by different peers, located at different locations in the network (i.e. that it is possible that all peers are connected via separated access networks to the core network). For information of the supporter (offering the non-technical service of building monitoring) two different variants exist. Variant 1: Supporting peers register at service 1 with indication of kind of event, specific building ID, and their corresponding contact information. Service 1 generates a list of supporters which are responsible for a specific event occurred in a specific building (or many buildings, e.g. fire brigade). The supporters also report their current availability status and geographical locations continuously to service 2. Service 2 manages the availability information as well as the geographical locations of supporters and responses location and availability information of supporter, if requested. If a supporting peer should be informed about an event, then a SIP NOTIFY message is sent to it (Fig. 7, step 10). Variant 2: Supporters don't report their current availability and location information. If the support is required they receive a SIP SUBSCRIBE message and response with a SIP NOTIFY message about acceptance (Fig. 7, step 10). Service 3 records sensor data (e.g. smoke detector or intrusion detection sensor) and forwards the sensor value for requested sensor ID to service 4 (incl. destination address contained in request. Sensors transmit sensor values periodically or at state changes to service 3. Service 4 transmits requested sensor values to the contact destination contained in the request. Service 5 receives the current sensor values of a specific building and evaluates if an event has occurred. This service can be configured for self-contained request of sensor values at service 3 or advices same service to transmit the sensor value to a specific destination address. If this service detects an event, it generates a notification event. Service 6 specifies which supporter should be notified. This service receives an alarm event as well as building ID and determines (using service 1) the supporter which should be notified, depending on its availability and location information (using service 2). If supporter is available, the service returns the contact information as well as event occurred. Service 7 contacts the supporter about occurred events in monitored buildings, including information regarding event and location of building, either by sending a SIP SUBSCRIBE or by sending a SIP NOTIFY. Fig. 7 shows the combination of the services described above for realisation of the application for building surveillance.

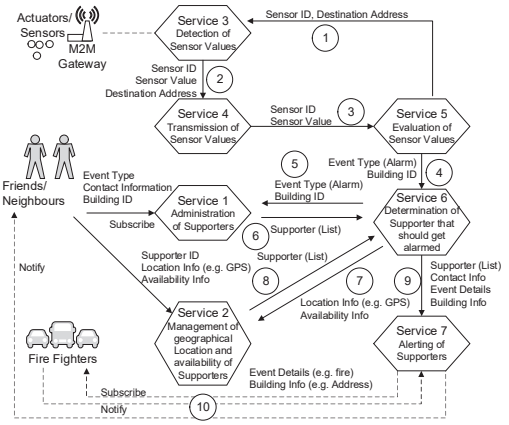

Fig. 7. Service Interaction of Application „P2P Building Surveillance“

VII. Conclusion

This publication presented a novel concept of service/ application provision in M2M and defines a so far missing framework using SIP-based P2P networks with communities. This concept offers new possibilities for applications, realised by several peers, independent of central appliances or corporations. Especially the concept of cooperative service provision enables new application fields. Requirements have been defined to realise service/ application provision in M2M. Definition and classification of software application/ service and applications in M2M as well as classification of execution environments of services and applications offers detailed indexing and evaluation of several approaches for service/ application provision. Based on this the evaluation of approaches for service/ application provision has indicated that the concept of P2P-based service/ application provision has explicit advantages compared with the other approaches, especially when combining the presented concept with elements of Fog Computing. The presented application “P2P Building Surveillance“ clarifies the concept and illustrates exemplarily which new application fields can be addressed by the concept, without utilisation of central appliances or corporations. Using the existing IP network infrastructure (Internet or NGNs) and devices (e.g. IADs or Smartphones) enables the realisation of M2M applications without additional hardware.

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