Opportunistic Service Provisioning in the Future Internet using Cognitive Service Approximation

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***Abstract*— With the advent of newer technologies and highly miniaturized and computationally capable communicating devices, many possibilities of service provisioning is opening-up. The ICT (Information and Communication Technology) devices are now getting into our everyday life without our notice. Since the needs of a person are different from another and so many different situations have to be dealt with, an exact service could not always be offered. This document offers a solution called an approximate service, which could be found with whatever the surrounding devices could provide opportunistically. We provide an example to motivate towards such a paradigm. We identify some structural components of such a service.**

***Index Terms*— Approximate Services, Cognitive Service Provisioning, Internet of Things (IoT),**

I. Introduction

Wireless technologies enable communication from anywhere. The availability of miniaturized transceivers and actuators is driving a lot of innovation in the way we use ICT (Information and Communication Technology) in our daily lives. Coupled with this, economic feasibility is also a driving force for people to increasingly use the ICT devices.

Communication technologies were previously used for Human-to-Machine communications. Now, they are also used for device-to-device (popularly called as Machine-to-Machine (M2M)) communications. This is used for automation of tasks with or without any human intervention. For example, a device with temperature sensor and transceiver equipment can read the temperature (of the ambience or equipment like boiler etc.) and send the value read to a receiver which can automatically take some actions, for instance - climate control. This eliminates the requirement of a person to monitor the temperature continuously. Machine-to-Machine (M2M) and Machine-to-Human (M2H), Human-to-Human (called Federations [10]) communications are being explored in order to provide more number of automated services, including the context based services. These services are based on human requirements or pre-programmed requests. However, the next step is to provide cognitive services that are based on learning from various sources and measurements of parameters from the surroundings. At the lowest level, a system can learn about a human need by communicating with an interfacing device; the other extreme is the service that is offered by the system after learning the user's context (and without an explicit action taken by the user for that service). For example an Alzheimer's patient who is supported by intelligent support system that helps him remember and lead a life on his own. It is observed that people are becoming much more dependent on the ICT devices with the availability of easily automated services. Dependency on (networked) device assisted living will increase our expectations on the availability of services at any place and at any time.

However in the real world, it may be noted that a perfectly matching service for a requirement (or tuned to a situation) may not always be available. In these situations, we humans try to locate an approximate and an alternative service for the required one that is available and can solve the immediate necessity. The idea is to extend this notion to the services offered by the ICT world. In this paper, we provide a roadmap towards service approximation so that we can experience a better availability of services.

We describe an example to illustrate the concept. Suppose there is a coffee vending machine with a stack of paper cups (Figure 1). If a user wants a cup of coffee, he can locate the coffee machine using his cell phone (assuming this functionality is already available). Now these coffee cups can be easily used for drinking water, tea, milk, juice, soup or any kind of liquid item. Moreover, one

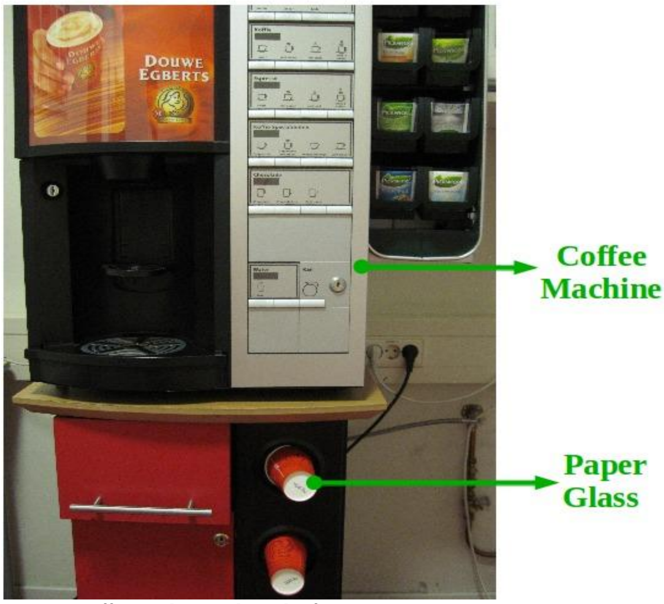

Fig.1: A coffee machine with stack of paper cups

Fig.2: A coffee cup is used as pen-stand

may use a coffee cup as a pen-stand (Figure 2) or even as an ashtray. Thus, the ICT service should be able to locate the coffee cup when a pen-stand is required. The services now would be based on the non-availability of the exact solution that is not possible to serve a requirement and availability of a close alternative. This paper deals with an opportunistic yet an approximate service paradigm in the Internet of the future, especially, in the light of exponential growth of Internet of Things. We specifically list the characteristics of such a service and also provide related structure to realize this framework of future ICT service support.

The rest of the paper is structured as following: Section II provides a brief note on the related explorations underway. Section III discusses how each and every device is represented in a digital world so that they can be located by a searching mechanism. Section IV describes how a service can be located using a service lookup model. Finally we conclude the paper along with a list of future work in V.

II. Related Works

The paradigm of Future Internet has been investigated in great details by many European FP7 projects, such as FIRE, FIND, GENI, etc. They describe the application of concepts like large scale networking, Cognitive Networking (including Cognitive Radios), network of networks, as well as architectures developed for a converged communication and infrastructure services. The European commission has taken a big step in identifying issues and encouraging new and innovative ideas under FIRE initiative [2]. NSF also dealt with the Future Internet initiatives in Future Internet Design (FIND) [1], which is focused on designing future networks that are more secure and available than today's Internet or by ensuring that functions like information dissemination, location management or identity management fitting in new design and environment. FIND also investigates how economics and technology can interact to shape the overall design of a future network. The NSF is also taking further steps to address the scalability of the future Internet by various means. One such attempt where many ideas by leading researchers were shared and discussed can be found in [3]. One could also find the Approximate Services concept towards the vision of pervasive Future Internet which is invisible but always present to support users [6]. Further, there are already some work is currently in progress under EU FP7 project iCore [4]. We now proceed to explain one possible way of realizing the dream of Approximate Service and related issues in the sequel.

III. Device Representation - Presence of an Object in the Digital World

A. Objects and Virtual Objects

It is easy to represent a device with ICT capability by an **object** in the digital domain along with its interfaces, properties, states and the services it may offer. For example, an object representing a printer with its properties like IP address, printing capabilities, etc can be stored in a server and can be made accessible whenever required. With the advent of Internet of Things and massive ICT infrastructure, it should also be possible to represent real world things, which may not be an ICT object, as an object in the digital domain. For example, a table, a chair or a coffee cup or an even apple should be represented. We call these representations as a **virtual object**. These objects too should be used in an opportunistic way to provide services. The difficulty though is that there is no way direct way to communicate with these virtual objects. Hence, we need some form of detection and/or sensing, which may not provide all the required information accurately.

B. Sensing

An object without any communication capability cannot be controlled or interfaced. Though now-a-days more objects are equipped with communication capabilities (may be a simple RFID interface), many virtual objects will not have the means to communicate by themselves. If a service of any of these objects are required, locating the required object need to be done with the help of another device(s) that is(are) ICT enabled. A number of sensors with various capabilities can be deployed in the interested regions. Thus either by direct communication or with the help of these sensors, an object's location can be identified. However, one question is how many sensors should be deployed optimally to cover maximum area or maximum number of objects. Alternative approaches to this direct sensing method can be virtual and indirect sensing.

C. *Virtual Sensing*

Sensing obtains data from direct measurement of the physical phenomena by placing sensor (transducer) physically at the location or on the object of interest. However, in many real life scenarios, obtaining the sensing data by placing the sensors at the exact location is difficult or even impossible. An alternative sensing method, known as "virtual sensing"', produces sensing data from other sensors which may not be even present at the location of interest. **Virtual sensing**, which uses physical sensing data and a suitable model to grasp the information of interest that is difficult or impossible to reach [5]. Depending on the model (used to produce the sensing data for the virtual location) there is always a chance of inaccuracy as there is some kind of approximation involved. In the context of service approximation, some form of virtual sensing is needed. As an example, assume a room having temperature sensors in the corner of the rooms. However, with just these sensors it is possible to estimate temperature value in the middle of the room i.e., for all practical purposes there *is* a sensor in the middle of the room that reads the temperature [9].

D. *Indirect Sensing*

Another form of approximate sensing is indirect sensing. The idea is to avoid the large scale direct and dedicated deployment of sensors [7]. Sensing data captured by a sensor (with a particular purpose) can be used for another purpose. For example, suppose we have installed sensors in every room of a building which switches on light when there is someone inside a room (say with motion or IR sensors). Otherwise the lights are switched-off to avoid electricity wastage. Now this sensing data can be used by the building security to infer whether a person is inside the building or not. This could be used in many ways in different situations.

IV. FINDING SERVICES

Finding a service or just even locating an object, as explained in our example, would be highly sought for objective in the Future Internet. From a very high level view finding a service (or identifying an object) is composed of two simple task - (i) representation of objects and their services in a manner so that they can be fetched in searchable environment and (ii) a search engine with required awareness to locate a service (possibly a list of available services with some ordering). The first part is partly described in the previous section. A schema for representation of services is required so that exact or approximate services can be easily searchable. In this section we will try to visualize how a service can be found.

A. *Service Proxy*

For the sake of simplicity, we consider a centralized service lookup model. We define a Service Proxy that intercepts a user's request (for a service), identifies the object(s) for the requested service, the fetch the functions from the objects on behalf of the user and then finally serve the user. The service proxy maintains the functional information about all objects in the vicinity. It runs an algorithm to find objects which can serve a request or approximately serve the purpose. So a service proxy acts as a search engine (searching is also a service) with required cognitive abilities such that it finds an approximate service when the exact service is not available. A service can be thought of as a conglomeration of functions and each function may not be served by a single objects. The service proxy breaks a service into smaller functions. If an exact functionality cannot be provided by any objects in the vicinity, the proxy tries to find an approximate alternative.

B. *Service Lookup Model*

The Service lookup model (Fig. 3) is closely coupled with the service proxy and works as following:

1) *Service Specification*

When a user needs a service, the requirements for the service must be specified. In the Figure 3, the user first sends a request for a service with a set of specification. The request contains context of the service, explicit requirement, etc. If required the service proxy itself may ask for further information about the desired service while serving. In some cases, the request can specify a "level of compromise" on the approximate service that it can tolerate.

2) *Objective of the service*

When a user requests for a service, the request first goes to the service proxy who processes the request. Service proxy is the immediate destination for each request. If the user explicitly knows the object which can provide the service, then the request can be sent directly to it. But there are a couple of complicated situations -

(i) An exact (in its desired form) service is not available, but some alternatives are available,

(ii) An exact service is available but a single object is not capable of serving the complete request, and

(iii) Multiple alternatives are available for a service (may not all of them are exact).

3) *Splitting a Service into Functions*

In these scenarios, to take a proper action on the user requirements, a highly cognitive mechanism must be in place which some devices might lack. On the other hand, the service proxy breaks a request into multiple smaller functions and finds a suitable object which can provide the functionality. A service can be composed of a multiple (individual) functionality. In that case, the service needs to be broken down into smaller functions. Let f_1, f_2, …. , f_N are

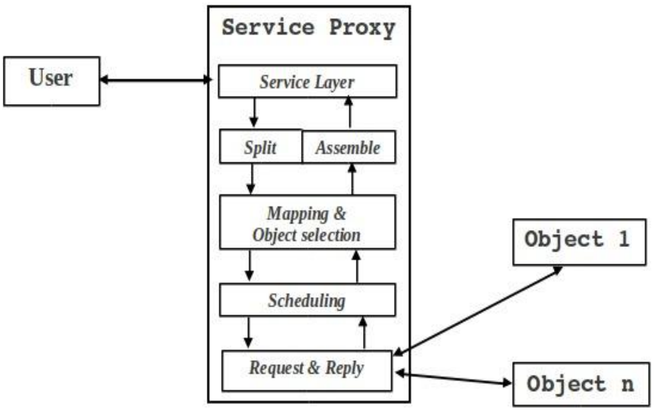

Fig. 3: Service Identification with the help of service-proxy

functions where each function is from one or more devices. We can then define an exact service as,

$$S_e = \Psi (f_1, f_2, \ldots, f_N)$$

Each function f_i plays a vital role in the provisioning of the service S_e. In composing an approximate service, however, some functions may be "approximated" and some may even be missing altogether. This mapping may be represented as

$$\Gamma: F \rightarrow A$$

where $F=\{ f_1, f_2, \ldots, f_N \}$ is the set of functions used to form S_e and $A=\{ a_1, a_2, \ldots, a_M \}$ is the set of approximate functions with respect to this service. Note mapping, Γ, is not a bijective function. Given this, we can define an approximate service as

$$S_a = \Phi(a_1, a_2, \ldots, a_M)$$

The missing functions are compensated by using alternatives found in the surroundings. Further, the alternatives may not be exact and thus, the capabilities available with the objects in the surroundings have to be compared with the requirements.

4) Mapping and Selection of the Objects

As we said that a service can be a conglomeration of functions, then each desired functions need to be mapped with an object which can perform the task.

Selection of a service may also depend on the distance between the user and the location of the service, and "level of compromise" in the service for the user.

5) Scheduling of Functions

After deciding about the objects which can perform any of the required functions, the scheduling of each function need to be done because output of a function might be required by another function.

6) Providing one/multiple functionality

After mapping the desired functions and scheduling them for different physical objects, it is time to get the results. So the selected objects are communicated according to the schedule. At this level the service proxy takes care of the connection heterogeneity, i.e. objects with different communication medium.

7) Getting reply from object(s)

Each object is supplied with a set of inputs and the outcome is sent to the service proxy. The output of each individual functions are collected at this lower layer.

8) Assembling the functional outputs into a single service

As discussed earlier, a service can be a conglomeration of multiple functions. Thus the output of each functions need to be assembled to get the final service.

9) Serving the request of a user

Finally, the requested service is delivered to the user. The service proxy hides the details about breaking/assembling of functions from the user. The user requests for service and gets the service.

C. Feasibility of using Service Proxy

A centralized service proxy can be overloaded with the information about virtual objects. Then searching its database would also become a heavier task. Another concern is whether anyone can search an object or a service. This will became a major concern from the aspect of security and privacy. These challenges can be addressed by using a smart service proxy scheme. We envisage that there will not be a single service proxy. A layered structure of service proxies can be deployed. A lower tier service proxy will store information about the virtual objects in its vicinity only. Moreover it will store a small amount of information. As finding a service does not require a millisecond granularity (in most of the cases), the service proxy can ask an object for more information about it online. When a user sends a request, it attaches his signature with the request. This will verify an authorized request. If required, the service-proxy can ask further authentication information.

D. Advantages of Approximation-Service approach

An approximate service might not always meet the user requirements. Moreover, it can sometimes trigger a false positive. Thus this approach may not be beneficial. However, there is a set of advantages which can be achieved by using approximate services. First of all an approximation will come into place only when the exact service is not available. It will never replace an exact service. Other advantages are:

(1) Better availability of services to the users;

(2) Resources are used in a more efficient way; and

(3) A large number of users can be served with varying needs.

V. Conclusion and Future Work

In this paper, we introduced Approximate Service and a simple framework with Service Proxy for lookup. We motivated towards the use of such a new paradigm. We provided a real life example. We provided a series of blocks that are necessary to offer such a service. We identified various steps towards finding and providing an approximate service. We plan to extend this work with a complete framework and also provide nuances of such a framework. We believe that Internet of Things would enable and require as well new paradigmatic shift towards completely cognitive service provisioning.

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