Approximate Service Provisioning in an Invisible Network of the Future

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***Abstract*— Communication and specifically networking has brought a huge change in our lifestyles. Coupled with the increased use of mobile services, more and more population is increasingly being networked. It is observed that people are dependent on networks, networked devices, and the services provided by them. People, in the near future, will get even more connected and dependent on the ICT systems. Higher the dependency, higher is the complexity of the desired services from these systems. Further, as we can see that this dependency will drive people to expect the services everywhere, and it may not be feasible always. Thus, when a particular service is unavailable at a location, one has to find some form of services that is as similar as possible to the one sought after. We envisage here a dynamic, approximate service composition. It is expected to satisfy the users under the given circumstance though it is not a complete service. Thus these approximate services may be seen as a conglomeration of different functions provided by different systems, entities or devices. Hence, we need to be ready to explore the possibilities of such services and architecture which are not rigidly defined.**

***Index Terms*— Approximate Services, Future Internet, Internet of Things, Opportunistic Services**

I. Introduction

Mark Weiser almost 20 years ago, in his seminal paper [1], provided his vision of the ubiquitous computing: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it". This vision is in fact is the driving force in the current context of miniaturized technologies and communication substrates. The idea is to enable seamless and interoperable connectivity amongst heterogeneous number of devices and systems, hide their complexity to the user while providing sophisticated services and applications. The challenge is to connect, collect and distribute information amongst devices with different degrees of complexity and capability - from simple and passive RFID tags to multi- front-end high speed networked and mobility enabled Personal Digital Assistant (PDA). Ideally, the Future Internet should be able to classify and represent information of communicating and non-communicating devices, objects and entities, which are present in the physical world.

"1000 devices per person" paradigm [5] is indeed a much discussed topic in recent years. However, there is no denying that the number of devices per person is growing steadfast. The expectation is to bring more efficiency in the use of all the resources that humans use now while boosting the quality of life. Whether it is 1000 or 100 devices per person, the complexity of networking and maintaining them is definitely a need of the hour. Moreover, each of these devices which support a person will not be complete in itself but they cooperate and support each other to form an end-user service. The vision of this article is that these devices are just similar to umpteen number of tools we use in our daily life. Similar to the way we use many of the tools in a harmonized way these devices surrounding us are also used.

Given the explosion of ICT enabled devices, we need to address many tough questions such as, management, availability, accessibility, service provisioning, etc. We envisage that in near future we will see many of the objects would have some form of presence in the digital world enabled by wireless interface on the device, or a RFID tag, or due to (nano-) sensors in the surrounding – thus these resources are decentralized and are in the periphery concentrating around small pockets such as homes, offices, cars, etc. The sensors and many other installations in the surrounding will be capable of providing some services to us. In the past we have seen many projects and research initiatives, for example Personal Networks and Federations [6] (Fig. 1), which is context aware, secure and self-organizing. In this short note, we try to think futuristically and concentrate on the service provisioning in such a large scale network.

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If we define “function” as the individual support offered by a device, “service” would be a conglomeration of such functions. Some of the functions may be re-used in a way that may not be conceived at its creation. These devices surrounding us and supporting us will be part of the Internet of Things (IoT). With many devices and services around a person, the first question is how to locate a service. Ontologies of devices and services are one method to classify, and locate services. While these are standard services, we conceive of IoT enabling services similar to humans i.e., approximate services. For example, the system should help a user locate a *hard* object (he needs a *hammer)* when a hammer is not in his vicinity. It requires a clear vision and also flexibility to provide services similar to humans.

The rest of the article is structured as follows. Section II describes an overview of projects and ideas about the future Internet. In Section III, we describe our vision of the future Internet i.e., approximate services. Sections IV and V describe the idea of approximate services and research issues in its construction. We conclude the article in Section VI.

II. Internet of Things and Future Internet

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 towards the Mark Weiser’s vision under FIRE initiative [2]. NSF also dealt with the Future Internet initiatives in Future Internet Design (FIND) [3], 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 [4]. While Future Internet research, development and deployment are going at a full pace, academics and industrialists are asking the question as to how to use promised futuristic networking capabilities. How to make the services offered to users better than before? Without a clear adjudication on this question, industry will not support the above initiatives. A critical challenge is the management of the future internet infrastructure, platforms and the vast amount of information, which is collected, distributed and stored. We have to evolve from the old Client-Server paradigm and Service Oriented Architecture [14], to new architectures which are at the same time both scalable and reliable while being flexible and dynamic in nature. In this context, we can clearly see that many cognitive and human decisions like aspects need to be addressed in the near future and they will be a major issue to deal with. We believe that the main goal Future Internet is to stitch together many functionalities offered by multiple devices (servers in the old parlance) to provide a *solution* to users’ needs.

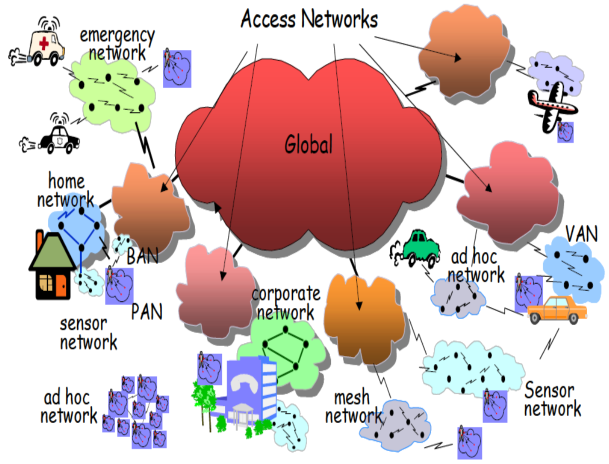

Fig 1.Personal Networks (EU-Magnet Beyond)

III. Our Vision

Humans can use instruments, objects, and all the available resources - physical or intangible (knowledge, experience, etc.) - adaptively in any situation. Humans derive applications based on the context and availability owing to previous knowledge. Thus, many times they indeed get services which are not exact but still are able to carry on with available and possible services. Let us take an example. A table knife that we use daily has one defined view – that is to cut the bread. However, it could be used by humans, in case required, for many purposes. For example, it can act as a screw driver, and it could also be an envelope opener. In a small area if one could somehow find an apple and if this information could be given to person who is hungry, then the purpose is served. Though this is trivial for us, it is not hard to imagine the complexity involved in enabling this in the digital world. The question that is driving us now:

“Is it possible to use the Internet (of Things) depending on the requirements and the context, just as we humans do?”

This sort of service provisioning has an advantage of using the system that is nearby and can resolve the requirements to an extent possible.

IV. Approximate Services

Every *object* (a representation of a physical entity; we shall restrict for the time being an object as a simple Internet enabled device) can provide certain functionality. A service can, thus, be defined as a as a set of re-usable functionalities with a pre-described interface with constraints and policies as specified in its service description.

The foremost requirement in the near future is to find services and may be even searching physical object[2]. Further, if the search is for a tangible object or service (not a virtual service in the Internet) searching in the vicinity of

[2]Just imagine that I am able to search for a green pen on my big table in my office, or to elegantly put it, searching for a book which is not in my shelf. Just as Google does it for us in the virtual world.

the user takes priority. Thus it is desired to explore a localized search space first for the service. However, finding the best and perfectly matching service requires a lot of time and infrastructure support. Most often than not, we tend to get a rough service (close to what we expect). A case in point is that when we search the web, we do not always find an exact answer to what we have looked for. Thus, we define the term *Approximate Service*, in very simple terms as, a service that is a conglomeration of various functions offered by a single or multiple object to satisfy a user in realtime.

A. Types of services

We classify types of services here, note that it is non-exhaustive. The services in future would thus be,

(1) Exact service;
(2) Approximate service;
(3) Opportunistic service;
(4) a Federation of multiple services to compose an approximate service which may not be good but is the best under the circumstances;
(5) Offloading computationally intensive tasks; and
(6) Dynamic composition of services.

We are more interested in the service types (2)-(6). The types are self-descriptive. Here we give an for each type. Some examples of approximate service provisioning were mentioned before. The system should help a user locate a *hard* object (he needs a hammer) when a *hammer* is not in his vicinity.

An example of opportunistic service provisioning is a smartphone or a PDA automatically recording a meeting (learns the user is in a meeting from the context).. A federation of services can be understood by the example of using a networked printer & scanner may act as a finger print authenticator. Offloading service example can be a mobile device asking its WiFi access point to check a file for malicious content. In dynamic composition of services, one or more objects slightly to suit the immediate need. For example, the scanner in previous example dynamically composed its service for authentication.

B. Construction of Approximate Services

We need to move from the paradigm where devices execute predefined tasks to an opportunistic and a malleable one. There are already some attempts to intelligently select and compose services [12, 13]. Many services of the plethora of heterogeneous devices surrounding us are to be abstracted into its generic functions. That means single service hitherto would be represented as multiple functions and with varied levels of intensity. Ontology of such functions is not known yet. Thus such representation should have the following variables, capability set, etc. One non exhaustive example set is given here:

(1) Functional capabilities;
(2) Resource capabilities;
(3) Latency (real-time) capability;
(4) Level of cognitive abilities;
(5) Lifetime/resources left;
(6) Dynamically found remaining resource/lifetime;
(7) Number of concurrent support functions;
(8) Generic functions (characteristics of the functions) offered; etc.

These generic capability set helps in application/service development. Now, the important question is how to get a service by combining the functionalities from multiple devices offering some support. If there is no predefined set for a particular service, then this service composition should happen on the fly. Formally, we can describe it as follows.

Let $f_1, f_2, \dots f_N$ are functions where each function is from one or more devices. We can then define an exact service as

$$S_e = \psi(f_1, f_2, ..., f_N)$$

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 $F = \{f_1, f_2, f_3, ..., f_N\}$ is the set of functions used to form S_e and $A = \{a_1, a_2, ..., a_M\}$ 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

$$S_a = \varphi(a_1, a_2, ..., a_M)$$

The missing functions are compensated by using alternate methods. For example if an iris-based authentication server is not accessible, then it may be replaced with a phone based authentication i.e., if the user has the phone with the same number as in the database, then he may be authenticated.

V. SERVICE PLATFORM

A. Aura as a Service platform

To enable the above objective, we propose the concept of an *Aura* around each person (Fig 2). This aura could have the range of a smartphone, RFID enabled ring, BAN. It is interesting to note the difference between aura proposed in [8], to our idea. In [8], authors define aura around an object with each object having the possibility of having more than one aura – each aura representing a space of interest for an object. However, we define aura of objects around a person. However, there are some functional similarities. We define aura only to support the concept of Approximate Service Provisioning. We envisage that the devices do have some form of cognitive/knowledge plane (it can be simple location matching to complex AI (Artificial Intelligence) based decision making) and their approximate location. We do not restrict the aura to be only around the person in the physical terms, it could also be the digital presence of a person in the cloud. A simple mobile device may be an interface to his/her aura in the cloud. The devices in the aura ask for some service on behalf of the person and the devices in the surrounding returns with a service composition based on available resources and the context. The decision to ask for a service is based on the cognitive ability of the aura. Highly evolved aura could seamlessly keep looking for services to support a person. This aspect makes sense in case of a patient with Alzheimer's disease. This requires some common language to express the requirements (like XML), cognitive and cooperative techniques, and approximate location information. With the introduction of aura, the supporting network would be invisible but always present opportunistically. We thus call this set up a completely an Invisible network.

The main idea seen here is breaking this humongous number of devices into smaller groups based on the aura and the vicinity and/or approximate and opportunistic services (refer to finger print authentication using a scanner). We believe this reduces a lot of traffic, and enables searching for services that is most natural (as humans do). Since the aura should start growing, mimicking the person, there will be business opportunities for service providers to keep updating the intelligence in the individual aura which would be retrieved whenever required. The approximation, opportunism and cognition and cooperation are the key elements for this future pervasive service provisioning.

Fig 2. An Invisible Network -- Aura around Persons

B. *Collaboration and Cognition for Sustenance*

An aura is not directly related to any location. An aura creates a virtual vicinity feeling for its user. Depending on the opportunistic nature of the existence of the objects, technologies, etc. the influence zone of the aura may change. Not all auras will be self-sufficient. Additional resources or services may be required. Although the user can query the service and use it inside its own aura there may be some services which exist outside and in other devices or others' auras. There has to be cooperation amongst auras and devices in the vicinity or remote is needed to complement each other's shortcomings. However, when the offered service leads to costs like capital, energy, privacy at the other devices, enforcement is required to sustain the cooperation. This enforcement may be an external one like reputation collection mechanisms where the more you help others your reputation increases which in turn allow you to exploit the services of others.

On the other hand, without an external enforcement which adds up to the complexity of the protocols and inference engines, the cooperation may emerge naturally amongst the devices. Five of the explanations of the evolution of cooperation, emerged from Evolutionary Game Theory, are presented in [10]. The five mechanisms are, (a) *Kin Selection*, (b) *Direct Reciprocity*, (c) *Indirect Reciprocity*, (d) *Network Reciprocity*, and (e) *Group Selection*. These mechanisms will invariably used in an aura when it interacts with surroundings and others. Depending on the relation among the peers, the cooperation might be observed in terms of one or more of the above cases.

With the above discussions, it is clear that the cognition has to be implemented in an aura. To implement cognition, we envisage devices and their functions be represented as an *object*. An object is an ephemeral compilation of functions and attributes, that provides a complete and coherent interface for operations. An object may span over multiple devices. Without cognition the approximate service composition as well as finding a solution would be impossible. Further, to achieve better approximation, the cognition should continuously evolve. If we want to achieve a seamless and invisible network in the future, aura should keep evolving with cognition and context and of course learning from the preferences and reaction of the owner of the aura. One way to introduce cognition and collaboration into the network is by introducing a cognitive control plane. As depicted in Fig 3., the cognitive control plane provides smart decisions to control resource sharing operations in objects, and collects and manages the state transitions over the lifetime of resource sharing operations [11]. While cognitive control plane is required to achieve a "thinking" network for realizing a set of objectives such us improving the quality of service or optimizing the management of the available resources, it is also required to handle the service requests, find what objects can involve to realize an approximate service. Based on the gathered context about the resources, user objectives and mobility patterns, the cognitive engine plans, decides and executes the proper action such as adapting a protocol parameter or allocating physical resources to applications or services. There may be situations when multiple approximate services can be realized, then the cognitive plane makes a decision to provide the best-fit service to the user. The elements in the cognitive engine may be neural networks, swarm intelligence, evolutionary programming, immune or fuzzy systems, etc. The cognitive engine adapts itself continuously by using the context database, and a priori actions and their feedbacks.

The context database is updated from the input through observations of the states of the virtual or physical resources via sensors; e.g., state of the congestion levels in the network, to which the multimedia trunks are assigned, residual battery levels, queue sizes of the services, memory utilization of the applications or user behaviors. Instead of using the vast amount of unprocessed data, the input can be filtered to extract the useful information that can be considered as feature extraction. Further, a continuous online processing of contexts, events, requests are required to take immediate decisions and steps. For example, whether to wait for a particular service to be fulfilled completely or to just go ahead with whatever is available though not to the complete satisfaction.

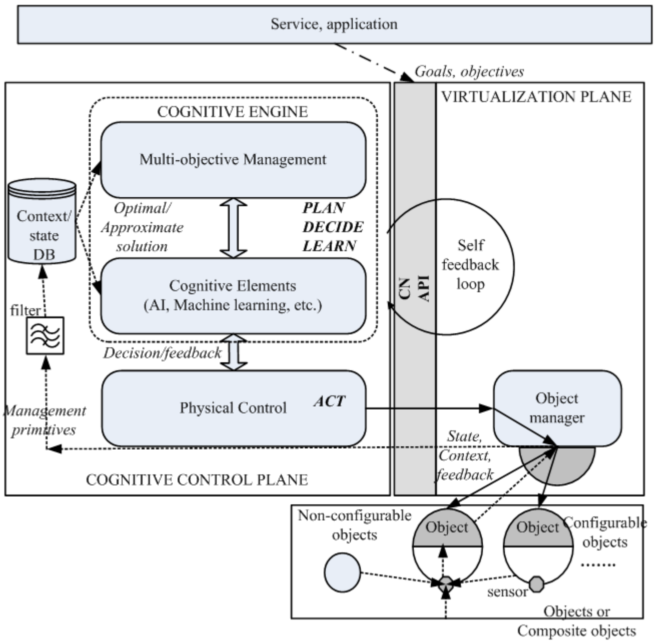

Fig. 3. Collaboration through cognition.

C. Ontologies and Tags

Ontology based frameworks can be used to classify, locate and achieve certain level of autonomy by the devices within the aura [9]. Resource Description Framework (RDF) language can be used to represent ontology at lower layers, and Ontology Web Language (OWL) can be used at the top layer. The ontological framework is for semantic description of services and devices, or in general, for objects. A reasonser such as Pellet can be used to infer logical deduction from set of axioms defined by the users. While such representation and reasoning is necessary for approximate services, but not sufficient. Implementing a "think-out-of-the-box" is not complete with this. However, the learnings of the reasoner, for example a new "usage" of an object was found, should be inserted into the framework.

Tags enable a bottom-up approach to resource or service location. In some cases, tags or knowledge tags, may be useful to compose services on the fly, with or without the support of ontological framework.

VI. Conclusions

We presented a vision for future internet and future outlook for IoT. It is expected that, in the near future, multiple devices offer multiple sets of functionalities and they have to be stitched together to satisfy the exact requirements. However, when such a possibility of completely satisfying a user doesn't exist what should be done? This article precisely addressed this question. It presented a grand new vision of approximate service provisioning. We also rendered some possible ways of achieving this type of services. We furnished possible constructs to build such services. We argued that, unless the services are provided seamlessly with whatever the level of satisfaction that could be achieved, the future Internet will not be able to evolve into a substrate in our lives. The prospect of something around a person, without the notice of the person, keeps looking for possibilities of providing useful services is very likely due to the advent of technology. The concept of Approximate Service Provisioning, thus, will make the future Internet a truly invisible network.

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