Social-driven Internet of Connected Objects

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***Abstract*—Internet evolution has been recently related with some aspect of user empowerment, mostly in terms of content distribution, and this has been ultimately accelerated by the fast-paced introduction and expansion of wireless technologies. Hence, the Internet should start to be seen as a communications infrastructure able to support the integration of a myriad of embedded and personal wireless objects. This way a future Internet will support the interaction between users' social, physical and virtual sphere. This position paper aims to raise some discussion about the technology required to ensure an efficient interaction between the physical, social and virtual worlds by extending the Internet by means of interconnected objects. Namely, it is argued that an efficient interaction between the physical, social and virtual worlds requires the development of a data-centric architecture based on IP-driven opportunisitc networking able to make useful data available to people when and where they really need it, augmenting their social and environmental awareness.**

***Index Terms*—user-centric paradigm, data-centric architecture, IP-based opportunistic networking**

I. Introduction

Recently, the Internet evolution has been related with some aspect of user empowerment (e.g. content generation and distribution by end-users) and this has been ultimately accelerated by the fast-paced introduction and expansion of wireless technologies. Wireless gave the means to expand Internet services beyond the working sphere and towards a social sphere. Hence, the Internet should be seen also as a communications infrastructure with capability to support interconnection and integration of a myriad of embedded and personal wireless objects. Today, the majority of such devices are able to communicate within short-range due to wireless capability, directly or via some third party, with social and contextual awareness, provided that a specific platform supports such interconnection. This is the beginning of a new computing and communication era that will significantly impacting society. In this new era the increment of processing power will increasingly and transparently embed technology into our everyday lives.

This idea is supported by forms of ubiquitous information made evident with the widespread use of networked gadgets that have become an integral part of everyday life for many millions of people. Such objects are normally connected into some infrastructure and normally rely on ambient information to interact both with the user, with infrastructures, and with the environment surrounding Internet users. More often, such objects have social requirements and may mimic up to some extent a social behaviour in the way they interconnect. Internet users are therefore the central point of focus in the way these objects interconnect, and impacts the way they change information.

Around the information society there is therefore a social ecosystem of objects that often may require spontaneous support for interconnection. The potential of such ecosystem as a driver of novel business and development opportunities is the motivation that supports the development of interconnected objects able to take advantage of spontaneous communication opportunisties. Such communication ecosystem is expected to support augmented entertainment, business, and social experiences embedded in our daily lives.

The overall requirement for an Internet of connected objects is to stimulate economic growth, improve people well-being, and to address some of today's societal problem namely by including interactions in the physical world as a source of communication opportunities in the virtual world. With this perspective in mind, this position paper aims to raise some discussion about the technology that is required to ensure an efficient interaction between the physical, social and virtual worlds while estending the Internet by means of interconnected objects.

II. User-centric Internet of Connected Objects

The vision pursuit in this position paper is of a user-centric Internet of connected objectd where users will implicitly interact with their physical and social environments by means of software embedded in portable objects with augmented sensorial capabilities. This pervasive embedded communication system will augment people's daily life experience, leading to a perfect relationship between virtual, physical and social worlds. In a world increasingly mediated by technology, the road to an Internet of connected objects can only be achieved through user-oriented strategies where there is a strong connection between stakeholders that create technology and those that use it. That is, people should be at the core of the overall vision, as their needs will be central to future innovation in this area. Indeed, technology and markets cannot exist independently from the principles of a social system.

The interconnection of physical objects is expected to amplify the profound effects that large-scale networked communications are having on our society, gradually resulting in a genuine paradigm shift. This vision does not rely on objects that are only capable of collecting and disseminating data to central databases. Instead, a user-centric vision of an Internet of connected objects is more consequential, in the sense that objects can now participate in conversations that were previously only available to humans: objects will be

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aware of dynamic community structures, thus being able to develop a spontaneous networking infrastructure based on the information to be disseminated and not only on the objects themselves.

The presented vision requires a IP-driven communication system able of sustaining seamless and intelligent communication amongst a large number of social-aware objects. Such objects may be intermittently connected most of the time, and may be capable of collecting and processing data without a constant human intervention. The result is a self-organised ecosystem able to make useful data available to people when and where they really need it, augmenting their social and environmental awareness.

A user-centric view of an Internet of connected objects is expected to result into a network platform capable of sustaining distributed communication among networked objects, being such communications local, through direct wireless links, or global, via the Internet. This requires a standardization effort in order to ensure the interoperability level required to achieve economy of scale and low market entry barriers.

III. Data-centric Architecture

Since the beginning that the Interent architecture aimed to create a communication model able to sustain the conversation between hosts. Thus IP packets contain two identifiers, one for the source and one for the destination host, and almost all the traffic on the Internet consists of (TCP) conversations between pairs of hosts. As the Internet become bigger in size and in number of applications, several challenges started to appear, such as more demanding applications, security issues and spam traffics. All these challenges increased with the creation of a broader Internet communication scenario, encompassing communication from and to a large number of connected objects.

To ensure its socio-economic success in this broader comunication scenario, the Internet architecture should be able to handle tussles [1] (i.e. conflicts of interest), leading to a major requirement: be design for change, based on the requirement of evolvability, which is difficult to achieve with an host-oriented architecture that requires a solid relationship between all pairs of communicating nodes. The current host-oriented Internet operation is based on routing packets using the destination host IP address, which means that the Internet was designed to serve the sources of traffic: packets are delivered to receivers triggered by the source. However, the current Internet architecture does not consider the possibility of the receiver being unwilling to collect specific types of data. Hence, the original design of the Internet has led to a sender-receiver tussle, in which the sender has too much control over the network. This is the cause of several problems, such as the large amount of unwanted traffic in the Internet. These problems will increase in a Internet of connected objects, in which sources and receivers of data are most of the time not synchronized.

Data-centric networking provides a potential scalable model for communication in an Internet of connected objects, since the architectural focus is shifted from the end-devices to data. In this context, network nodes and end-hosts may loss part of their importance, since the identification of sources of data may not be important in a transmission when the data is timely and correct.

One initial question is: what is the most suitable starting point for the development of a data-centric network? A number of networking architectures have been proposed recently that support data-centric operation. Many of these systems build on flat labels, such as ROFL [2] and DONA [3], or hierarchical names such as CCN [4].

Nevertheless, the first question that come up when designing any architecture is scalability, namely the balance between the data to be forwarded and the size of packet headers. In the Internet design, the packet header contains the destination address and all nodes know their next hop towards all destinations. The only known way to make that design to scale is to aggregate the address space so that state is needed only for each aggregate. On the other hand the Internet may use source routing, where the path is described hop by hop in the packet header. This way, a single forwarding node does not have to know anything else than its neighbors. However source-routing is well-known by its problems related to packet sizes and security. A data-centric approach is based on the assumption that there are no stable end-to-end addresses for the network nodes, since such addresses used as identifiers reduce the ability to support mobility and multi-homing, and removes from the receivers the ability to control data sent to them. However, a network design that does not require nodes to have addresses may generate several problems, especially for routing and forwarding.

In order to ensure a smooth migation towards an data-centric Internet of connected objects, several architectural challenges have to be addressed including:

- Removing the barriers of deployment and wide-scale acceptance of the Internet of connected objects,
- Establishing corresponding mechanism for its efficient integration into the service layer of the future Internet.
- Defining a resolution infrastructure allowing scalable look up of object resources in the real world.
- Defining technology to augment the usefulness of objects in generating local and timely data, which needs to be synchronised with human/object behaviour.

IV. IP-based Opportunistic Networking

In terms of networking capabilities, many of today's sensor networks are evolving toward a protocol translation gateway model, similar to what happened before with computer networks. However, protocol gateways are inherently complex to design, manage, and deploy. The network fragmentation leads to inefficient networks, because of inconsistent routing, for instance. Of importance in a future Internet of connected objects is the transparent integration of mobile objects and embedded systems into an overall Internet communication architecture. For IP capable devices, IPv6 is a natural solution with suitable address space to cater for the size and scale of a network.

While IPv6 and Wi-Fi may be the most promissing candidates to extend the Internet to a set of personal connected objects, such as smart-phones, in what concerns the utilization of IPv6 in embedded devices, one of the most interesting candidates is proposed by the 6LowPAN IETF working group. The 6LowPAN approach tries to make embedded objects accessible through IPv6 by mapping and compressing the IP header information and translating addresses for IEEE 802.15.4 networks. The benefit here is that the routing/gateway functionality is only needed on the networking layer. In the same context, the *IP for Smart Objects Alliance* (IPSO) aims to study the utilization of IP for communicating smart objects, as suggested by the action plan for the deployment of Internet Protocol version 6 (IPv6) in Europe [5].

Nevertheless, a vast amount of effort still needs to be invested in coping with disruptions due to mobility in wireless networks, which is assumed to occur very often in an future Internet of connected objects. Recently, in sensor networks there has been a shift from dealing with uncontrolled mobility to exploiting controlled mobility, where for instance, the delay and communication cost of data collection is improved by designing movement trajectories for collector sinks.

However a user-centric Internet of connected objects should not consider that the mobility of devices is controllable. Moreover, we cannot assume that there is always an end-to-end path between any pair of nodes in the network in any moment in time. In such scenario, routing based on wireless mesh or ad-hoc routing protocols, as the one being standardized for 6LowPAN networks (RPL [6]), may not suffice since all current proposals assume that at any time at least one end-to-end path between any pair of nodes exists. In a user-centric Internet of connected objects, routing by intermittently connected networks may happen upon a contact opportunity resulting from the social ties between people and their mobility. From these approaches, SimBet [7] and BubbleRap [8] present a new perspective to routing for challenged networks by identifying social factors as major building blocks. This is not inline with the current view of the IRTF DTN Research Group, which is not focus on the routing problems of opportunistic networks, presenting proposals such as PROPHET [9] as potencial starting points in the standardization process.

Since these proposals pose strong assumptions about the feasibility of creating communities on-the-fly, SocialCast [10] show that forwarding can be achieved not only based on the social ties of people and their mobility, but also considering the interests programed of captured by destination devices. However, the assumption that nodes with similar interests are co-located does not always hold, thus limiting the scenarios where the proposed approach applies.

Hence, more effort should be employed to develop an approach within the information-centric and user-centric perspective to support the routing task, by adapting state-of-the-art approaches and by proposing innovative ones.

V. Summary

In this position paper it is argued that the major requirement for an Internet of connected objects is to stimulate economic growth, improve people well-being, and to address some of today's societal problem namely the replaced of interaction in physical world with intertion in the virtual world. With this perspective in mind, this position paper aims to raise some discussion about the technology that is required to ensure an efficient interaction between the physical, social and virtual worlds by means of extendign the Internet via the use of interconnected objects.

A balanced interaction between physical, social and virtual worlds is supported by the development of a data-centric architecture based on IP-driven opportunisitc communications able to make useful data available to people when and where they really need it, augmenting their social and environmental awareness.

In what concerns the development of a data-centric architecture, several potential adoption concerns have to be analysed, since the supported paradigm is very different from the end-to-end paradigm that have been supporting the growth of the Internet since its origin. In what concerns the inclusion of IP-driven opportunistics communication, several standardization efforts to implement IP in embedded object need to be complemented with solutions able to handle opportunistic network formed by the mobility and social behaviour of users corrying different types of objects.

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