User-Centric Networking

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1. Introduction

In the latest years the highly nomadic lifestyles that Internet users experience, and the strong entanglement between society and technology, lead to the appearance of community networks where the end-user has, most of the times, an active role in terms of sharing Internet access. Such networks range from basic functionality, such as the ability to create a wireless (ad-hoc) network on-the-fly with a simple PC (e.g., Internet Connection Sharing functionality from Microsoft), or more elaborate cases of commercial success, e.g. FON. Wireless networks provided by end-users are expected to grow, despite the limitations imposed by traditional operator-centric Internet communication models. In this new scenario the end-user (or a community of end-users) is a micro-operator in the sense that he/she shares his/her subscribed broadband Internet access based on some incentive scheme. Besides Internet access sharing, being a micro-operator also means providing other network functionality, such as local mobility management and store-cache-forward mechanisms, based on the right set of incentives as well as on adequate information concerning the way people interact and move. User-provided networks disrupt Internet communication models due to its user-centricity. First, any regular end-user device may behave as a relay of information and consequently becomes part of the network, which has an impact on the Internet architecture: the central building block of the Internet, the end-to-end principle, describes a clear splitting between network and end-user systems. Second, user-provided networks grow spontaneously based on the willingness of users to share subscribed Internet access and to relay data. Such willingness is sustained by trust management and incentive mechanisms that mimic social behavior. Third, between communities of users connectivity is intermittent. User-provided networks have to consider mechanisms that support routing in intermittent connected networks, as well as quick and transparent mobility management between micro-operators. Fourth, people mobility has an impact on connectivity provided by user-provided networks, since human carried devices will also be willing to operate as networking devices. This characteristic means that a realistic modulation of human mobility and social patterns is fundamental for the optimization of user-centric networking technologies. Fifth, most of the devices used by humans will use wireless technologies to communicate, which means that taking advantage of the broadcast nature of the wireless media by means of cooperative networking techniques is of core importance to an efficient deployment of user-centric technologies, in terms of throughput gain and energy saving for instance.
The purpose of this seminar is to bring together researchers from core disciplines for the future of user-centric networking: Internet architecture, human behaviour and mobility modeling, as well as wireless and routing optimization. We outline such disciplines in the following five areas of interest:

- Impact on Internet design. Considering that the end-user is part of the network has implications on the architectural core of the Internet, given that there is no clear splitting between intelligence on the middle of the network and on end-user devices. Impact of middleboxes that have been emerging due to the Internet evolution (e.g., NATs, proxies, firewalls) increased complexity in the network to the end-user. User-provided networking goes a step further, given that end-user devices will be part of the network. This area will consider Internet design from the perspective of the four main properties, namely reliability in end-to-end transmission, routing, mobility, and security.

- Trust models and incentives. User-provided networks are highly dependent upon mechanisms capable of quickly developing a network of trust in environments where devices have a highly nomadic behavior. Grassroots mechanisms are one of the basis of debate within this area. Mechanisms capable of transposing community beliefs and user expectations (e.g. level of confidentiality that the user expects on a specific moment and for specific applications) to networking will be addressed. In addition, systems that aim to fight back selfishness of peers (fight back the tragedy of the commons) are to be considered.

- Human behaviour and mobility models. Mobility of end-users in user-provided networks highly affects topology, the way information is routed or relayed, as well as the type of information to be passed. Mobility of individuals gives the chance to devise adequate connectivity models, provided that one can mimic human behaviour in terms of movement. This area will be focused on discussing the nature of mobility and social patterns for humans, as well as ways to transpose such behaviour into a network perspective. The basis for discussion will be community-based models, of which we highlight the recent trend in social mobility models.

- Wireless cooperative networking. In addition to cooperation as a tool of trust management, this area will focus on cooperative MAC aspects as a starting point to develop augmented medium access, relaying, and to optimize resource management. The goal is to allow networks of users to organize themselves taking advantage of human behaviour and highly dynamic surrounding conditions, while preventing surges of network load that may endanger the access subscriptions.

- Robust routing algorithms for dynamic networks. Devised algorithms able to make routing decisions based upon information about node resource constraints (e.g. energy, transmission opportunities) as well as users’ behaviour (e.g. mobility patterns, social interaction) and their willingness to cooperate (e.g. by sharing Internet connectivity and/or forwarding capabilities). Discussion should also consider routing algorithms able to operate based on the notion of information, moving away from the current endpoint-centric networking model.

2. Technical Contributions

2.1 User-centric Networking in the New Smartphone Era: Some Thoughts

By Mirco Musolesi

Mobile phones are increasingly equipped with sensors, such as accelerometers, GPS receivers, proximity sensors and cameras, that can be used to sense and interpret people behaviour in real-time. Novel user-centered sensing applications can be built by exploiting the availability of such technologies in these devices that are part of our everyday experience. Moreover, data extracted from the sensors can also be used to model people behaviour and movement patterns providing a very rich set of multi-dimensional data, which can be extremely useful for social science, marketing and epidemiological studies.

This talk aimed to discuss the key issues in building user-centric sensing systems, addressing the key system design challenges and outlining the key open issues for the networking community. I I will briefly discuss how we are using these data to model people activity and movement patterns in the geographical space.

2.2 Mobility in User-Centric Networks: shall users participate?

By Susana Sargento

This talk discusses the mobility management in user-centric environments. User-centric architectures bring in several challenges to the traditional and tightly controlled mobility management schemes. First, in user-centric scenarios, the network elements are usually devices either carried or controlled by regular Internet users or providers. Second, users share subscribed Internet access. Third, users (and hence, the devices they own) tend to be mobile, with large dynamicity. Fourth, in these networks it is envisioned that some control features can go to the network formed by the users. If in these control features we consider mobility, a new paradigm for mobility may be required in user-centric scenarios.

This talk discusses the possibility to include mobility control features in the network elements, where some of these elements can be owned by users, analyzing different aspects of the problem: (1) the pros and cons of such an approach; (2) which control functions can go to the users; (3) the concept of seamless mobility in these networks; (4) trust and security concerns; and (5) what can mobile users expect from mobility in user-centric networks, from performance to service differentiation and privacy aspects.

2.3 User-centric Networking: Boon or Bane?

By Stefan Wevering

End-user centricity is on everyone's lips in the Telco industry. In the context of this presentation User-centric networking is understood as User-provided networking, meaning end-users share their Internet access with other individuals. One popular example is the so-called WiFi sharing communities, FON being maybe the most prominent community.

The motivation for sharing Internet access is manifold and needs to be analyzed from the different angles of end users, network and service providers and communities. Especially the service provider perspective is very important, given that traffic volumes to be transported over their networks are increased, without additional revenue generation. This leads to the situation that some service providers disallow network access sharing contractually. On the other hand in some countries service providers are partnering with WiFi sharing communities. The motivation of the service providers for these co-operations is not publicly available.

But also from the end user perspective, i.e. those users, who share their Internet access, needs to be addressed. In Germany for instance, end users do not sufficiently protect their WiFi access against utilization by third parties are at least partially guilty if their Internet access is being misused. This leads to the situation that content owners request warning fees from the contractual Internet access users in case of copyright infringements.

For investigating the impact of user-provided networking further, it is important to discuss and consider the Business models for the different stakeholders. Furthermore, any kind of network architecture needs to take into account national regulations and laws in order to be successfully used.

2.4 Droplets: Condensing the Cloud

By Jon Crowcroft

The commercial reality of the Internet and mobile access to it is muddy. Generalising, we have a set of cloud service providers (e.g., Amazon, Facebook, Flickr, Google, Twitter, to choose a representative few), and a set of devices that many, and soon most, people use to access these resources (i.e., so-called smartphones such as Android, Blackberry, iPhone, Maemo). This combination of hosted services and smart access devices is what many people refer to as ``The Cloud'' and is what makes it so pervasive.

But this situation is not entirely new. Once upon a time, as far back as the 1970s, we had `thin clients' such as ultrathin glass ttys accessing timesharing systems. Subsequently, the notion of thin client has resurfaced in various guises such as the X-Terminal, and Virtual Networked Computing (VNC). Although the world is not quite the same now as back in those thin client days, it does seem quite similar in economic terms.

But why is it not the same? Why should it not be the same? The short answer is that the end user, whether in their home or on the top of the Clapham Omnibus, has in their pocket a device with vastly more resource than the mainframe of the 1970s by any measure, whether processing speed, storage capacity or network access rate.

Meanwhile, the academic reality is that many people have been working at the opposite extreme from this commercial reality, trying to build ``ultra-distributed'' systems, such as peer-to-peer file sharing, swarms http://bittorrent.com/, ad hoc mesh networks, mobile decentralised social networks, http://joindiaspora.com, http://peerson.net/ in complete contrast to the centralisation trends of the commercial world. We choose to coin the name ``The Mist'' for these latter systems. Haggle, Mirage and Nimbus are examples of architectures for, respectively, networking, operating system and storage components of the Mist.

These approaches are extreme points in a spectrum, each with its upsides and downsides. We will expand on the relevant capabilities of two instances of these ends subsequently;

2.5 Enabling community-based Wi-Fi access

By Pantelis Fagroulis

In densely populated urban areas Wi-Fi networks are ubiquitous. Wi-Fi Access Points are typically attached to broadband links, which often have excess capacity. The question that naturally emerges is whether this user-provided infrastructure can be exploited to achieve inexpensive wireless connectivity for nomadic users, thus offering a low-cost alternative to cellular services. To this end, community-based wireless access schemes have been developed, with FON being one of the most well-known ones. On the other hand, we have developed a fully decentralized architecture for peer-to-peer Wi-Fi sharing based on the concept of indirect service reciprocity. The distinctive characteristics of our approach are that (i) it requires no user registration with any central authorities, (ii) does not assume altruistic users, and (iii) makes use of tunneling mechanisms to protect user traffic from untrusted APs and to protect visited APs by malicious visitor activities, for which AP owners could be held responsible. A comparison between our system and FON reveals several design options and trade-offs, such as centralized vs. decentralized design and commercial vs. not-for-profit operation, among others. Also, there are important issues that are yet to be tackled, which include enabling wireless communities that scale beyond cities, dealing with user mobility, developing solutions that are user-friendly and minimize managerial overhead, managing interference and, last but not least, overcoming potential legal barriers (such as Wi-Fi sharing restrictions imposed by ISPs or the need to ensure user traceability).

2.6 Trust Management: Requirement in User-Centric Networking?

By Rute Sofia

In the latest years a trend for free and/or shared Internet access has been emerging in the form of social wireless networking, being FON the most emblematic commercial case as of today. In the FON model a user registered in the FON community acquires a “social access point/router” to share an already existing Internet access with other FON users. Several other cases similar to FON abound, and this is a trend that the authors believe has tendency to further spread. Such trend relates to a new way of performing networking, where the user becomes part of the network, and hence, these networks are known as User-Provided Networks (UPNs).

Current UPN examples relate mostly to simplistic technical ways of sharing already existing Internet subscriptions. Most of today’s UPNs simply disregard data confidentiality and user anonymity aspects. For instance, in FON the user sharing a connection has a private slice of the shared access resources, but the users that are profiting from the shared resources are provided with an insecure wireless connection. Moreover, in the FON model the sharing node is imputed with all the responsibility in terms of the traffic being generated by visiting users.

Having data confidentiality and the notion of social trust in mind, WiFi.com, provides users with the Whisher plugin, which allows sharing the connection based on trust levels derived from social networking tools, e.g. Facebook. This opens up the possibility of having different types of access depending upon the social trust that a sharing user has with others.

Providing UPNs with adequate security mechanisms is not trivial to achieve, as we shall explain. UPNs consist of three main entities: the user, the Micro-Provider (MP) and the Virtual Operator (VO). The MP is a user that shares/provides some form of networking service to regular users. The VO is the entity or organization that manages the community but however does not hold a specific infrastructure nor does it specifically sell a service. A VO is therefore not an Internet Service Provider

(ISP), given that it does not provide Internet access, nor does it provide any type of service, like what is today provided by an Application Service Provider (ASP).

UPN growth is today mostly sustained by the “free roaming” incentive but however, security incentives should be taken into account, particularly considering that UPNs will evolve to accommodate few-hop access sharing. Other worrying factors in terms of security related to the autonomic nature of these networking architectures, which makes it hard to consider specific security mechanisms to be generically applied.

A key factor that has assisted so far the expansion of these type of architectures is trust as perceived by humans in social networking. Currently, the examples that are around us have expanded solely by the willingness of the end-user to become part of these communities, i.e., to trust unknown users (e.g. in terms of the nature of generated traffic and in terms of the supported data confidentiality). Hence, UPN scalability is basically growing due to the end-user’s belief that the benefit of using them is higher than the risk incurred, as well as due to the type of use UPNs are offering.

From a global perspective, UPNs are growing and expanding due to a social trust management scheme, which is decentralized and controlled in an ad-hoc manner by individual users. This means that in reality there are strong security concerns associated with these networks, in particular related to data confidentiality from an end-to-end perspective. And when there is some attempt to provide a sense of security, confidentially is only ensured partially, given that it is only ensured on the wireless link to the MPs. A user can cope with this gap by relying on specific privacy mechanisms, e.g., using some specific application or establishing a tunnel to a specific, trusted entity (e.g. a VPN to an enterprise). The flip-side of this is the associated overhead both in terms of configuration/processing time, and in terms of data. However, despite the fact that the MP communication is protected, malicious traffic may pass by the MP device (e.g. access point) provoking serious access violations.

What is argued upon in this paper is that UPNs should integrate trust models that mimic social trust behavior, in order to achieve better scalability. By ensuring that users are trusting in some form users with whom they have some interaction, UPNs will scale in a more robust way, transparently to the involved parties and to access providers, with whom MPs may or may not hold an Internet access subscription. Trust modeling in UPNs requires as basis grassroots mechanisms, the foundation for social trust management. Such trust models can assist in evolving UPNs into new paradigms that will revolutionize the way we perceive Internet access and services, like is already happening today.

2.7 User-centric Network Fault Detection and Repair

By Henning Schulzrinne

Using modern networks remains frustrating for both technical and non-technical users. Applications fail or are impaired for no discernible reason, or temporarily perform poorly. Users resort to the retry-reboot-and-reinstall philosophy of system management, and the various providers of services, from ISP to application service providers, are incentivized to blame others for failures. We propose DYSWIS (Do You See What You See), a new peer-to-peer mechanism where users cooperate to isolate faults and, where possible, provide work-arounds, e.g., for NAT and DNS problems. DYSWIS analyzes protocol behavior, detects problems, asks others for diagnostic assistance and provides a user-focused report of the likely problem sources. Protocols include the lower-layer protocols such as IP, DNS and DHCP, as well as higher-layer protocols such as RTP and SIP

2.8 Cooperation Framework For User-Centric Networking

By Paulo Mendes

In recent year the Internet has evolved from providing personal experience, by means of technology such as email or skype, to a platform able to provide social and environmental experience to end-users.

Social experience may be achieved by means of the so popular social networks, and by means of using user-centric technology to share the internet access, such as FON, wifi.com or even mifi.

Environmental experience can be provided by plugging sensor networks to the Internet (which has seen the majority of the research effort in last couple of years) and by making use of end-user computation power as well as sensorial and communication capabilities to create on-the-fly cooperative networks of communicating objects.

The development of technologies aiming to augment the social and environmental experience in our daily life may benefit from a data-oriented Internet centered in the devices carried by users (e.g. smartphones, embedded objects), of that users have at home (e.g. WiFi access points).

The realization of a data-oriented Internet able to profit from the increasing number of end-user devices (their computation power, location, storage, etc) may require the investigation of a certain number of technologies such as: a) models able to allow a better understanding of the incentives needs to motivate users and access operators to adopt a novel technology; b) networks of trust able to reduce the risk that users may see in sharing resources with others; c) technology able to make the best of transmission opportunities in order to allow operation in challenging environments; d) technology able to allow the aggregation of computational power in other to create scalable and low-cost computing infrastructure.

A central aspect of all the above mentioned technologies is the capability to achieve the best trade off between make usage of any transmission/computational opportunity and the capability of compensating wrong opportunistic decisions, by employing cooperative (diversity, user, spatial) technologies

2.9 User-Centric Paradigm for Seamless Mobility in Future Internet

By Fikret Sivrikaya

This talk aims to bring in a different view of user-centric networking, driven by the ongoing EU Project PERIMETER. In this view users do not serve or share network connectivity but become an essential part of the network operation by providing and exchanging network performance and measurement data in the form of Quality of Experience (QoE) reports. A generalization of this may be thought of as a first step towards the distributed, user-centric formation of a knowledge plane for the Future Internet. Another aspect of user-centric networking mentioned in the talk relates to the access scheme and identity in future cellular networks, where users may not be tied to a single operator with contractual agreements but get real-time connection offers and dynamically choose their access provider among different operator offers. A distributed database of user-centric QoE reports mentioned earlier, supported by a reputation mechanism, becomes essential for users' decision making in such a scenario.

2.10 Towards Crowd Computing

By Eiko Yoneki

Today’s smartphone is a powerful computer. A modern smartphone, such as the iPhone 4, has a one-gigahertz processor, half a gigabyte of RAM, and 64 gigabytes of flash storage. They also contain a variety of other processors such as 3D GPUs and DSPs. And perhaps most interestingly, they contain an array of sensors, like a multi-megapixel camera, accelerometers, compass and GPS receiver. Furthermore, increasing number of options for network connectivity is equipped with such modern smartphones. Of course smartphones have a 3G connection possibly even 4G these days. But there is also the potential for peer-to-peer transfer using WiFi or Bluetooth. For longer tasks, we can exploit mobility in the network, first to gain access to far more devices, and second to give a much larger network capacity. Inspired by the increasing prevalence of smartphones, and research into opportunistic networking in our previous work in the Haggle project, we introduce the potential of using these devices to carry out large-scale distributed computations. We call it crowd computing. A crowd computation spreads opportunistically through a network, using ad-hoc wireless connections that form as devices come into proximity. The devices can exchange input data and intermediate results.

Why is crowd computing attractive? Previous work has shown that people will voluntarily contribute their desktop computer resources for running scientific workloads. We could imagine a similar application for mobile devices that provides free content or functionality in exchange for volunteered cycles. Furthermore, unusual devices such as graphics cards and games consoles have been used to perform high-throughput computing. A modern smartphone has several special-purpose cores (such as DSPs and A/V codecs), which could similarly be applied to large-scale problems. Moreover, opportunistic networks in which the nodes are mobile offer potentially huge bandwidth, turning a collection of smartphones into a mobile supercomputer. Alternatively, we can use crowd computing as a means of distributing human interaction tasks to mobile devices. For example, Amazon Mechanical Turk has created a marketplace for carrying out work that is difficult for computers to process, but relatively simple for humans. Many qualitative classification tasks are much easier for humans than computers, such as “What is the best Sushi restaurant in San Francisco?” By combining this model with crowd computing, it would be possible to exploit geographic locality in the respondents. We begin by seeking an upper bound for the computational capacity of an opportunistic network in our work, where we have shown preliminary results that indicate the potential for crowd computing. Human interaction can be used to spread computation through an opportunistic network, and collect results. Furthermore, a simple task farming model can achieve reasonable performance in such a network and dramatically better performance when social network structure is used.

Task Farming

In order to build a practical system for mobile distributed computation, intelligent task farming is required for achieving parallelism. Task farming is the basis of many distributed computing systems, including Condor, BOINC, MapReduce and Dryad. In all of these systems, a single master process manages a queue of tasks, and distributes these amongst an ensemble of worker processes. When a worker completes a task, it requests another from the master. The algorithm naturally handles worker failure and load balancing. Task farming is therefore an obvious candidate for distributing work in our crowd computing system. We modify our model of distributed computation as follows. The overall job can be decomposed into a large number of atomic, independent tasks, which have a constant duration. The initiator acts as the master, which maintains a (potentially infinite) queue of tasks to be executed. We can improve the efficiency of distributed computation by exploiting the social network formed by human interaction. Previous work has looked at the influence of graph structure and community detection on the efficiency of opportunistic networks used for communication. We have investigated the use of community structure to improve the overall utility of a computation. By analysing real world interaction traces, we have seen that people's interaction patterns provide ample opportunities for computation to spread through a network of devices. We can improve the efficiency of these systems by exploiting social information: by analysing the social graph formed by the interactions.

We must acknowledge that optimising distributed computation in crowd computing is a complex parameter space. We are also developing programming languages that enable developers to implement a crowd computation, which enables programmers to create an opportunity for new scheduling algorithms that take execution order into account. We hope that our work will serve as a starting point for crowd computing to grow in the future.

Acknowledgement: This work has been done together with Derek Murray, Jon Crowcroft and Steve Hand at the University of Cambridge.

2.11 Cooperative Wireless Networking: User-centric networking in the wireless domain

By Shivendra Panwar

Wireless will be the dominant mode of internet access for end users in near future. However, bandwidth limitations of the wireless channel, interference from multiple users operating in the same band, and channel variations due to fading become bottlenecks for typical multimedia applications that require high bandwidth and an error resilient communication medium. Cooperative networking, by enabling wireless terminals to assist each other in transmitting information to their desired destinations, provides a promising technology for significantly improving the performance of wireless networks. Cooperation can be built into WiMAX standards like IEEE 802.16j and 802.16m, as well as LTE Advanced, both of which incorporate relays. The emergence of user-owned femtocell base stations offers the option of the availability a large number of femtocell access points that also act as relays, or “femtorelays,” in contrast to the small number of dedicated relays that have been considered in studies thus far. This fundamentally changes traditional cellular architecture, while offering a cost effective means of increasing their capacity.

In this talk we provide an overview of cooperative wireless networking, and summarize some of our recent research activities that span multiple layers of the protocol stack. By incorporating the notion of user cooperation at the medium access control (MAC) layer, we show how these benefits can be realized in a large network. Applications like video are facilitated by cooperation, particularly when using randomized distributed space-time coding (RDSTC). We also outlined our current efforts in building a experimental cooperative networking tested.

2.12 Random Thoughts on User-Centric Networks

By Ioannis Psaras

We began from the notion of User-Provided Networks, where users share connectivity resources. In particular, home-users share their broadband Internet connections with roaming strangers, i.e., guest-users.

Although there are a lot of interesting issues to investigate in this realm, we realised that sharing connectivity resources only is not the most we can make out of User-Centric Networks. We therefore, went one step further to investigate the possibility of sharing and exploiting other types of resources. We realised, for example, that the home-AP, the central entity for connectivity sharing according to UPNs, can provide other types of services as well, e.g., storage services.

Exploiting sharing of storage resources together with connectivity resources among users, we can achieve user-centric content localisation. According to that notion, content can be stored closer to the user, i.e., closer to where it is actually needed. In that sense, content can transparently “follow the user”, instead of “chasing the user”, as is done in today’s host-to-host communication platform. That could benefit a number of players and network operations. For instance, delays to reach home-, or mobile-users will be minimised and also ISPs can offload traffic to the edges of their networks. This, in turn, obviously raises a number of open research issues, from efficient content storage and dissemination to load balancing at the edges of the network and further to new business models.

Building on the above ideas, we elaborated on the broad area of Home-Networks and realised that future smart homes need a device that can serve as the Home Cloud. This device can provide new services and applications, not available today and in a user-centric manner. A common interface and new OS functionalities would be needed in that case, in order to coordinate both home appliances with networking functionality and traditional fixed and mobile networking devices. Although there has already been some research done in these areas, it is not yet evident that a future Home App Market can be supported.

2.13 *-Centric Networking

By Erik Nordstroem

This talk is about finding the intersection between a number of often loosely defined areas of network research that aim to break free from the host-centric communication model of the Internet. Such areas are typically labelled content-centric, people-centric, service-centric, user-centric, context-centric networking, and so forth. Here we group them together under the term *-Centric Networking. Often, these areas of research differ more in name than definition, or vary widely in scope depending on person. Despite discrepancies in definitions, this talk makes the conjecture that there are common key lessons and principles that can be distilled from these areas of research. The fact that so many of these research areas have emerged during the past few years indicate a community unhappy with the status quo, but also that it might not yet have formulated a strategy for future solutions or figured out the means to solve the underlying problems.

This talk approaches the problem of distilling key principles and lessons by drawing upon recent work in two network research projects: Haggle, focusing on community-driven content sharing between mobile devices, and SCAFFOLD, focusing on building flexible large scale services and data centers, typically operated by large corporations. These two projects represent two opposite ends of the networking spectrum -- yet, they have many commonalities. For example, principles such as late binding, flat names and identifiers, and dynamicity are at the core of both projects. Identifying such common grounds will hopefully help the research community to quickly home-in on the key principles and designs for the future communication networks.

2.14 Intelligent Algorithms and Clever Applications in User Centric Networks

By Artur Arsénio

We aim at covering several aspects relevant for user-centric networks, and potential applications. Current research work is discussed with respect to eHealth applications, focused on body area network of sensors connected to the internet through edge gateways (such as mobile devices, home or automobile gateways).

Context and learning play in important role, in order to provide new levels of remote healthcare to patients. We discuss the importance of correlating such user information with social networks to identify new patterns for diseases spreading. Energy efficiency is also discussed in the scope of sensor and telecommunication networks. Finally, we discuss heterogeneous wireless networks to increase throughput, energy efficiency and communication reliability.

3. Conclusions

The presentation and brainstorming sessions allowed all participants to discuss the role of the user-centric networking in several different perspectives such as user-centric requirements (e.g. social behaviour; energy efficiency), mobility management, access aspects, cloud architecture, trust management, network fault detection and repair, cooperative networking, identity management and applications.

Based on the results of the brainstorming session, it was decided that would be interesting to create a User Centric Networking Working Group (UCN-WG) to continue the discussion started in this Dagstuhl seminar. To start wit it was created a mailing list (ucn@uitc.ulusofona.pt) and a wiki page. The latter should be used to collect links about relevance information, from presentations to publications, running code, etc.