A Software Defined Network Solution for Spontaneous Wireless Access Extension

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Abstract. Spontaneous wireless networks enabled by mobile end-user devices (e.g. smartphones) are receiving considerable interest due the possibility to offer a wide range of novel, highly pervasive and user-centric network services and applications. Novel and extremely flexible network deployment strategies are required in order to cope with the user mobility, the limited communication capabilities of wireless devices, and the intrinsic dynamism of traffic loads and QoS requirements. In this paper, we want to trace the path, and related challenges, that lead toward a *Community Owned Wireless Access Network* (COWAN) to provide Internet and Cloud-based services through the sharing of resources owned by the end-user devices. In such way, Software-Defined Networking (SDN) solutions could play a central role in order to make easier the network creation and management and to deliver performance guarantees to end users. However, the extension of the SDN paradigm to mobile devices requires facing the challenge of moving some network control on end-user devices to support network interaction capabilities and services.

Keywords: Wireless access networks · Software defined networks · Self-organizing and spontaneous networks

1 Introduction

Recent advances in telecommunications have led to the proliferations of wireless devices able to access the Internet through a multitude of wireless technologies. At the same time, we register an increasing research interest towards spontaneous networks composed by mobile end-user devices which share their network resources in order to extend Internet coverage and services availability.

The interest is encouraged by the availability of several wireless interfaces (e.g. WiFi, Bluetooth, LTE) through which spontaneous networks can be dynamically established. A new communication paradigm, characterized by the fact that the access network has a strong spontaneous nature and is primarily made up of users owned devices, is emerging.

Several authors conducted previous works in such direction. In [1] a new generation of network nodes able to provide intelligent and city-wide services for citizens, city authorities and utilities was proposed. The proposed STEM-Net was conceived as an evolutionary solution for deployment, extension and

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management of the network infrastructure in a smart city. The proposed solution was capable to face the heterogeneity of devices and network technologies and the fragmentation of coverage and connectivity in urban areas. The STEM-Net paradigm foresees the realization of a new generation of wireless devices, called Stem Nodes (SNs), that are able to self-configure at multiple layers of the stack on the basis of their hardware configurations, and thus to assume multiple network roles (i.e. gateway, relays, etc.). Such a multi-purpose nature justifies the parallelism with the biological counterpart. Similar with a stem cell, a stem node can undergo mutation in order to fulfil a given task. Mutation is driven by both built-in node capabilities and additional capabilities that are dynamically learnt by cooperating with other nodes.

In [2] authors focused their attention on emergency-related scenarios and investigated the potential of spontaneous networks for providing connectivity over the emergency area through the sharing of resources owned by the end-user devices. A novel approach toward the deployment of spontaneous networks composed by wireless SNs was proposed to emphasize their ability to cover multiple network roles (e.g. gateway, router). The self-organization of the spontaneous network was achieved through the local reconfiguration of each SN.

In [3], a special case of User-Centric Networks (UCNs) named Spontaneous Smartphones-based Networks (SSNs), has been treated where the role of the end-user devices is played by smartphones that are, "*evolutionary*" and more active in supporting communication services. SSNs present key features like spontaneity in the creation of the network and redefinition of the device role in order to make them continuously adaptive to both network and users requirements. The work was devoted to identify the potential advantages of SSNs, by also providing a clear definition of the challenges and the issues that need to be faced in order to make this emerging paradigm effective and practically deployable.

As a natural evolution of these previous works, in this paper, we want to trace the path that leads toward a *Community Owned Wireless Access Network* (COWAN) to provide Internet and Cloud-based services through the sharing of resources owned by the end-user devices. This new approach offers great advantages in terms of *(i)* lower costs required to set up the network access, *(ii)* reduced or no maintenance at all for network management, and *(iii)* possibility to set-up a network even on scenarios where the infrastructure is poorly available (i.e., disaster scenarios, rural areas, least developed countries, etc.).

Despite the enormous potentials, a COWAN based on smartphones or similar devices (e.g., phablet, tablet), is still a challenge [3]. Usually, the network creation and management requires a massive intervention from the users that, however, would prefer being agnostic about technological issues. This requirement constitutes a unique challenge of COWAN compared to traditional self-organizing systems and generic multi-hop ad hoc networks [4,5]. Hence, a framework able to limit the human intervention, with the aim of making the network management as much spontaneous as possible, is mandatory for the success of the COWAN approach. In such way, Software-Defined Networking (SDN) contribution could play a central role in order to make easier the network creation and management and to deliver performance QoS guarantees to end users.

The rest of the paper is organized as follows. In Sect. 2 we introduce the concept of Community Owned Wireless Access Network. In Sect. 3 we motivate the benefits of a SDN contribution introducing open issues and challenges and then conclusions follow in Sect. 4.

2 Community Owned Wireless Access Network Scheme

Community Owned Wireless Access Network (COWAN) are based on smartphones or similar devices. The deployment of such kind of network is particularly suited on scenarios where the infrastructure is poorly available (Fig. 1). An extended pervasive wireless Internet access can be obtained by naturally extending the coverage of wide areas using the huge density of smartphones located in all daily life environments. When natural catastrophes disrupt traditional network infrastructures, a COWAN can support communications between survivals and rescue teams. Moreover, when special events (e.g., concerts, trade fairs, Olympic games) involve huge numbers of people with risks of overloading the communication infrastructure, COWAN can be used to offload mobile data traffic from cellular networks.

The logical architecture of a generic end-user smartphone is illustrated in Fig. 2. In our design, a network node is defined as a special case of Stem Node [2] and, in particular, we use the term Community Smart Node (CSN) to indicate novel family of software enhanced smartphones. We further note that in our view, a CSN may be like a simplified variant of Stem Phones (SPs) defined in [3], so a

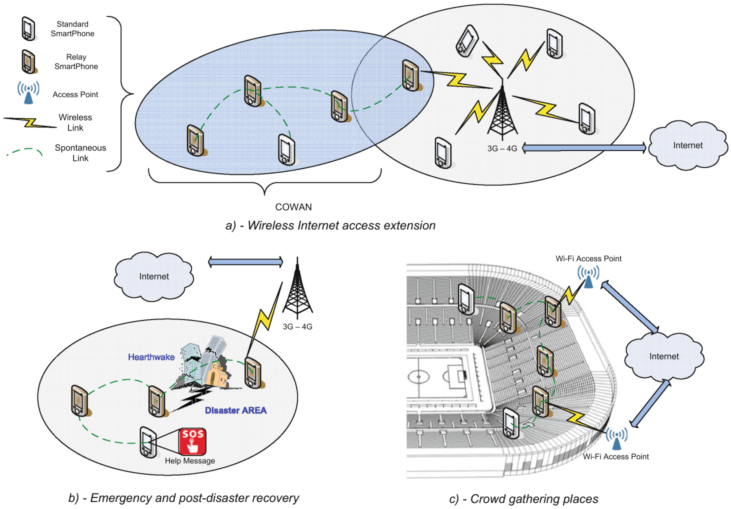

Fig. 1. COWAN communication scenarios.

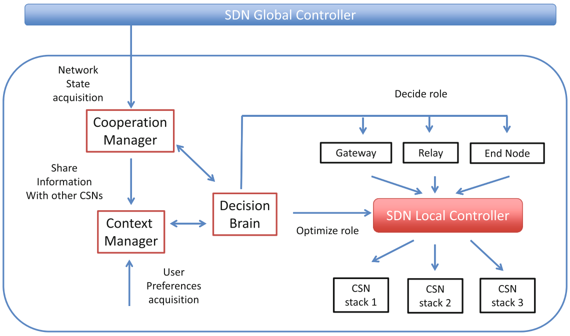

Fig. 2. Community Smart Node architecture.

limited fraction of the existing smartphones that can still provide useful services to the neighboring legacy phones.

Each CSN, participating to the COWAN setup, can play a given set of roles according to the network capabilities/functionalities supported by the specific device. The basic set of roles of each CSN include the ability *(i)* to produce/receive data (i.e. End Node role), *(ii)* to forward the traffic of other terminals (i.e. Relay role) and *(iii)* to act as a gateway (i.e. Gateway role) providing access to global network resources to other terminals.

The set of roles played by each CSN can vary in accordance of its own built-in characteristics (i.e., hardware features or user preferences). For example, the gateway role could require the simultaneous use of different communication technologies to connect other nodes (e.g., Wi-Fi, Bluetooth, IEEE 802.15.4) and to access to global network resources (e.g., LTE). Moreover, each role is mapped to a stack configuration and it is foreseen the possibility, for a CSN, to change its configuration over time for self-optimization purposes.

3 SDN Contribution to COWAN Scheme: Open Issues and Challenges

To make really feasible a COWAN solution the big challenge is to limit, or reduce to zero, the user intervention in the network creation and management. Such processes should be as much spontaneous and transparent as possible. In such way, Software-Defined Networking (SDN) contribution could play a central role in order to make easier the network creation and management and to deliver performance QoS guarantees to end users [6,7].

The main benefit of SDN is the separation of the data and the control plane to provide a global view of network and allow an easier way to configure and manage it. In SDN, user devices are substantially responsible only for packet forwarding. Existing mobile phones are generally equipped with multiple network interfaces, complicating the process of selecting the best access technology at each moment (e.g. WiFi hotspots, WiFi access to fixed residential home gateways, LTE cells). A generic mobile node may decide to use the available access network options sequentially (i.e., move all traffic from one technology to another) or simultaneously (i.e., move selected flows from one access to another).

In our vision, we suppose that telecom operators, which already offer both residential fixed and mobile connectivity services, can also offer to external parties (e.g., service providers) a set of SDN API to make available SDN services at the edge of the network. This particular condition influence the decision of which access technology should be used to deliver a certain type of traffic to a specific mobile terminal or group of users. In such a context, it can be assumed that each mobile node can easily join to a Software Defined Wireless Network (SDWN) [8].

These strong assumptions are away from the scope of our proposal and we are aware of the presence of several challenges, not yet overcome, which make such scenario extremely difficult to achieve. However, the main contribution that we want to provide is another step forward, the creation of a multi-hop extension of a SDWN, namely the COWAN.

To meet this challenge, we propose to export SDN software modules in the architecture of a Community Smart Node (CSN). The design of SDN is based on centralized control functionality for simplicity and flexibility (i.e. OpenFlow, NOX). However, they did not adequately address scalability and reliability requirements of a COWAN architecture. Some alternative distributed and/or hierarchical solution could be compliant with our purposes [9–11].

The Kandoo scheme [10] appears to be the most suitable because it is a hierarchical implementation of SDN controller for OpenFlow. Kandoo creates a two-level hierarchical SDN controlling system that distinguishes local controllers and management applications from global ones. The local controllers manage a subset of nodes and execute applications which do not need network-wide views, whereas the global controller is responsible for managing all the local controllers and implementing global policies. In such a way, the SDN integration is provided introducing a hierarchical implementation in CSNs architecture. The consequent introduction of a SDN Local Controller block allows each node to be able to select the most appropriate protocol stack, SDN compliant, related to the specific role to play.

4 Conclusions

In this work we have presented the potential of COWAN, motivating the need to integrate the functionalities of SDWN to minimize users' involvements in network set-up and maintenance. We believe that the implementation of SDN modules in each smartphone architecture, could favor the diffusion of research activities focused on Community Owned Wireless Access Network.

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