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# Enhancing reflection and self-determination in a real-life community mesh network

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ABSTRACT

This article discusses the Network Characterization Daemon (NCD), a piece of software that provides users of Community Mesh Networks (CMNs) with an interactive tool to monitor, evaluate and fine-tune their network nodes.

First, CMNs are introduced as a particular case of Community Networks (CNs), and their participation challenges are analysed. The NCD is then discussed as a novel solution that provides CMN end users with mechanisms to assess network performance and improve their quality of experience by modifying their devices' network configuration. The relation of the NCD with Quick Mesh Project (qMp) and the BatMan-eXperimental version 6 (BMX6) routing protocol is detailed as part of the social and technological context.

The NCD also provides an experimentation framework to evaluate network performance in real-life CMNs. The latter part of this article covers the experiments performed using the NCD to assess network performance (in terms of path selection, Round-Trip Time (RTT), etc.) when different BMX6 routing policies are applied. The results show how, under different traffic conditions (e.g. distinct packet sizes), using specific routing policies leads to an improvement in network performance.

Finally, the integration of the NCD in qMp is discussed, in order to ensure its long-term sustainability.



## 1. Introduction

Community Networks (CNs) are IP-based networks designed, built, operated and maintained by communities of individuals that join together and cooperate to satisfy their telecommunication needs. They consist of distributed and decentralized network devices – hooked up via wired and wireless links – that interconnect computing systems, service providers, content repositories, end user devices, etc., handling the traffic between them. The sizes of CNs range from a few nodes to the tens of thousands [1,2].

The main difference between the CNs paradigm and the traditional commercial Internet Service Providers (ISPs) is that end users are not mere consumers, but active contributors and stakeholders of the infrastructure [3]. This empowerment comes along with rights and duties: having a voice for decision-making, the obligation by some sort of network license or agreement [4,5] and, to a limited extent, the freedom to audit and participate in the control and management of the network resources and infrastructure.

There are, however, several obstacles that significantly limit this freedom. Leaving aside CN issues like participants' organization, technical and legal aspects of the network deployment, etc., this document focuses particularly on the day-by-day usage, monitoring and maintenance of the CN. For such an important task, there is a lack for convenient

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tools to help end users evaluating and understanding the state of the CN as a whole (or, at least, the part of the network around them, which plays the most important role in the perceived performance and quality of experience). Despite the existence of many networking tools [6,7] to inspect particular characteristics of Metropolitan Area Networks (MANs), they are tailored for use cases that significantly differ from those of CNs. Typically, MANs are owned or controlled by a single or few entities. There, persons in charge of the network administration are well-skilled, able to perform complex evaluation tasks and have comprehensive control over all core components. This is not necessarily the case for an average CN user, whose boundaries for a comprehensive control are given by the nodes he owns. Furthermore, his/her skills can range between those of customers of a traditional ISP (i.e. being able to deal with an intuitive web portal on the home router) and those of a tech-savvy user.

To address the shortcoming of convenient tools for CNs, their members have created pieces of software to visualize the network topology, evaluate the links' quality and bandwidth capacities, etc. (see Section 2.1 for more details). However, these tools do not provide sufficient feedback about the performance of individual links and end-to-end (e2e) routes, nor illustrate the chosen path and the links involved when traffic is sent towards a given destination. This lack of information and control significantly hinders the potential of these networks and their routing protocols (RPs) to simultaneously adapt the route selection to both (i) temporary or long-term topology characteristics and (ii) user- or application-specific priorities.

### 1.1. Objectives and vision

The envisioned benefits of the NCD for CN users shall be illustrated with an example: a non-expert CN user is trying to obtain the best possible downlink connection to a server outside of the CN, reachable only via Gateways (GWs) or proxies located several hops away. By looking at the current network topology, shown on the web interface of the home router (the CN node), the user can learn about the topology of the CN, the capacity of the links, etc. and actively measure network performance in real time. As a result, the user can take actions to improve his/her network usage experience, by configuring the home router to apply different routing policies that bring to better performance. This way, optimal trade-offs between path delay, bandwidth and packet loss can be selected for different applications (voice over IP, large file downloads, etc.).

The NCD contributes to fill the gap between the CMN (consisting of devices running the Operating System (OS) and the RP, which provide most of their information via the command line, and the average CMN user, who is eager to interact with the network nodes using the mouse on a graphical environment. This is achieved by implementing a web-based graphical interface that allows the user to learn about the current network status, actively run performance tests and modify the routing policies of his/her network devices. The interface is built around a graph where the network topology, links' quality, etc. are displayed from a user-centric point of view. Additionally, the NCD provides a framework for experimentation that allows to systematically run sets of network tests, displaying the results in the graphical web interface itself. This capability is exploited and discussed later in Section 5.

The remainder of this article is structured as follows. Section 2 discusses the related work and Section 3 describes the technology and the concepts that have been leveraged for the development of the NCD. In Section 3.1 we briefly describe the CN selected for integrating our development and the challenges met during this task. Next, Section 4 presents the tool that has been created to facilitate users the interaction with their network, discussing its software architecture. Afterwards, in Section 5, we report on the tests made with our tools by executing two typical experiments. Finally, the conclusions of our work can be found in Section 6, as well as the future work plan.

## 2. Related work

Over the last few years, the upraising of Community Mesh Networks [1,2,8] has attracted an increasing amount of attention and several studies have been published to analyse the characteristics [9–12] of these networks from an academic perspective. However, apart from the increasing recognition and understanding of their insights, they provide little help to typical CMN users that often encounter the day-to-day real-life problems (such as capacity shortages, fluctuating bandwidth, etc.) and lack means to detect, understand, and solve these phenomena.

### 2.1. Monitoring tools for Community Networks

Various tools exist for CN providing a global overview of the network topology as well as detailed information about existing links and nodes. Some of them take the information from a rather static database (Guifi Network Map [13], WiND [14], Nodeshot [15]); some retrieve data from the nodes dynamically via Simple Network Management Protocol (SNMP) (Freimap [16]) and others use a combination of both (Nodewatcher [17]). A downside of these tools is that they require some sort of centralized infrastructure, introducing single points of failure. Moreover, advanced knowledge on systems administration and networking is required to deploy them.

Another type of mapping tools are decentralized monitoring services, which are often integrated in Mesh Node System (MNS) firmwares and are accessed via the nodes' web interface (FreiFunk [18], Gràcia Sense Fils (GSF) [19], qMp [20], Lugro-mesh [21], Commotion [22], etc.). These tools mostly rely on the topology information locally available from the RP (optionally, they enhance the representation with street map data from external services like OpenStreetMap [23]). These tools can show nodes and links that are known to the running RP but cannot assist in any centralized management task like node registration, address assignment or representation of planned links. However, they are instantly available to the users and showing a live snapshot of the topology.

The existing tools lack means to link a given CN topology with the experienced performance at a particular location in the network. Besides, they do not assist at all in fine-tuning the RP to improve the network experience. There, tools like *traceroute*, *tracepath*, My Trace Route (MTR), etc. are only of partial help because they only provide unidirectional e2e routes, leaving the impression to the user that the return path