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URBAN WIRELESS COMMUNITY NETWORKS: A PARADIGM TO BOOST SMART APPLICATIONS AND AN ACTIVE CITIZENSHIP

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Abstract—The smart evolution of a city is based on the widespread adoption of Information and Communications Technologys (ICTs). ICTs promise, in fact, to boost innovation into many domains. New mobility paradigms, social networks, educational platforms and monitoring tools for the safety of citizens could be all enhanced exploiting ICTs. These applications run on top of a mix of mobile and fixed networks maintained by Internet Service Providers (ISPs). This networking paradigm hides threats to the social and economical sustainability of the network. For instance, ISPs can manipulate users' data, since they have full control of the traffic in the network. Moreover, an urban network is tailored to be economically and socially more sustainable. In this context Urban Wireless Community Networks (UWCNs) should be favoured, as they represent a sustainable networking paradigm, ideal for the creation of innovative services for a new generation of smart-cities. The main purpose of this paper is to present the Urban Wireless Community Networks, with a brief analysis of the underpinning technologies and highlighting their prospective social impact. To this end, a review of potential applications is provided, concluding with an outline of the open- challenges that still needs to be addressed in order to foster the growth of a Community Network in the city of Trento.

I. INTRODUCTION

All the efforts towards the creation of a Smart City share the common goal of improving the quality of life of citizens. These efforts need to be sustainable: technological tools advocated to build the Smart City should therefore not be driven by the overfishing of resources. These tools must be also considered and evaluated in terms of their potential of attracting human, professional and economic resources, enhancing their value. In this context the concept of Social Capital, studied by Putnam [1], is revitalized. ICTs' goal is to emphasize the natural Social Capital of a city by creating digital tools able to stimulate the creation of values from the bottom, directly from the so called *active citizenship.*

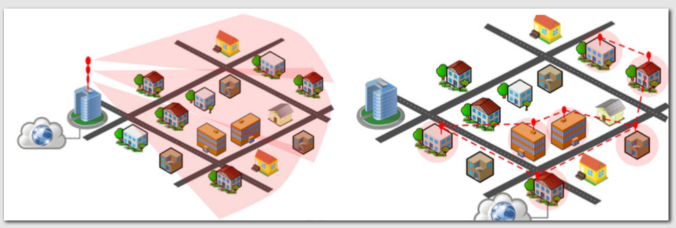
The factors that hamper this sustainable development and hinder the spontaneous contributions provided by an active citizenship must be therefore identified and tackled. Among these factors, the current networking paradigm emerges as serious obstacle. Consider for instance how users access digital services and, furthermore, ask yourself where do these services reside.

The answer is that users access all digital services from devices connected to a network: the network turns out to be the key infrastructure not only to access services, but also to host them. It is clear that the users' experience with digital services is greatly influenced by the kind of networks that host these services and provide a way of accessing them. Typical networks familiar for most users are mobile networks, daily used by people connected to Internet with their smartphones, and fixed networks, that reach almost every house in a city and empower connectivity in all buildings frequently visited by the public such as schools, hospitals, municipal offices, hotels and shops.

The first kind of these networks, the mobile networks, are built upon the cellular technologies. Large areas are divided in cells and, for each cell, a fixed-located transceiver offers wireless connectivity to all mobile devices present in the area. Cellular networks are built to maximize coverage, so to reach the largest number of users as possible. Reaching a large number of clients is fundamental for the few telecommunication companies that competes at a national level to attract clients and make profit out of them. The fixed networks is built on top of different technologies: instead of wireless links, copper paired wires and fiber optic lines are employed to ensure high- bandwidth and low-latency communication channels.

Both kind of networks share a business-oriented nature. The telecommunication companies (telcos) running these networks always ask users the payment of a fee so to bear with the costs faced for building and maintaining their network, which are of two kinds. The first cost is associated to the Capital Expenditure (CAPEX) needed to buy and deploy the networking equipments, while the second cost is associated to the Operating Expense (OPEX), i.e. the indispensable expenses to keep the network working over time. Moreover, consider that Service Providers need suitable hardware platforms for their services. It usually happens that these services are installed in big-data centres, so that hardware sharing allows significant cost reduction. By the way, it also means that all services are monitored from a central point of control in the network.

It is clear how the design principles kept in mind by telcos when building their network are business-inspired: these design principles maximize telcos' profits but do not to offer flexible services to users. For instance, the traffic due to users communicating inside a city is usually, very inefficiently, redirected outside the city so to reach one big-data center, where all traffic is actually always processed. This means that networks are not built taking advantage of the traffic locality we could expect using services related to a specific city. For example: to check the timetable of a bus in Trento, a mobile user may need to be connected to a data-center located in Rome, or even farer away. Moreover, the centralization of all services in big data-centres is a big danger for the privacy of users. The existence of a single point of control allows traffic inspection and manipulation, not only to authorized governmental agencies. The considerations drawn so far highlight the inadequacy of the current networking paradigm to serve a Smart City from different perspectives. From a technological point of view the mobile and fixed networks are not tailored to serve a city, but rather to connect users to data-centers irrespective of the traffic locality. From a social perspective we have to be aware that telcos and service providers have full control on users' data and manipulate it to make their own profit, thus putting in danger not only users' privacy, but also the expected neutrality and democracy of the network. Lastly, the range of services offered to citizens is entirely determined by service providers. An active citizenships willingly to craft and push an innovative crowd-based service would not be able to find a proper network where to install and run this service.



(a) A typical Wireless Internet Service Providers (WISP) offering connectivity via a powerful Base Transceiver Station (BTS). (b) Multihop paths highlighted in a mesh network.

Fig. 1. A comparison between the Wireless Internet Service Providers (WISP) network model and a Mesh Network (MN). (source: https://merge-it.net/talks/progetto-netcommons/slides.pdf)

UWCNs come into place as a new networking paradigm, a strategic alternative to offer local services and to enable innovation. UWCNs should not replace fixed and mobile networks, but rather complement them. They could represent the smart living space where users are free to experiment new technologies or develop innovative services, leveraging on the creativity and spontaneous contributions of active citizens.

To further introduce and explore UWCNs, in Sec. II the technologies underpinning these networks will be presented, followed by an outline of possible applications that can be built on top of UWCNs, as reported in Sec. III. The open challenges that still need to be addressed in order to favour the widespread adoption of UWCNs are discussed in Sec. IV; conclusions and final consider ations are presented in Sec. V.

II. ENABLING TECHNOLOGY: WIRELESS MESH NETWORKING

The technology enabling the creation of UWCNs is a mix of Mesh Networking and Wireless Communication Technologies. Unlike classic networks, which typically exhibit a hierarchical organization with an engineered topology, in a Mesh Network (MN) nodes connect to any reachable neighbour, ending up to build a mesh topology. Neighbouring nodes connect to each other via wireless links established between their respective antennas. Directional antennas must be used to create point- to-point links, but in general the same radio interface could be used to establish a link with different neighbours, thus Mul- tipoint Connection are the most common type of connection. Compared to a hierarchical and wired networks, in a Wireless Mesh Networks (WMNs) nodes need to face with care the problem of radio-interference.

The self-organized nature of MNs implies the lack of a central orchestrator governing the network. In a MN, nodes must therefore cooperate to route traffic. If two nodes are not in direct transmission range, they will have to implement a multihop-routing mechanism to let information travel across the nodes that separate the two communicating nodes, called communication endpoints. Multihop-routing is one of the main feature of WMNs, in contrast to the single-hop paradigm implemented in networks built by a typical Wireless Internet Service Provider (WISP). A comparison between the WISP model and the networking paradigm offered by a MN is illustrated in Fig. 1.

A WISP provides Internet Service by installing a Base Transceiver Station (BTS) in the area where clients reside, connecting each of them to the BTS directly or, in other terms, within a single hop, while multihop-routing is necessary in a WMN. The intrinsic advantages of WMNs are many.

Installation and maintenance costs are reduced, compared to a fixed or mobile network, with almost no wiring costs. Consider that wiring a network is expensive, time consuming and make the network inflexible. For instance, inside a city wiring usually requires digging and thus roadblocks, becoming even more costly. Furthermore WMNs provide coverage in outdoor environments and, in general, in areas not reachable by a wired infrastructure. Distributed management protocols are employed in WMNs in place of typical central coordination schemes and, thanks to these distributed protocols, WMNs are said to be self-healing and resilient [2]. In fact, if a network node fails, then the other nodes are still able to route traffic relying on the cooperative multi-hop routing. One last feature of WMNs is extensibility. Adding a new node only requires little expenses and no wirings at all, whoever wants to connect to the mesh network just need to find a neighbour to connect to.

Fig. 2. People installing a CN node on the roof of a building (source: https://blog.ninux.org).

A. COMMUNITY NETWORKS

The advantages offered by Mesh Networking and the new, cheap Wireless Communication technologies allowed the birth and growth of Community Networks (CNs). CNs are networks made of hundreds or thousands of nodes, which typically provide Internet access in under-served areas, sometimes even replacing the Internet for some specific services. This kind of networks grows when a group of people decides to build its own network, for many possible reasons. The process starts from few users and evolves involving more and more people, who contribute to the community buying and maintaining a new node, to be installed on the roofs of buildings, as shown in Fig. 2. In this regard, CNs exhibit a bottom-up network infrastructure and represent a virtuous example of collective cooperation enabled, from a socioeconomic perspective, only by voluntary contributions. From a technical point of view, the enabling technology for CNs is mesh networking: it boosts the resource sharing within the community, increases the reliability of the connection towards Internet gateways and keeps the traffic local among community users, which otherwise flows (inefficiently) through the Internet.

The networking paradigm offered by CNs has been pointed out as one of the most promising model to bring connectivity in rural areas and thus to address the digital divide problem [3]. But CNs can become a useful tool also for cities of well de- veloped countries that do not suffer for a lack of connectivity. In an urban context, for instance, a CN can be built by citizens to create, own and control the city's networking infrastructure: this will boost innovation, overcoming the technical and social restrictions imposed by telcos and ISPs as described previously at the end of Sec. I.

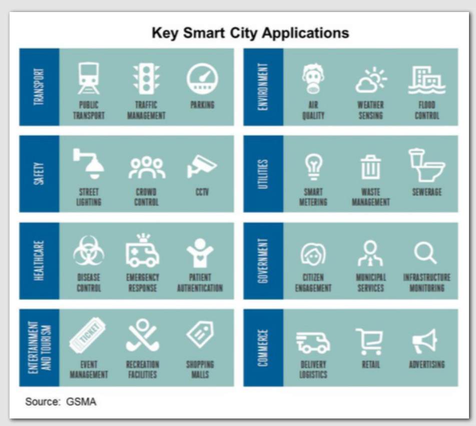


Fig. 3. Potential applications empowered by a UWCN in a Smart City. (source: https://preview.tinyurl.com/ycdwo8kk).

III. APPLICATIONS

The potential applications empowered by a UWCN are many and span over multiple domains. The illustrative table depicted in Fig. 3 provides an outlook of these applications.

A. MOBILITY

The UWCN infrastructure could be used to connect elements of the road network, so to enhance traffic monitoring and control. Traffic lights, for instance, could be optimized and tuned dynamically according to the traffic-data gathered by wireless sensors and by video cameras distributed in the whole city. This scenario is depicted in Fig. 4. Citizens in their car, connected to the same UWCN directly from their smartphones or from their smart-cars, could be alerted in real-time about accidents, deviations and roadblocks. Relevant info about public transportation, like delays of buses, could be provided by citizens and be distributed on the UWCN. A simple service that could be implemented by citizens for themselves, in collaboration with the municipality, is the open- access to video-cameras in the vicinity of bus stops: a worker at home could decide to leave home as soon as he noticed the bus arriving at a given bus-stop, or could even be notified with a message received on the smartphone.

Commuters that regularly travel inside the city can share their travel plan in the UWCN: users interested in catching the ride can avoid to take their own car, thus jam and pollution could be reduced implementing a car-sharing platform at a municipal scope.

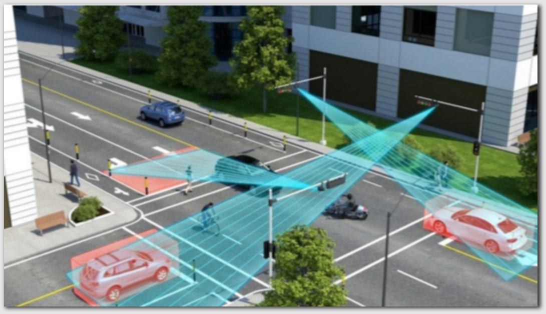


Fig. 4. An illustration showing how video-cameras installed on traffic lights could be part of the UWCN so to implement an optimized traffic control system. (source: https://preview.tinyurl.com/ychsv36x).

Another mobility application enabled by a municipal network infrastructure is is platooning: i.e. coordinated driving of vehicles in convoys. Platooning can have several benefits in smart cities such as efficient use of roads, time-saving through route optimization, and minimizing traffic in peak times [4].

Also a parking service could be implemented on top of the UWCN; users could control if parks at their intended destination are available by looking at the real-time data offered by a parking systems connected to the UWCN.

B. SAFETY

The UWCN is the ideal communication media for informa- tion considered to be of interest only within the scope of a city. Data gathered by sensors deployed to monitor relevant urban elements should be therefore exchanged in the UWCN, with citizens free to enrich this data providing their feedback. In the context of Safety, the monitoring tools deployed to check, for example, the water level of a river crossing the city during heavy-rains, if accessible to the whole citizenship via the UWCN would increase the perceived level of safety among the public. In general, making monitoring tools for the safety of the public accessible via the UWCN would enlarge the audience of citizens, so that users can either actively provide alerts or be reached faster by urgent communications.

At the core of any monitoring tools there are sensors like video-cameras that need to stream their recordings to controllers. In this regard, citizens offering their video-camera to the UWCN could create a cooperative streaming optimized for WMNs with state-of-the-art techniques [5] already imple- mented in freely available Open Source streaming platform1.

The UWCN is the natural network also for other appli- cations relevant for a city. The exchange of data between smart rubbish bins and a central coordination point could be empowered by the UWCN, thus implementing an ecological waste management.

C. E-GOVERNMENT AND DEMOCRACY

The UWCN could be seen as the network connecting citizens directly with their represen- tatives and with Public strengthened by a Digital Consultation Tool deployed, in front of little costs, in the UWCN. The usual problem is, in fact, that public consultations are avoided for cost reasons. Keeping schools and public offices open as polling stations is indeed expensive, moreover citizens that for some reason cannot reach the polling stations cannot vote. If people could vote via the UWCN all these issues would be cleared.

An UWCN can strengthen democracy also by supporting municipal information channels fully controlled by citizens. Web-TVs, web-radios and online local newspapers could be created by active citizens, enlarg- ing the number of independent source of information and hence safeguarding the plurality principle of democracy. Moreover, being the news broadcast in the UWCN, telcos and ISPs would not have control on this network and could not perform any censuring action.

D. EDUCATION

The UWCN could become the communication channel for the dissemination of educational resources. Consider how the different schools of a city usually ask to students of the same age to study on the same books. Even if the books are the same, all students have to buy them on different sales channels and bring a copy in the classroom. This paradigm could be enhanced at least for books provided for free in elementary schools by the welfare system. Digital resources could be hosted in the municipal CN and students should have access to them from school or home via the UWCN.

The UWCN could be the aggregation and dissemination channel for information of different sort provided by citizens. Tourist services, including tourist guides, audiovisual services and public transportation timetables could be made available to the public. At the same time local entrepreneurs could promote their business on the UWCN communication media, thus attracting tourists in the city.

IV. OPEN CHALLENGES TOWARDS URBAN WIRELESS COMMUNITY NETWORKS

The technology underpinning UWCNs and the potential applications empowered by this new networking para- digm have been introduced so far to start imagining how to shape a new generation of Smart Cities. However, to convince citizens to invest their money and time in order to build and maintain the UWCNs is a challenge. The Economic Sustainability of a CN is, in fact, a well-known problem [6], and many incentives for participation and active collaboration [7] have been proposed. As long as the community behind the CN is small, around tens of participants [8], an informal self-organization scheme is sufficient to both govern the network and to supply the minimum funding necessary to bear with the OPEX and CAPEX of the network. But when the com- munity grows in size, without a clear governance and planned fundraising activities the CN may collapse. A study of the more structured CN [9] highlighted in this regard two common negative behaviours hindering the growth of a CN: i) the "dumping" and ii) the "club of techies" problems.

The first problem arises because users tend to not acknowl- edge the value of the network, but rather perceive the value only of the applications that run on top of this network. If people that join the CN installing a node on their roof are not aware of being a piece of the network, or simply care only about the applications they can access via the CN, then sooner or later they will avoid the necessary maintenance activity or will intentionally shut-down their node to save on the electricity bill. This kind of behaviours produce negative consequences on the performances of the whole network.

The second problem emerges because, usually, the first persons building the network are few geeks who intend to solve few of their own connectivity problems. But when friends and other non tech-savvy persons join the network, then the few geeks are asked to to deal with an always larger and larger network. After a while the required effort to manage the network will force the geeks to abandon the community. As a consequence, nobody is able to maintain the network anymore and the network stops working.

What can be done to avoid these problems? This is an open issue and researchers in the field of Economy, Sociology and Computer Science are working to design a compensation system to stimulate people in providing their contribution to their CNs. Some schemes developed up to now rely on an initial synergy between the no-profit community and few for- profit companies, that will help the community in bootstrap- ping the network and could initially provide and transmit to the community the needed know-how to manage the network. Other recent proposals appeared in the literature envision a fully autonomous community leveraging on a compensation system based on crypto-currencies transactions recorded in a community blockchain [10], [11].

A. A PROSPECTIVE PLAN FOR AN UWCN IN TRENTO

In the context of the city of Trento, the joint effort of the Municipality and the University could be the spring- board for the development of an UWCN. As part of an educational programme designed to promote the confidence of citizens with ICTs, the Municipality could coordinate a project involving the students of high-schools, which will be asked to learn how to manage a wireless node and to install one such node at home. The University of Trento will provide the educational resources for teachers and the technical skills needed to design a cheap, basic equipment to be delivered to all participating students. This way many families in Trento will become part of the UWCN, that will rapidly be bootstrapped and could quickly attract the interest of the rest of the population. With a working UWCN, with OPEX assigned to public institutions and CAPEX equally divided in little fractions among the whole citizenships, we expect the network to become a sustainable engine for new, innovative and smart digital services.

V. CONCLUSIONS

This White Paper introduced the Urban Wireless Com- munity Networks (UWCNs) comparing them with standard mobile and fixed networks maintained by for-profit telecom- munication companies and Internet Service Providers (ISPs). UWCN turns out to be a new, cheap networking paradigm with users in full control of the network infrastructure, which is totally owned and managed directly by citizens. The UWCN can boost the creativity of citizens by being the ideal space to host local digital services. A large plethora of applications empowered by an UWCN has been presented to highlight the prospective impact of this new networking paradigm which, however, could not be straightforwardly implemented. A compensation system to make UWCN sustainable is needed but, once developed, will finally set in motion the virtuous circle made of citizens that build their own network to offer better digital services to the same citizens.

ACKNOWLEDGMENT
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[1]PeerStreamer is an Open Source effort supported by the DISI-ANS research group of the University of Trento. See http://peerstreamer.org

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