Extending the Outreach: From Smart Cities to Connected Communities

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Connected Communities (CCs) are *socio-technical systems* that rely on an information and communication technology (ICT) infrastructure to integrate people and organizations (companies, schools, hospitals, universities, local and national government agencies) willing to share information and perform joint decision-making to create sustainable and equitable work and living environments. We discuss a research agenda considering CCs from three distinct but complementary points of view: CC metaphors, models, and services.

CCS Concepts: • **Human-centered computing** → **Web-based interaction**; • **Social and professional topics** → *Socio-technical systems*;

Additional Key Words and Phrases: Connected communities, rural-urban divide, service models

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1 INTRODUCTION

As world populations concentrate in urban areas, communities worldwide are facing new challenges. On the one hand, cities face overcrowding, physical and environmental resource constraints, and increasing pressure on the part of governments and businesses toward ensuring continuing economic growth. On the other hand, rural areas may become depopulated and have a hard time keeping up with changes in business technology and management. In this context, the term Connected Communities (CCs) [5] has been used in different disciplines with different meanings. Social scientists have described CCs as networks of relations and interdependencies [7], while technologists focused on collaboration and consensus building tools [6].

We start by proposing our own working definition: CCs are *socio-technical systems that rely on an information and communication technology (ICT) infrastructure to integrate people and organizations (companies, schools, hospitals, universities, local and national government agencies) willing to share information and perform improved decision-making to create sustainable and equitable work and*

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living environments. To clarify the relation between the emerging notion of CCs and the one of Smart City, we can compare the above definition of CC with the current definition of Smart City given by the European Telecommunications Standards Institute (ETSI)[1] : "*A 'smart city' uses digital technologies to: engage more effectively and actively with its citizens, enhance the city performance and the wellbeing of the citizens, reduce operational costs and the city resource consumption, generate new business opportunities and increase the attractiveness of the city and much more ...The creation of smart cities will only be achieved with a holistic approach, supported by globally acceptable standards that enable fully interoperable solutions that can be deployed and replicated at scale.*"

Two main differences hit the eye. First, our definition of CC does not contain the semantically loaded term *city*, which implies the idea of boundaries (*city limits*) and, even more, of a *uniform density of resources* and population within these boundaries [4]. In other words, we do not assume all individuals who take part to a CC to be equally "smart," that is, equipped with high-end smart phones and broadband connections (not to mention wearable sensors) and connected 24/7 to the Internet. Many are unable to take part in the digital experience due to financial, physical, cultural, educational, and language barriers. Instead, CCs can (and often do) exhibit lack of continuity in resource distribution, showing *gaps* or *divides* between population groups who have different access to resources, such as basic communications, individualized health care, environmental management, security, and so on. The need to fill gaps between an advanced city core and a more remote countryside has been formalized as the *Bridging the Urban-Rural Divide* (BURD) problem [8]. BURD is probably the best-known, but by no means the only need for filling fractures in the ICT infrastructure's outreach and operating conditions.

It is important to remark that Smart cities are no longer the sole paradigm, and multi-gap CCs are becoming the rule rather than the exception. The average annual rate of change of the percentage of urban dwellers is 1.1% in Africa and 1.5% in Asia [9]. In Asia, populous countries such as China and Bangladesh are urbanizing at a rate of 2.4% annually. Still, despite unprecedented rise in the number of large cities, most residents in developing countries live in places with a population of less than half a million. Other regions of the world, including the Middle East, are now urbanizing at a slower pace, having reached a high percentage of urban dwellers decades ago.

Second, our definition of CC explicitly mentions collaboration and consensus-building between individuals and institutions at various levels. In other words, we envision policies and digital services to be multiply sourced: *bottom-up*, that is, starting from initiatives of small, self-organized groups of individuals, and *top-down*, that is, coming from national and local government levels. In the Smart City definition, instead, policies and digital services are rolled out apparently without consultation and citizen *engagement* looks limited to their operation and management. Furthermore, having multiple regulatory sources means that policies need to be *concurrently enforced* via competing incentives, subsidies, or other forms of promotional schemes that involve community members' free choice.

Finally, while both definitions refer to ICT infrastructure and digital services, the CC definition highlights some specific digital services for collaboration, information exchange and consensus creation. Our TOIT Special Issue on Connected Communities aim to report on recent research around technologies for CC that promise to bridge gaps, improve social inclusion, and enable interaction among community members around issues of common interest, supporting participation/intervention in designing and deploying the technology itself.

The 10 articles accepted for this Special Issue can be divided in three broad categories: (i) those addressing the human-centered digital services enabling CCs, (ii) the application frameworks they support, and (iii) their potential threats and vulnerabilities.

[1] http://www.etsi.org/technologies-clusters/technologies/smart-cities.

The first category includes Wan et al.'s "Adaptive Message Routing and Replication in Mobile Opportunistic Networks for Connected Communities," which revisits the classic notion of "people network" and shows how it can be effectively supported by advanced routing and replication techniques. In turn, Taehun et al. use neighborhood discovery for CC self-organization in their work "A Multi-Dimensional Smart Community Discovery Scheme for IoT-Enriched Smart Homes."

The other articles in this category focus on human-centered services. "On the Need of Trustworthy Sensing and Crowdsourcing for Urban Accessibility in Smart City" by Prandi et al. describes a novel crowdsourcing approach that can improve the trustworthiness of information about CC locations and services, making shared urban space more accessible and friendly for people with impairments. Using crowdsourcing for supporting data collection in CCs is also a central feature of the work "Crowd-sourced Data Collection for Urban Monitoring via Mobile Sensors" by Longo et al. A related but distinct research line is followed by Ambrosin et al.; their article, "ODIN: Obfuscated Consensus for Decentralized Information Fusion in Device Networks," presents a privacy-preserving technique used to reach consensus among different actors performing fusion of the information they hold. "Quantitative Analysis of FRAM" by Bellini et al. provides a fresh look at quantitative measures of CC structure and behavior.

The second category is represented by two articles about applications. Rathore et al. describe an innovative application using Big Data analytics to achieve CC healthcare goals in the article "Hadoop-based Intelligent Care System (HICS): Analytical Approach for Big Data in IoT." In their work "Real-Time Traffic Event Detection from Social Media," Wang et al. use social network events together with sensor data for traffic control. Finally, the third category of articles on threats and vulnerabilities facing CCs includes the work "Seamless Virtual Network for International Business Continuity in Presence of Intentional Blocks," by Fujikawa et al., which presents an interesting scenario of cyber-warfare, and the article "Behind the Myths of Citizen Participation" by López et al., which unveils some hidden threats to CC fair governance and operation.

2 A RESEARCH AGENDA

While dealing with different subjects, all articles in this Special Issue share CC-specific metaphors, models, and services. In this section, we briefly present and discuss an agenda for further CC research.

2.1 Metaphors

CCs require new metaphors that may be profoundly different from the ones introduced for Smart Cities. A well-known example of urban metaphor is the credit-card metaphor for deferred payments. Credit cards were born as a way for affluent diners to defer payments of their restaurant meals. Per some, the metaphor underlying credit cards was conceived in 1949 when a man named Frank McNamara had an expensive business dinner in the fashionable Major's Cabin Grill restaurant in New York. When the bill arrived, McNamara realized he had forgotten his wallet and wondered if there could be an alternative to paying cash. McNamara and his partner, Ralph Schneider, returned to Major's Cabin Grill in February of 1950 and paid the check with a small cardboard card. Apocryphal or not, this story conveys clearly the original metaphor underlying the invention: a buyer shows to a seller the equivalent of a purchasers visit card (endorsed by an affluent third party) as a proof of his/her solvency and willingness to pay later. While the underlying technology has evolved for 60 years to include recent contactless and smartphone-based solutions, the visit card-based metaphor has remained substantially unchanged along the years. This metaphor looks hardly a good fit for payment services in cash-centered communities of emerging countries, where written documents are not always trustworthy and the link between a card and the identity of the cardholder may be perceived as weak [1]. This is particularly the case in rural areas that are dependent on agricultural or casual labor where there is significant transient population of workers. We believe research to be needed on a new set of metaphors suitable for the diverse stakeholders of multi-gap CCs. In the previous example, alternative metaphors underlying a deferred payment obligation between a buyer and a seller include the one of a "digital banknote" to be ripped in two parts, one held by the buyer and the other held by seller until the former delivers the goods [10]. Such metaphors are at the basis of *human-centered design* [2] that accompanies (and takes advantage of) consensus-driven usage patterns for digital services. It is interesting to remark that the fundamental notion of hash-based *distributed ledger* underlying consensus-building based on Blockchain has yet to find an effective metaphor entirely accepted by its user community. Describing blocks in Blockchain as pages in a book seems effective at first sight, as book pages do contain metadata about themselves: at the top of each page of a book one can find the book title and the chapter number, while the page's footer always shows the page number. Still, metadata about a page do not depend on the content of previous pages—a book is not a chain of pages in the same sense as Blockchain is a chain of blocks. Despite many interesting proposals made by the user community (see http://www.metamia.com/analogize.php?q=blockchain), the quest for an effective analogy for Blockchain operation is still open.

2.2 Models

Every decision a CC makes may affect the vital interests of some of its stakeholders. For this reason, decision making has traditionally involved arbitration between competing interests. The notion of a decision-making process for CCs is a different one. It relies on reaching consensus among stakeholders to share information supporting prediction, simulation, data visualization, and decision management. Research is focusing on two types of community models: *predictive models*, which enable forecasting community members' needs and behavior to optimize their operation, and *simulation models*, which support a priori analysis of the community performance in terms of economic activities and of the underlying costs. Simulation models are particularly valuable in the face of uncertainty. Regardless of the model type, CC require a highly adaptable modeling process. For instance, models must be applicable to retrofitting an existing urban area as well as to designing a service for a newly formed community. Further work is required to support the Rural Economies where environmental management and concerns co-exist with the drive for job creation and new enterprise development, especially in sectors linked to Smart Farming and Agritech. Countries such as India, Peru, Brazil, China, and Africa require special attention [16].

As an example, let us consider CCs managing their local healthcare services. Community-specific models need to search through data from past treatment outcomes as well as on dwellings and living conditions of community members and compute predictions, say, on responses to medications or hospital readmission rates. There are two major ways in which CC predictive models for healthcare need to differ from traditional ones: First, predictions need to be made for individuals and not only for groups. Community members need to make decisions regarding themselves, and want to rely on custom predictions rather than on decision rules scoring good overall success rates. Second, and perhaps more important, CC predictive models cannot in general assume features to have a single normal (Gaussian) distribution community-wide, as data include social and technological features that show discontinuities across gaps.

The modelling specifics of CCs are particularly relevant for the application of Bayesian prediction techniques to collective behavior [11]. In its simplest forms, Bayesian prediction of an unknown parameter (e.g., the outcome of a healthcare treatment) requires two steps. The first one is introducing prior distribution on the unknown. This can be based on some *a priori* knowledge (e.g., on the treatment's rate of success in the general population) or be just a placeholder, providing an entirely guessed incidence. The second step is computing the conditional probability distribution of the unknown (again, the treatment outcome) given some observables, obtaining a posterior distribution that will be used for decision making, for example, deciding whether the treatment should be funded or not.

As far as the first step of Bayesian prediction is concerned, we remark that Smart City applications routinely rely on *uninformative priors* [12, 13], taking advantage of massive (Big Data) collection of observables to train their predictive models. However, we argue that complex environments like CCs may require strategies for specification of informative prior distributions.

For the second step, techniques are needed for fast calculation of the predictor's posterior distribution when huge amounts of observables are available and the distribution type is unknown. Recent advances in Big Data processing coupled with developments in Markov Chain Monte Carlo (MCMC) have opened promising directions [14].

Research is also focusing on using computational intelligence techniques such as Deep Learning to create prediction algorithms from past individuals. Such models can then be "deployed," so a new individual can get a prediction instantly among, say, different treatment options [15].

In terms of our example, research on predictive models will deeply impact on CC members' role. Individuals and healthcare services alike will become aware of possible health risks sooner due to alerts from models. In CCs, individuals will assume more responsibility for their own care, and the physicians' role will likely change to the one of a consultant who advises and help individual patients. Institutions such as hospitals and insurance providers will see changes as well. For example, predictive models may reduce unnecessary hospitalizations, resulting initially in less revenue. Over time, however, treatments will be more effective and less costly.

2.3 Services

A major objective of CC research should be enabling urban and rural ICT infrastructures to seamlessly support all processes and services needed for citizens' safety, health, security, and quality of life. Desirable properties of the ICT infrastructure underlying such services include (i) full scalability by elastic allocation of ICT resources (sensors, actuators, virtual network and computing devices), (ii) sustainability and energy-efficiency (iii), real-time monitoring and control, and (iv) certifiable security and privacy. For example, supporting people mobility across urban-rural divide requires gap-aware handling of historic and real-time sensor data on traffic and road conditions, open data on weather, and user feedback, reconciling high density of an expensive (energy- and maintenance-wise) sensor network in the city core with other indirect information sources for the periphery.

CC Information Resources: Research is needed on digital services supporting collaboration and data exchange, including transparent and tamper-resistant polling systems enabling CC members' participation in decision making. For example, a utility service interface should be able to share consumption data providing some degree of visibility over how scarce water is allocated in a region, for example, giving priority to hospitals a and less priority to high volume individual users. Research needs to reconcile transparency and shared governance requirements with privacy and security aspects. Research is also required on the key interactions between new digital infrastructure design, capacity planning, deployment strategies and network management—wherein "design for robustness" is embedded in the system architectures to avoid the negative impacts when the "digital crutch" fails. In so doing, the interplay between network technologies such as fiber optics, 5G wireless, and SatCom can be assessed to provider solutions that can scale beyond the boundaries of the urban environment to the most remote communities in the rural areas [17, 18].

CC Infrastructure Services: Infrastructure services provide CCs with access to infrastructure facilities (transportation, energy, and communication). Research is needed on network overlays bridging CC gaps (people and vehicular networks) and preserving privacy and integrity of data in transit. Also, services are needed providing citizens with inspection and incident reporting interfaces, so they can report and be informed on issues concerning community infrastructure.

CC Dwellings: An interesting research line has been started on digital services to be made available public buildings, but also campuses, open-air markets, and other human dwellings to use them as virtual workplaces for the entire community. Such services enable occasional access to the ICT infrastructure on the part of CC members who do not have an individual network connection (or whose network connection is patchy). Also, they provide accessing information on buildings, informal dwellings and land, including on-site public sensors, and real estate records.

4 CONCLUSIONS

Based on the current state of CCs research as represented by the articles published in this Special Issue, we discussed a research agenda involving CC metaphors, models, and services. There is, in our opinion, little doubt that CC research will bring more benefits in quality of life to individuals as the use of powerful metaphors, models, and services will become widespread. Potentially, individuals will receive services that will work for them and not be attracted into unnecessary usage just because a service is used by other people. The role of service users will also change as CC members will work collaboratively with institutions and agencies to achieve better outcomes with human-centered design at the core.

We are also fully aware of the many risks brought about by the CC notion. The largest risk is shared with Smart City applications but is perhaps more severe for CCs: bringing more information to everyone on everyone else may lead to privacy violations for individuals and even to discrimination toward minorities. However, we see the CC approach as having the definite advantage of fairness over the Smart City one. By bridging divides and ICT access gaps, future CC solutions will hopefully prevent privileged "core" users from making consistently better decisions than others (e.g., due to availability of apps, wearable devices, and monitoring systems unavailable to others). The entire community will share decisions about available lifestyles and future well-being.

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