Connected Self-Organized Citizens in Crises: An Interdisciplinary Resilience Concept for Neighborhoods

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ABSTRACT

When facing major crisis events, such as earthquakes, flooding, or attacks on infrastructure, people start to organize within their neighborhoods. While this has historically been an analog process, people now use collaboration or messenger apps to support their self-organization. Unfortunately, these apps are not designed to be resilient and fail with communication infrastructure outages when servers are no longer available. We provide a resilience concept with requirements derived from an interdisciplinary view enabling citizens to communicate and collaborate in everyday life and during crisis events. Our human-centered prototype integrates concepts of nudging for crisis preparedness, decentralized and secure communication, participation, smart resource management, historical knowledge, and legal issues to help guide further research.

CCS CONCEPTS

• **Human-centered computing** → **Collaborative and social computing theory, concepts and paradigms**; • **Software and its engineering** → *Software prototyping*; • **Networks** → **Ad hoc networks**.

KEYWORDS

Crisis, Device-To-Device Communication, Connectivity, Resilience, Participation, Nudging

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1 INTRODUCTION

In the future, cities will require information and communications technology (ICT) to enable efficient management of resources such as water, energy, transportation, and shared space. However, what happens when a crisis occurs – such as an earthquake, flood, or terrorist attack and ICT is limited as a consequence? How can we build our digital infrastructure to encourage and prepare citizens of an urban society to engage in ad hoc, self-organized solutions as part of a comprehensive resilience strategy? We are an interdisciplinary research group studying social and technological challenges in crisis scenarios [19] and consider digital self-organization through the lens of different disciplines (history, law, political science, engineering and computer science including human-computer interaction). To support resilient digital cities we first provide an overview of requirements for a resilient neighborhood app with the explicit goal of developing a holistic picture and creating awareness of common social challenges that are often disregarded. Our considerations include the preparedness of citizens, establishing trust, mechanisms of self-organization, and the impact of communication infrastructure failure on digital societies. Based on the requirements, we present an app prototype design that nudges and encourages users to prepare for an emergency by providing a set of features generally useful in everyday life that can also be beneficial for coordination during a crisis. Furthermore, by supporting decentralized ad hoc connectivity and disruption-tolerant networking (DTN), thus taking advantage of physical movements of citizens, our approach can be used to better cope with ICT outages and intermittent connectivity.

2 REQUIREMENTS FOR A RESILIENT NEIGHBORHOOD APP

In the following, we list requirements for a resilient neighborhood app adopting a holistic approach that we derive from related literature and our interdisciplinary background.

2.1 Participation, self-organization and trust

Supporting a resilient digital urban society is not only a technological challenge but also heavily depends on the willingness of the population to participate in the solution and to self-organize at the community level.

(Req 1.1) The potential for digital self-organization and participation needs to be supported through trust and security. Urban crisis governance must focus on coordination that enables citizens to participate in solutions to the crisis [4, 26]. The effective and legitimate involvement of citizens in governance requires low-threshold participation of all citizens [14, 15] and an officially supported integration of ICTs and trust [8, 11]. A private, secure, and trusted space should resemble a local community that meets in person – however, this feeling of social closeness is lacking in social media even when used for volunteering [42]. While physical representation can build trust and closeness in neighborhoods, digital representation enables users to coordinate mutual aid and pooling of resources [12]. Hence, an app that enables participation must establish fundamental trust, which requires both identification and privacy, even during a crises [37] Identities that enable citizens to know who they are interacting with and a design considering patterns of trust [21] form the basis of cryptography that enables trustworthy and secure communication [13]. Moreover, users are more likely to accept an app as trustworthy when it respects their privacy by providing information and affording them control over communication with other individuals [29].

(Req 1.2) Citizens should be trained to use digital tools for cooperation and collaboration before a crisis occurs. In crisis situations, people spontaneously self-organize and volunteer to fill gaps left by official assistance, by sharing food and supplies, sheltering people, or searching for pets [27]. To understand crisis behavior, we consider how present forms of digital volunteering including social media [35], and the historical context affect preparation for future crises [18, 36]. During the 1978/79 snow disasters in northern Germany, resulted in power outages, driving bans and supply shortages, the local governments called for neighborhood help, and volunteers organized to create snow removal campaigns on their own, and supplied volunteers with hot drinks, shared food, gas cookers and tools. However, as a subsequent evaluation showed, the capacities of the affected population could not be fully utilized due to a lack of trained volunteers [9, 10]. Today, volunteers with digital skills are much more efficient due to better organization during crisis management [39]. The need for preparedness is essential for resilience.

(Req 1.3) Limited resources should be manageable by self-organized citizens. When the socio-technical nature of supply infrastructure is considered adequately, resilience is attainable [31]. By means of self-organization collaborative infrastructure management is enabled that addresses the handling of limited common resources such as water and electricity during a crisis [24]. Citizens may also share additional unconventional resources, e.g., water in a boiler or electricity stored in car batteries or sourced from privately owned solar panels to charge phones. Thus, instead of failing, resource distribution degrades gracefully [33].

2.2 Connectivity in a crisis

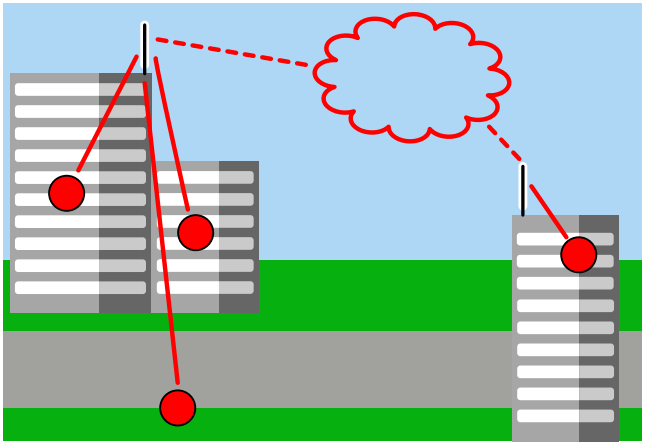

Figure 1: Collaboration using a cellular mobile network (red lines) connected to the internet (cloud).

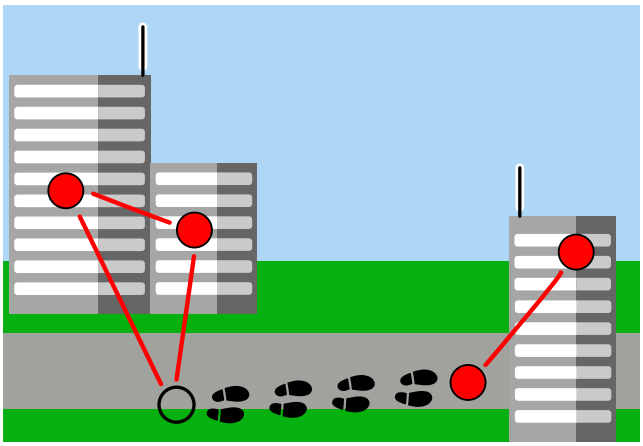

Figure 2: Self-organizing citizens try to establish ad hoc connections when central connections fail. Physical movement bridges connectivity through multi hop communication.

Cities are characterized by networks of infrastructure systems that have developed over time [40]. These systems influence each other with cascading effects, e.g., power-outages lead to Internet outages, which affect other infrastructure [1]. The co-occurrence of outages due to such a domino effect renders that communication unavailable when it is most needed.

(Req 2.1) Communication is ensured regardless of the ICT situation in a crisis. Technical solutions using decentralized communication, such as disruption-tolerant networking (DTN), allow the

self-organization of citizens in urban areas even when central infrastructure is unavailable [5, 28, 32]. Here, communication does not require a reliable end-to-end connection (Fig. 1), but messages are opportunistically forwarded to other participants through available communication channels, e.g., WiFi, Bluetooth, LoRa, or audio [6, 7] (Fig. 2). This store, carry and forward architecture delivers data on a hop-to-hop basis when connectivity is possible between peers that also act as data mules for a message.

(Req 2.2) New metaphors and visualizations are needed for decentralized networks and connectivity situations. Many apps lack a design approach for decentralized and intermittent connectivity [17]; thus, a failure to meet is not only a challenge at the technological network level but also in the interface design level based on users' understanding and expectations of possible actions and limitations requiring new metaphors and visualizations that extend beyond connectivity bars showing network coverage.

(Req 2.3) New modes of communication with decentral architectures must be supported with legislation. Using decentralized device-to-device (D2D) communication raises not only questions of trust and privacy but also questions of legality due to the lack of a controller in the sense of the general data protection regulation (GDPR)[3] and questionable classification under telecommunications law, as previous projects have shown [30].

3 A RESILIENT NEIGHBORHOOD APP

Self-organization happens at neighborhood level both in everyday life and in a crisis. To consider typical collaborative functionalities of neighborhood apps together with our requirements, we are developing a "neighborhood app" prototype written in Flutter (Fig. 3). Our prototype provides direct messaging, discussion boards for groups, offers/requests, general news/announcements, public warnings, and a map view. The neighborhood app facilitates cooperation and builds trust in everyday life contexts. During a crisis, the same app functionalities are applied for crisis organization and communication. This familiarity enables citizens to coordinate mutual aid and resource sharing in the event of a disaster by drawing on practices already practiced in daily life. This eases the transition from normal to crisis operation and reduces sudden stress on technical systems by avoiding cascading failures and facilitating graceful degradation. To involve citizens, we use a human-centered design approach, establish trust in the app and consider surrounding legal conditions.

3.1 Self-organization with trusted people

Citizens in the same neighborhood can form direct social bounds, which they build on for secure and trustworthy communication. Confidential messaging, known from apps such as Signal and Threema, must establish trusted identities [13]. We plan a pairing process where citizens meet in-person to extend trust from physical identities to digital ones [37]. Digital identities are linked using secure device pairing (SDP) and short-range communication, either using QR codes or acoustic communication [25]. By offering a handy tool for neighborhood use in everyday life, we nudge [38] citizens to establish a trusting network before a crisis. Preparedness is so important for urban societies that it is also desirable to encourage people using "legislation"; however, this is questionable from a legal perspective [16, 41].

3.2 Staying connected with the neighborhood

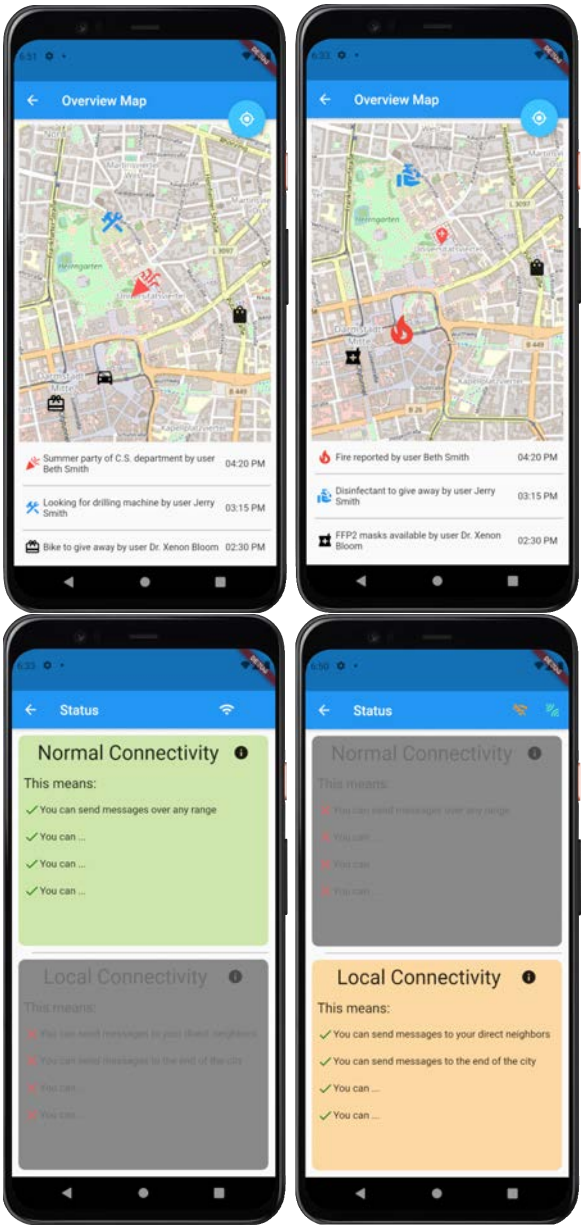

Figure 3: The app prototype supports citizens with typical neighborhood tasks of everyday life, such as sharing food and organizing events (Screen 1). When a crisis occurs, the same learned behavior is supported for self-organization among citizens (Screen 2). If internet access is available, communication uses a central server architecture (Screen 3), and without internet access communication remains possible in a decentralized mode (Screen 4).

Our app provides competitive functionality relative to other hyperlocal social apps such as Nextdoor. In addition, our app works on unreliable networks and we present first design outlines to help users understand these new capabilities (Fig. 3). Unlike existing solutions for collaboration, ours automatically resolves conflicts (known from, e.g., Google Docs) but also enables offline use (similar to how, for example, Dropbox files are available on a local computer). Technically, we use conflict-free replicated data types (CRDTs) to merge copies that have diverged due to local edits [34]. CRDTs are well suited for interactive apps such as the one proposed here [20, 22, 23] for partial replication in the case of only limited bandwidth [2] and for decentralized communication.

3.3 Legal questions of operations

Various legal issues arise in the operation of this app. Two of these which are of fundamental relevance based on the European legal framework (GDPR, the ePrivacy directive and the European Electronic Communications Code, and the German law resulting from these, with the German Telecommunications Act [TKG], being of particular relevance) and which have not yet been conclusively clarified will be discussed in more detail hereinafter. Such issues arise primarily from the seamless transition from centralized to decentralized communication:

In general, how is responsibility under data protection law to be assessed in the case of decentralized device-to-device (D2D) communication? As previous projects have shown [3, 30], the applicability of the GDPR to D2D communication apps fails due to a lack of accountability. The app provider has no control over message routing and therefore cannot decide on the necessary purposes and means of processing. Due to the versatility of use in both normal (central) and crisis operations (D2D), the question arises as to whether the responsibility of the controller in the sense of Art. 24 GDPR, which is generally given in normal operation, has an impact on the use of D2D communication? Here, an extension of responsibility for the timing of the D2D communication could be considered, since the use of these communication channels is already provided (by the app provider) when the controller is held responsible. This extension of responsibility to the time of D2D communication also seems appropriate because the app operator is the only one who has the possibility to take measures to ensure the informational self-determination of the users.

How should D2D communication be classified in telecommunications law? Since D2D communication enables individual communication, this scenario could be subject to telecommunication law. This leads to the follow-up question of whether the individual communication enabled here qualifies as interpersonal communication within the meaning of Section 3 No. 61 lit. b TKG (so-called over-the-top telecommunications services [OTT-TC services], such as WhatsApp). However, even if OTT-TC services are included in the scope of the TKG, applicability to this case of P2P communication is likely to be excluded, as there is no provider of a telecommunications service here. This results from the fact that the operator has no functional control over the telecommunications network. Instead, the respective user could assume the role of service provider, although here, too, functional control is questionable and the implementation of corresponding obligations is probably not possible in practice.

4 CONCLUSION AND OUTLOOK

With our work in progress all requirements have not yet been fully covered, and the proposed designs and functionalities have to be further evaluated. The first results of our prototype demonstrate that our vision is realizable from technological and social perspectives. Our requirements and prototype provide a baseline for further interdisciplinary research on topics such as device pairing, decentralized communication, replicated data types, UI patterns, legal issues, resource management, governance, and participation. The strength of our approach is also a challenge, as we must consider all aspects in a single app prototype to demonstrate its practicability. Despite being centered on resilience in a crisis, our concept fills gaps of other approaches because we do not limit our idea to technological aspects or crisis reactions. We consider digital citizens with all needs and social aspects even before a crisis occurs instead of only as a reaction to a catastrophe. This leads to increased acceptance and prevalence of potential users, because our app brings immediate benefit to their everyday lives. People are encouraged to form a resilient and trusted network of both devices and people within their existing neighborhoods. This self-organized network brings people together, and prepares them to better react to crises, by teaching them to use a digital communication that still functions in cases where, today's ICTs would fail. Our approach features technologically advanced network protocols with no additional complexity for the user.

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REFERENCES

[1] Giuseppe Aceto, Alessio Botta, Pietro Marchetta, Valerio Persico, and Antonio Pescapé. 2018. A comprehensive survey on internet outages. *Journal of Network and Computer Applications* 113 (2018), 36–63. https://doi.org/10.1016/j.jnca.2018.03.026

[2] Paulo Sérgio Almeida, Ali Shoker, and Carlos Baquero. 2018. Delta state replicated data types. *J. Parallel Distributed Comput.* 111 (2018), 162–173. https://doi.org/10.1016/j.jpdc.2017.08.003

[3] Lars Almon, Flor Álvarez, Patrick Lieser, Tobias Meuser, and Fabian Schaller. 2018. *Ad-Hoc-Kommunikation–Gesellschaftlich wünschenswert, rechtlich ungeregelt.* Springer, Wiesbaden, 77–98. https://doi.org/10.1007/978-3-658-23727-1_5

[4] Sherry R. Arnstein. 1969. A Ladder Of Citizen Participation. *Journal of the American Institute of Planners* 35, 4 (1969), 216–224. https://doi.org/10.1080/01944366908977225

[5] Lars Baumgärtner, Paul Gardner-Stephen, Pablo Graubner, Jeremy Lakeman, Jonas Höchst, Patrick Lampe, Nils Schmidt, Stefan Schulz, Artur Sterz, and Bernd Freisleben. 2016. An experimental evaluation of delay-tolerant networking with serval. In *2016 IEEE Global Humanitarian Technology Conference (GHTC)*. 70–79. https://doi.org/10.1109/GHTC.2016.7857262

[6] Lars Baumgärtner, Jonas Höchst, and Tobias Meuser. 2019. B-DTN7: Browser-based Disruption-tolerant Networking via Bundle Protocol 7. In *2019 International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*. 1–8. https://doi.org/10.1109/ICT-DM47966.2019.9032944

[7] Lars Baumgärtner, Patrick Lieser, Julian Zobel, Bastian Bloessl, Ralf Steinmetz, and Mira Mezini. 2020. LoRAgent: A DTN-based Location-aware Communication

System using LoRa. In *2020 IEEE Global Humanitarian Technology Conference (GHTC)*. 1–8. https://doi.org/10.1109/GHTC46280.2020.9342886

[8] Eric Corbett and Christopher A. Le Dantec. 2018. Going the Distance: Trust Work for Citizen Participation. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3173574.3173886

[9] Wolf R. Dombrowsky. 1983. Hilfe in einer regionalen Katastrophe: Bedingungen und Abläufe prosozialen Handelns während der schleswig-holsteinischen Schneekatastrophen 1978/79.

[10] Wolf R. Dombrowsky. 1983. Solidarity during Snow-Disasters. *International Journal of Mass Emergencies and Disasters* 1, 1 (1983), 189–205.

[11] Sheena Erete and Jennifer O. Burrell. 2017. Empowered Participation: How Citizens Use Technology in Local Governance. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 2307–2319. https://doi.org/10.1145/3025453.3025996

[12] Anton Fedosov, Airi Lampinen, William Odom, and Elaine M. Huang. 2021. A Dozen Stickers on a Mailbox: Physical Encounters and Digital Interactions in a Local Sharing Community. *Proc. ACM Hum.-Comput. Interact.* 4, CSCW3, Article 240 (Jan. 2021), 23 pages. https://doi.org/10.1145/3432939

[13] Niels Ferguson, Bruce Schneier, and Tadayoshi Kohno. 2010. *Cryptography Engineering*. Wiley Publishing, Inc. https://doi.org/10.1002/9781118722367

[14] Cornelia Fraune and Michèle Knodt. 2017. Challenges of Citizen Participation in Infrastructure Policy-Making in Multi-Level Systems—The Case of Onshore Wind Energy Expansion in Germany. *European Policy Analysis* 3, 2 (2017), 256–273. https://doi.org/10.1002/epa2.1022

[15] Cornelia Fraune and Michèle Knodt. 2019. Verfahrensakzeptanz im Kontext der Mehrebenengovernance der Energiewende – Herausforderungen aus politikwissenschaftlicher Perspektive. In *Akzeptanz und politische Partizipation in der Energietransformation. Gesellschaftliche Herausforderungen jenseits von Technik und Ressourcenausstattung*. VS Verlag für Sozialwissenschaften, Wiesbaden. http://tubiblio.ulb.tu-darmstadt.de/117948/

[16] Stephan Gerg. 2019. *Nudging: verfassungsrechtliche Maßstäbe für das hoheitliche Einwirken auf die innere Autonomie des Bürgers*. Vol. 5. Mohr Siebeck.

[17] Sukeshini A Grandhi, Linda Plotnick, and Starr Roxanne Hiltz. 2020. An Internet-Less World? Expected Impacts of a Complete Internet Outage with Implications for Preparedness and Design. *Proc. ACM Hum.-Comput. Interact.* 4, GROUP, Article 03 (Jan. 2020), 24 pages. https://doi.org/10.1145/3375183

[18] Jutta Helmerichs, Vitali Heidt, Christoph Groneberg, and Thomas Knoch. 2017. Bevölkerungsverhalten in Krisen und Katastrophen. Eine Auswertung naturbedingter Großschadenslagen der letzten fünfzig Jahre in Deutschland. https://smarter-projekt.de/wp-content/uploads/2017/12/Auswertung_Bev%C3%B6lkerungsverhalten_Krisen_Katastrophen_Dezember_2017.pdf

[19] Matthias Hollick, Anne Hofmeister, Jens Ivo Engels, Bernd Freisleben, Gerrit Hornung, Anja Klein, Michèle Knodt, Imke Lorenz, Max Mühlhäuser, Peter Pelz, Annette Rudolph-Cleff, Ralf Steinmetz, Florian Steinke, and Oskar von Stryk. 2019. The Emergency Responsive Digital City. In *2019 World Congress on Resilience, Reliability and Asset Management (WCRRAM)*. http://tubiblio.ulb.tu-darmstadt.de/121649/

[20] Martin Kleppmann, Adam Wiggins, Peter van Hardenberg, and Mark McGranaghan. 2019. Local-first software: You own your data, in spite of the cloud. In *Proceedings of the 2019 ACM SIGPLAN International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software, Onward! 2019, Athens, Greece, October 23-24, 2019*, Hidehiko Masuhara and Tomas Petricek (Eds.). ACM, 154–178. https://doi.org/10.1145/3359591.3359737

[21] Bran Knowles, Mark Rouncefield, Mike Harding, Nigel Davies, Lynne Blair, James Hannon, John Walden, and Ding Wang. 2015. Models and Patterns of Trust. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing* (Vancouver, BC, Canada) *(CSCW '15)*. Association for Computing Machinery, New York, NY, USA, 328–338. https://doi.org/10.1145/2675133.2675154

[22] Ragnar Mogk, Lars Baumgärtner, Guido Salvaneschi, Bernd Freisleben, and Mira Mezini. 2018. Fault-tolerant Distributed Reactive Programming. In *32nd European Conference on Object-Oriented Programming, ECOOP 2018, July 16-21, 2018, Amsterdam, The Netherlands (LIPIcs, Vol. 109)*, Todd D. Millstein (Ed.). Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 1:1–1:26. https://doi.org/10.4230/LIPIcs.ECOOP.2018.1

[23] Ragnar Mogk, Joscha Drechsler, Guido Salvaneschi, and Mira Mezini. 2019. A fault-tolerant programming model for distributed interactive applications. *Proc. ACM Program. Lang.* 3, OOPSLA (2019), 144:1–144:29. https://doi.org/10.1145/3360570

[24] Elinor Ostrom. 2010. Analyzing collective action. *Agricultural Economics* 41, s1 (2010), 155–166. https://doi.org/10.1111/j.1574-0862.2010.00497.x

[25] Florentin Putz, Flor Álvarez, and Jiska Classen. 2020. Acoustic Integrity Codes: Secure Device Pairing Using Short-Range Acoustic Communication. In *Proceedings of the 13th Conference on Security and Privacy in Wireless and Mobile Networks (WiSec '20)*. ACM. https://doi.org/10.1145/3395351.3399420

[26] Christian Reuter, Amanda Lee Hughes, and Marc-André Kaufhold. 2018. Social Media in Crisis Management: An Evaluation and Analysis of Crisis Informatics Research. *International Journal of Human–Computer Interaction* 34, 4 (2018), 280–294. https://doi.org/10.1080/10447318.2018.1427832

[27] Christian Reuter, Alexandra Marx, and Volkmar Pipek. 2012. Crisis Management 2.0: Towards a Systematization of Social Software Use in Crisis Situations. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)* 4, 1 (Jan 2012), 1–16. https://doi.org/10.4018/jiscrm.2012010101

[28] Erika Rosas, Felipe Garay, and Nicolas Hidalgo. 2020. Context-aware self-adaptive routing for delay tolerant network in disaster scenarios. *Ad Hoc Networks* 102 (2020), 102095. https://doi.org/10.1016/j.adhoc.2020.102095

[29] Leonie Schaewitz, Stephan Winter, and Nicole C. Krämer. 2020. The Influence of privacy control options on the evaluation and user acceptance of mobile applications for volunteers in crisis situations. (Feb 2020), 1–17. https://doi.org/10.1080/0144929X.2020.1723703

[30] Fabian Schaller. 2018. Projekt smarter - sichere Kommunikation im Katastrophenfall. *ZD Aktuell* (2018), 06–10.

[31] Benjamin Scharte. 2019. Educating engineers for resilience. 7, 3 (2019). https://doi.org/10.3929/ETHZ-B-000377063

[32] Sebastian Schildt, Tim Lüdtke, Klaus Reinprecht, and Lars Wolf. 2014. User Study on the Feasibility of Incentive Systems for Smartphone-Based DTNs in Smart Cities. In *Proceedings of the 2014 ACM International Workshop on Wireless and Mobile Technologies for Smart Cities* (Philadelphia, Pennsylvania, USA) *(WiMobCity '14)*. Association for Computing Machinery, New York, NY, USA, 67–76. https://doi.org/10.1145/2633661.2633662

[33] Fiona Schulte, Eckhard Kirchner, and Hermann Kloberdanz. 2019. Analysis and Synthesis of Resilient Load-Carrying Systems. *Proceedings of the Design Society: International Conference on Engineering Design* 1, 1 (2019), 1403–1412. https://doi.org/10.1017/dsi.2019.146

[34] Marc Shapiro, Nuno M. Preguiça, Carlos Baquero, and Marek Zawirski. 2011. Conflict-Free Replicated Data Types. In *Stabilization, Safety, and Security of Distributed Systems - 13th International Symposium, SSS 2011, Grenoble, France, October 10-12, 2011. Proceedings (Lecture Notes in Computer Science, Vol. 6976)*, Xavier Défago, Franck Petit, and Vincent Villain (Eds.). Springer, 386–400. https://doi.org/10.1007/978-3-642-24550-3_29

[35] Kate Starbird and Leysia Palen. 2011. "Voluntweeters": Self-Organizing by Digital Volunteers in Times of Crisis. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 1071–1080. https://doi.org/10.1145/1978942.1979102

[36] Birgitta Sticher and Anna Will. 2014. Involvement of the Population in Crisis and Disaster Management in Germany (FRG) after World War II: Shown on the example of five disaster events: Katastrophenschutz-Leuchttürme [Disaster protection "Lighthouses"] as contact points for citizens in crisis situations. https://doi.org/10.4393/Wiss-Text-FB-15

[37] Milan Stute, Florian Kohnhauser, Lars Baumgartner, Lars Almon, Matthias Hollick, Stefan Katzenbeisser, and Bernd Freisleben. 2020. RESCUE: A Resilient and Secure Device-to-Device Communication Framework for Emergencies. *IEEE Transactions on Dependable and Secure Computing* (2020), 1–1. https://doi.org/10.1109/TDSC.2020.3036224

[38] Cass R Sunstein and Richard H Thaler. 2014. *Nudge: Improving decisions about health, wealth, and happiness*. Penguin Books.

[39] Annemijn F Van Gorp. 2014. Integration of volunteer and technical communities into the humanitarian aid sector: Barriers to collaboration. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM 2014)*, Starr Hiltz, Mark Pfaff, Linda Plotnick, and Patrick Shih (Eds.). University Park, PA, USA, 622–631.

[40] Dirk van Laak. 2021. Infrastructures. *Docupedia-Zeitgeschichte* (2021). https://doi.org/10.14765/zzf.dok-2215

[41] Johanna Wolff. 2015. Eine Annäherung an das Nudge-Konzept nach Richard H. Thaler und Cass R. Sunstein aus rechtswissenschaftlicher Sicht. *RW Rechtswissenschaft* 6, 2 (2015), 194–222.

[42] Marisol Wong-Villacres, Cristina M. Velasquez, and Neha Kumar. 2017. Social Media for Earthquake Response: Unpacking Its Limitations with Care. *Proc. ACM Hum.-Comput. Interact.* 1, CSCW, Article 112 (Dec. 2017), 22 pages. https://doi.org/10.1145/3134747