TRANSFORM 911

Chapter 6: 911 Technology and Infrastructure

Introduction

The U.S. 911 system was created in 1968 and its expansion was facilitated by the Wireless Communications and Public Safety Act of 1999, designed to ensure immediate response to public requests for fire, police, and emergency medical services.[1] Nationwide, the 911 system currently fields an estimated 240 million calls every year,[2] yet the degree of technological sophistication associated with routing, responding, and documenting this tremendous volume of calls varies greatly from one jurisdiction to another. Technological advances create opportunities to upgrade and modernize these 911 systems by generating more accurate information in support of efficient and equitable responses to calls for service and facilitating data sharing and interoperability between different dispatcher systems and responders. Technology could streamline call taker decision making to enable a more accurate assessment of priority and risk, and reduce unnecessary police response and biased outcomes. It could also ensure the quick re-routing of calls from 911 to alternative hotlines. In addition, technology could be employed to improve the wellbeing of 911 professionals and first responders through reducing strain and burden on this critical frontline workforce. However, the effectiveness of technology in fulfilling these goals has not been examined empirically.

The proliferation of cell phones and internet-based communications to interact with a 911 system designed for land line use poses certain challenges. Some public safety answering points (PSAPs), also known as Emergency Communications Centers (ECCs), are not able to automatically detect a caller's location if they dial from a mobile phone,[3] and most are ill equipped to receive and securely store photographs and videos shared by the public. In addition, some technologies designed to automate 911 processes may be racing ahead of data-driven and inclusive development of the processes to be automated.[4] Indeed, the fast pace of technology advancement makes it difficult for ECC leaders to assess which new technologies are necessary or superfluous, instead relying on the guidance of vendors who have a vested interest in their adoption.[5]

In response to these opportunities, challenges, and limitations, a variety of technology-related initiatives are currently under way in the 911 space, from Federal Communications Commission (FCC) rules on wireless Enhanced 911 (E911) services to third-party smartphone apps that provide enhanced 911 dialing capabilities. The most publicly visible 911 upgrade effort is Next Generation 911 (NG911), a nationwide initiative to upgrade 911 from analog phone systems to Internet Protocol (IP)-based systems

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[1] FCC, "911 and E911 Services," accessed December 21, 2021, https://www.fcc.gov/general/9-1-1-and-e9-1-1-services.
[2] National Emergency Number Association (NENA), "9-1-1 Statistics," accessed October 26, 2021, https://www.nena.org/page/911Statistics.
[3] NENA, "9-1-1 Statistics."
[4] Transform911 Technology Workgroup discussions.
[5] Transform911 Technology Workgroup discussions.

that are capable of handling text and multimedia messages. In addition, independent companies have developed applications to streamline call-taking and triaging processes and enable members of the public to share critical information about themselves and their household members, particularly those with medical conditions, special needs, and disabilities, in advance of emergencies.

This research brief highlights the technological challenges specific to 911, including the limitations introduced above, as well as the system's limited capacity during natural disasters or widespread emergencies and challenges related to accessibility for people with disabilities and the aging population. This review describes the NG911 initiative, the challenges ECCs are encountering in transitioning to NG911, and other measures to deploy technology in the service of improving 911 service delivery. The research on this topic is particularly sparse and mostly confined to methods and algorithms designed to expedite or automate certain 911 call-taking and emergency response functions. As such, this brief closes with several questions in need of additional research evidence.

The State of Practice: Existing 911 Call Technology

At its most basic, a 911 call is simply audio communication between a caller and a call taker, with no supporting information. An estimated 93 percent of US counties with 911 coverage have technology at least one step above basic: "enhanced" 911, which automatically makes the caller's phone number and address available to the call taker, provided the caller is using a landline.[6] Wireless phone service providers are able to provide additional information to ECCs when a call comes from a mobile phone, including the cell tower location, caller's GPS coordinates (in some cases), and mobile phone number[7] (useful for calling back in case the call drops or the caller hangs up). The table below describes five technological stages of 911, spanning three types of communications networks (landline, wireless, and internet).

Table 6.1 ***Descriptions from National Emergency Number Association.***[8]

Stage	Description
Basic 911	Emergency and its location are communicated by voice or teletype, using the public switched telephone network (PSTN).
Enhanced 911	ECC has database information that display caller's phone number and address to call-taker.
Wireless Phase I	Call-taker automatically receives wireless (mobile) phone number and location of cell tower handling the call.
Wireless Phase II	Call-taker automatically receives wireless phone number and caller's location information.
Voice over Internet Protocol (VoIP)	Internet Protocol (IP)-based systems rely on broadband internet rather than the public switched telephone network (PSTN) and have the capability to transmit multimedia messages in addition to voice calls. This is the major component of NG911.

[6] NENA, "9-1-1 Statistics."
[7] NENA, "9-1-1 Statistics."
[8] NENA, "9-1-1 Statistics."

The decentralized nature of 911 implementation and regulation, coupled with limited data-sharing, makes it difficult to confidently summarize the state of 911 practice from a technology infrastructure perspective. For example, as of this writing, the National Emergency Number Association's (NENA) map of state NG911 (VoIP) transition progress was last updated in 2018,[9] and 911.gov's NG911 progress snapshot was last updated in 2017,[10] though the webpage states that the National 911 Program collaborates with 911 associations annually to collect this information. The mapping and routine tracking of ECC migration to NG911 nationwide would be a useful undertaking to identify leaders to learn from and stragglers in need of additional assistance.

Computer-aided dispatch (CAD) systems have become indispensable to 911 emergency response over the past 40 years.[11] CAD systems can help 911 professionals prioritize and record incident calls, coordinate incoming data from multiple streams, and manage or automate dispatch and monitoring of field responders.[12] CAD systems can also incorporate information from records management systems (RMSs), which keep detailed records of incidents and reports from partner agencies – for example, law enforcement RMSs contain arrest and crime reports. CAD systems and RMSs may come packaged together with a mobile data terminal and mobile report entry system as a software suite from a particular technology vendor, which then provides support to an entire department.[13] Often times, however, CAD systems and RMSs are owned and operated by different agencies and are not linked. This underscores the importance of examining ECC technology issues and needs within the context of where the ECC is housed (e.g., police department, public safety office, fire department) and what standard operating procedures and procurement policies govern its operations and technological capabilities, capacities, and needs. Indeed, it is important to recognize that ECCs do not operate independently with regard to technology acquisition, upgrades, and usage.

Despite the ubiquity of CAD systems, little research has been done on their use or best practices. Recent reports in this area include a variety of internal studies of departmental practices or impact assessments brought to the public in a particular jurisdiction. A 2019 report by the Seattle Police Department described the extent and use of CAD surveillance data and included a variety of comments from public meetings about this technology.[14] What recent scholarship on CAD systems that does exist is largely from surveillance studies or a sociological perspective rather than a technical perspective.[15]

Challenges and Opportunities

The current and evolving 911 system in the United States experiences both challenges and opportunities in the context of technology. The challenges result from the fact that technology has advanced more rapidly than existing 911 infrastructures, creating barriers to communication particularly during

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[9] National Emergency Number Association (NENA), "Status of NG9-1-1 State Activity," last updated February 2, 2018, https://www.nena.org/page/NG911_StateActivity.

[10] 911.gov, "Next Generation 911," accessed November 16, 2021, https://www.911.gov/issue_nextgeneration911.html.

[11] Kent W. Colton, "Police and Computer Technology: The Case of the San Diego Computer-Aided Dispatch System," *Public Productivity Review* (1980): 21-42, https://www.jstor.org/stable/3380055.

[12] U.S. Department of Homeland Security, "Tech Note: Computer Aided Dispatch Systems," September 2011, https://www.dhs.gov/sites/default/files/publications/CAD_TN_0911-508.pdf.

[13] Brad Brewer, "Versadex PoliceCAD," *Law and Order: The Magazine for Police Management* 56, no. 7 (2008): 38-43, https://www.ojp.gov/ncjrs/virtual-library/abstracts/versadex-policecad.

[14] Seattle Police Department, 2019 Surveillance Impact Report: Computer-Aided Dispatch (CAD), April 24, 2019, https://www.seattle.gov/Documents/Departments/Tech/Privacy/SPD%20Computer%20Aided%20Dispatch%20Final%20SIR.pdf.

[15] James N. Gilmore and McKinley DuRant, "Emergency Infrastructure and Locational Extraction: Problematizing Computer Assisted Dispatch Systems as Public Good," *Surveillance & Society* 19, no. 2 (2021): 187-198, https://ojs.library.queensu.ca/index.php/surveillance-and-society/article/view/14116/9776.

widespread disasters. The opportunities come from innovations that afford new ways of communication and automate 911 processes. NG911 represents both an opportunity and a challenge: migration to the new system by all ECCs nationwide should result in improved interoperability, reliability, security, and service delivery, but the process of adopting NG911 is difficult for many ECCs owing to antiquated infrastructures and limited resources.

Challenges with Existing 911 Technologies

Technology has introduced new forms of communication, such as text messaging, cell phone video calling, and telecommunications spectrums like the 5th Generation (5G) network. These features enable the conveyance of more comprehensive information to call takers, and make 911 more accessible to people who are deaf or hard of hearing, or who speak a language other than English.[16] However, 911 still runs largely on analog call systems that are unable to support email, text, or any other form of multimedia communications.[17] Moreover, while analog systems support Teletypewriter Devices for the Deaf (TTY), most non-hearing individuals no longer use the decades-old device, instead opting for cell phones or VoIP, in part because TTY is unreliable on digital networks.[18] As such, people who are deaf, deafblind, hard of hearing, or have a speech disability lack a reliable means of communicating with 911.[19]

Existing system use of analog and narrow broadband communications networks, which are unable to incorporate wider broadband data connection and communication, can cause network congestion, low data rates, and interoperability problems.[20] Furthermore, in situations like severe storms or natural disasters, cell service may face outages, resulting in 911 being unable to support people in need of help.[21] Public safety systems also face challenges such as lack of cooperation between different agencies and rupture of base stations during disaster situations.[22] Risk maps are required to guide safe travel during disasters, but dissemination of such maps requires cellular service that is often lacking. Cyberattacks on 911 call centers are also a source of vulnerability that can take an entire jurisdiction's call infrastructure offline. Such attacks have become concerningly common during the transition to NG911,[23] but with proper mitigation strategies[24] the NG911 system overhaul could improve security once it is fully in place.[25]

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[16] 911.gov, "Text-to-911," accessed October 26, 2021, https://www.911.gov/issue_textto911.html.
[17] Patrick Purdy, "An Inquiry Regarding the Development of an Effectual Architecture Framework Supporting Next Generation 9-1-1," (Masters Thesis, Regis University, 2011), 631, https://epublications.regis.edu/theses/631.
[18] Richard Lorenzo Ray, "Americans with Disabilities Act (ADA) and Twenty-First Century Communications and Video Accessibility Act (CVAA)," report prepared at the request of United States Senator Edward Markey (May 2021).
[19] Ray, "ADA and CVAA."
[20] Abhaykumar Kumbhar et al., "A Survey on Legacy and Emerging Technologies for Public Safety Communications," *IEEE Communications Surveys & Tutorials* 19, no. 1 (2016): 97-124, https://arxiv.org/pdf/1509.08316.pdf.
[21] Ramon Ferrus et al., "LTE: The Technology Driver for Future Public Safety Communications," *IEEE Communications Magazine* 51, no. 10 (2013): 154-161, https://ieeexplore.ieee.org/document/6619579.
[22] Ferrus et al., "LTE."
[23] Jon Schuppe, "Hackers Have Taken Down Dozens of 911 Centers. Why Is It So Hard to Stop Them?" NBC News, April 3, 2018, https://www.nbcnews.com/news/us-news/hackers-have-taken-down-dozens-911-centers-why-it-so-n862206.
[24] U.S. Cybersecurity & Infrastructure Security Agency, "Cyber Risks to Next Generation 9-1-1," November 2019, https://www.cisa.gov/sites/default/files/publications/NG911%20Cybersecurity%20Primer.pdf.
[25] Colin Wood, "Will a Cyberattack Take Down Next-Generation 911?" StateScoop, October 19, 2021, https://statescoop.com/will-a-cyberattack-take-down-next-generation-911/.

Technology challenges are also evident in the ability of ECCs to access data housed in CAD systems and data dashboards operated by third-party vendors. ECCs do not always have real-time access to such data and language in vendor contracts can be unclear on issues of data ownership and access.[26] These challenges can be overcome by specifying data ownership and access requirements in requests for proposals, and by ensuring contractual language aligns with those requirements.[27] This includes requiring cloud-based vendors to offer ECCs the option of local mirroring of data and ensuring that data are fully exportable to avoid potential vendor lock-in practices.[28]

A related issue that merges data and technology pertains to ethics in securing the privacy and confidentiality of personal information in emergency service decision-making.[29] The 911 profession currently lacks uniform data ethics guidelines to ensure that data are used to improve service delivery while safeguarding the privacy rights and protections afforded to all people. Technological advances in data anonymization techniques, such as generating and sharing synthetic data from aggregated sources, could be applied to 911 operations.[30]

Innovations in 911 Dialing

NENA estimates that 80 percent of calls to 911 are placed from mobile phones.[31] The near-ubiquity of smartphones can present challenges to 911 operations – mainly, the need to ask for a caller's location verbally in ECCs with basic or enhanced 911,[32] and calls being routed to the wrong ECC based on cell tower location.[33] However, many smartphones make dialing 911 easier through shortcut or quick-dial 911 features,[34] and a variety of apps offer 911 dialing with enhanced information-sharing (e.g. the Uber app "emergency button" shares car description, location, and license plate number[35]). Both dialing shortcuts and app safety features can cut down the time needed to call and communicate with 911 in an emergency, though shortcuts may exacerbate the prevalence of resources wasted on accidental 911 calls and hang-ups.[36] Smart devices like Apple Watch even claim to share location data with 911 automatically,[37] though whether this happens depends on the ECC's ability to receive said data.

Many elderly individuals currently use Personal Emergency Response Systems (PERS) pendant devices, which allow individuals to connect with family members and the 911 system by the push of a button.[38] However, using PERS is not foolproof, as individuals need to manually activate the button to call for

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[26] Transform911 Technology Workgroup discussions held from October 6, 2021 to February 8, 2022.
[27] Transform911 Technology Workgroup discussions.
[28] Transform911 Technology Workgroup discussions.
[29] Transform911 Technology Workgroup discussions.
[30] Transform911 Technology Workgroup discussions.
[31] NENA, "911 Statistics."
[32] William B. Millard, "Dialing Down the Delta: Wireless Telephones at Odds With 911 Systems," *Annals of Emergency Medicine* 68, no. 6 (2016): A18-A24, https://www.annemergmed.com/article/S0196-0644(16)31216-1/fulltext.
[33] S. Rebecca Neusteter et al., "The 911 Call Processing System: A Review of the Literature as it Relates to Policing," Vera Institute of Justice, July 2019, 6-9; 34-36, https://www.vera.org/downloads/publications/911-call-processing-system-review-of-policing-literature.pdf.
[34] See Apple's Emergency SOS for iPhone, https://support.apple.com/en-us/HT208076.
[35] Uber, "Uber's Emergency Button," March 14, 2019, https://www.uber.com/newsroom/emergencybutton/.
[36] CBS Minnesota, "Apple Upgrade Blamed For Thousands Of Wasteful 911 Hang-Ups," July 31, 2019, https://minnesota.cbslocal.com/2019/07/31/apple-upgrade-blamed-thousands-wasteful-911-hang-ups/; Jonathan Fortier, "Smart Devices Causing More 911 Hang-ups," WEAU News, January 14, 2020, https://www.weau.com/content/news/Smart-devices-causing-more-911-hang-ups-566985441.html. *See also* Neusteter et al., "Understanding Police Enforcement: A Multicity 911 Analysis," Vera Institute of Justice, September 2020, https://www.vera.org/downloads/publications/understanding-police-enforcement-911-analysis.pdf.
[37] Apple, "Use Emergency SOS on your Apple Watch," April 27, 2021, https://support.apple.com/en-us/HT206983.
[38] William C. Mann et al., "Use of Personal Emergency Response Systems by Older Individuals with Disabilities," *Assistive Technology* 17, no. 1 (2005): 82-88, https://escholarship.mcgill.ca/downloads/8910jz98x.

help.[39] In cases of unconsciousness, or in cases where an individual is not wearing the pendant device, a PERS device loses its utility.[40] In response to such challenges, many companies are introducing sensors to detect if a user has fallen and to automatically send out an emergency response,[41] as well as static buttons installed in high-risk locations like showers.[42]

For car emergencies, In-Vehicle Systems (IVS) can automatically connect individuals involved in car accidents to the emergency help system. IVS utilizes cellular data to connect with the appropriate ECC. The IVS system requires standardization across ECCs through the development and implementation of the NG-eCall system.[43]

The Next Generation 911 (NG911) Initiative

To update the 911 system on par with overall technological innovations, and to match consumer behavior around communication systems, the US government has been working towards upgrading the system by shifting to a Voice over Internet Protocol (VoIP) based network, an initiative commonly known as NG911. VoIP utilizes internet connection instead of the public switched telephone network (PSTN), thus utilizing an already established digital network. As the internet has allowed personal communication to move beyond voice calls, and to incorporate multimedia forms of communication, the NG911 system utilizing VoIP will be able to provide services which are not restricted to voice calls. VoIP can also allow callers to choose the area code from where the complaint is being made, allowing for a direct routing to the right ECC.[44]

The NG911 system is being developed to handle higher call volume, have more reliable network connections, and provide richer information to first responders.[45] The NG911 system can also help address the challenges of data integration for the use of the first responders.[46] NG911 will utilize an upgraded form of network called the Emergency Services Internet Protocol Networks (ESINets). ESINets will allow for transmission of large amounts of data to first responders, and are able to function in emergency and disaster situations where faults may occur at end points or some circuits might break.[47] NG911 will also allow for the detection of incident location and thereby allow interoperability between neighboring ECCs.[48]

These capabilities hold great promise, but migrating all ECCs to NG911 nationwide is a monumental task, and one that requires technical assistance and resources. To facilitate this transition, the National Telecommunication Industry Administration and the National Highway Traffic Safety Administration have initiated a NG911 grant program. NG911 funding has also been proposed as part of the LIFT

[39] Mann et al., "Personal Emergency Response Systems."
[40] Mann et al., "Personal Emergency Response Systems."
[41] Tine Smits and Andrea Ryter, "Personal Emergency Response System (PERS) with Optimized Automatic Fall Detection Shows Greater Effectiveness than PERS Alone," Philips Lifeline, 2015, https://www.lifeline.philips.com/content/dam/PLL/PLL-Common/PDFs/WhitePaper-AA_Analytics-j.pdf.
[42] E.g., LifeAlert shower button, http://www.lifealert.com/HELPButton.aspx.
[43] Risto Oorni and Ana Goulart, "In-Vehicle Emergency Call Services: eCall and Beyond," *IEEE Communications Magazine* 55, no. 1 (2017): 159-165.
[44] Andre Pierre Guerlain and Nicholas James Algiere, "IP-Enabled WAN EMS System," Worcester Polytechnic Institute Interactive Qualifying Projects (2013), https://core.ac.uk/download/pdf/212990288.pdf.
[45] Andrew Jackson Coley, "NG9-1-1, Cybersecurity, and Contributions to the Model Framework for a Secure National Infrastructure," *Cath. UJL & Tech* 27, no. 1 (2018): 127, https://scholarship.law.edu/cgi/viewcontent.cgi?article=1062&context=jlt.
[46] Coley, "NG9-1-1 and Cybersecurity."
[47] Coley, "NG9-1-1 and Cybersecurity."
[48] Coley, "NG9-1-1 and Cybersecurity."

America Act in March 2021[49] and the Build Back Better (BBB) Act in September 2021,[50] though the $10 billion in NG911 funding proposed in the BBB Act was cut by over 95 percent while the bill was in the House of Representatives.[51] In addition to grant funding to promote NG911 migration, 911.gov has developed the 911 DataPath Strategic Plan, a model for a nationally uniform 911 data system to standardize data collection in support of secure data sharing and collaboration among jurisdictions.[52]

Smart911

Another technological advancement related to 911 is Smart911, a for-profit platform that enables voluntary users to enter information about themselves and other members of their household, including pets, into the platform to be stored for retrieval by ECCs. The system is designed to equip call-takers, dispatchers, and responders with quick access to vital information in the event of an emergency.[53] Smart911's Vulnerable Needs Registry allows users to submit information about their medical conditions, medications, allergies, disabilities, and language preferences.[54] When an enrolled household dials 911, this information is displayed on call-taker screens, provided that the ECC participates in the Smart911 program. Smart911 also shares alerts and notifications and real-time information about weather, traffic, and other emergencies with Smart911 subscribers.[55] ECCs in Atlanta, GA, Chicago, IL, Nashville, TN, Seattle, WA, and Washington, DC, as well as in the states of Arkansas, Delaware, and Michigan currently participate in Smart911. While Smart911 claims that its platform reduces response times and saves lives, no studies have been conducted on the effectiveness of Smart911 in streamlining the provision of emergency services.

Research Evidence

What measurable impacts do analog 911 systems have on emergency response?

Even in ECCs that have wireless enhanced 911 capabilities, some types of calls present real challenges. One study found that nearly all alarm system alerts to 911 are made via phone calls over PSTN, limiting information-sharing to verbal communication between alarm monitoring operators and 911 call takers, and leading to long processing times as well as wasted call-taker time due to numerous false alarms. The study estimated the annual cost to the emergency response system (and therefore to taxpayers) of the approximately 62 million yearly false alarms at around $3.1 billion.[56,57] If alarm systems were able to use NG911 to send video or audio footage directly to a call taker, unnecessary police dispatch to false alarms could be greatly reduced, as could potentially harmful interactions between officers and reportedly "suspicious persons."

Does current 911 technology impact medical emergency response?

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[49] U.S. Congress, House, "LIFT America Act," H.R. 1848, introduced in House March 12, 2021, https://www.congress.gov/bill/117th-congress/house-bill/1848.

[50] U.S. Congress, House, "Build Back Better Act," H.R. 5376, introduced in House September 27, 2021, https://www.congress.gov/bill/117th-congress/house-bill/5376/.

[51] Margaret Harding McGill, "Congress Decimates 911's Digital Upgrade," Axios, November 25, 2021, https://www.axios.com/congress-decimates-911s-digital-upgrade-845c5730-d1b2-4478-b32d-9d980793570d.html.

[52] 911.gov, "Introducing the 911 DataPath Initiative," accessed February 12, 2022, https://www.911.gov/pdf/911_Data_Information_Sharing_Strategic_Plan_Final.pdf

[53] Smart911, "Smart911," accessed January 2, 2022, https://www.smart911.com/.

[54] Smart911, "Smart911."

[55] Smart911, "Smart911."

[56] Cirrus Foroughi, "Understanding the Data Gap in Emergency Response: Evidence from US 911 Agencies," working paper, available at SSRN (2020), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3633580.

[57] Neusteter et al., "Understanding Police Enforcement."

The current system of first response in hospitals relies on the estimations of "pre-hospital providers" (i.e., Emergency Medical Services or EMS) about response time and arrival time at the hospital, which are often incorrect. For example, one study in Oregon found that pre-hospital providers' *estimated* duration of transport time was accurate within five minutes of the *actual* transport time in fewer than 16 percent of instances studied,[58] which can result in unnecessary downtime or delays at the emergency department. Moreover, the reliance on pre-hospital providers also led to a delay in the hospital receiving medical reports and making suitable response arrangements for the incoming patient.[59] EMS are now trying to incorporate Geographical Information Systems (GIS) technology to identify location and choice of transport (air or ground) for faster response. GIS is also being used for other purposes, such as trauma triage and ambulance deployment.[60] Similarly, the use of Global Positioning Systems (GPS) can allow for live mapping systems and help in better predicting transport times, which can then help in making dispatching and response team decisions.[61] In addition, platforms such as Smart911 may streamline the provision of emergency services and result in more effective emergency response because responders will have information about medical conditions and special needs of residents. These developments may offer promise for 911 call taking, dispatching, and response – particularly for those instances in which response may involve transporting the subject of a call to an emergency department or other medical facility.

What challenges are expected from the transition to NG911?

While the NG911 system will be a transformative improvement in technological capability and sophistication from the existing 911 system, it will bring new challenges that will need to be addressed by governing bodies. For example, given that ECCs in most states operate independently, the advantages of NG911 will be limited until all ECCs, particularly those serving neighboring jurisdictions, have adopted NG911 and thus have full interoperability, the capability to receive VoIP calls, and the ability to receive and manage text and video media.[62] Many ECCs currently rely on antiquated legacy CAD systems and outdated technology comparable to that used by systems 30 years ago,[63] which will need to be upgraded to comport with NG911 requirements and capabilities.[64] Measures to upgrade these networks occur at the ECC level, resulting in different technologies and ways of coding calls that make data sharing and interoperability challenging.[65] Governance at all levels is therefore needed to fund and coordinate the transition to NG911 to enable service interoperability and mitigate cybersecurity risks.[66]

Given the large volume of data which will be part of the NG911 system, privacy breaches and cybersecurity risks will pose challenges.[67] Furthermore, since NG911 aims to amass data and promote connectivity, security breaches or blockages to the system can be especially disruptive to the network's

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[58] Ross J. Fleischman et al., "Predicting Ambulance Time of Arrival to the Emergency Department Using Global Positioning System and Google Maps," *Prehospital Emergency Care* 17, no. 4 (2013): 458-465, https://doi.org/10.3109/10903127.2013.811562.
[59] Fleischman et al., "Predicting Ambulance Time."
[60] Fleischman et al., "Predicting Ambulance Time."
[61] Fleischman et al., "Predicting Ambulance Time."
[62] Neusteter et al., "911 Call Processing System."
[63] Coley, "NG9-1-1 and Cybersecurity."
[64] Abobakr Y. Shahrah et al., "Developing and Implementing Next-Generation Computer-Aided Dispatch: Challenges and Opportunities." *Journal of Homeland Security and Emergency Management* 14, no. 4 (2017).
[65] Rob Grace and Jess Kropczynski, "Communicating Next-Generation 911 with Local 911 Professionals: Preliminary Recommendations," in *2020 IEEE International Professional Communication Conference* (2020): 110-114, https://par.nsf.gov/servlets/purl/10281186.
[66] Coley, "NG9-1-1 and Cybersecurity."'
[67] Grace and Kropczynski, "Communicating NG911."

public safety and communication services. The significant increase in volume of data associated with NG911's ability to transmit photos and videos will also present significant data storage challenges.

The large volume of complaints that will come in the form of multimedia calls, texts, videos, and pictures are also expected to impact the mental health and stress levels of 911 professionals.[68] In particular, 911 professionals are concerned about having to view violent or disturbing images that may increase their risk of traumatic stress.[69] 911 professionals already face psychological and traumatic stress due to the kind of emergency calls and complaints that they have to answer.[70] With NG911, 911 professionals will now be exposed to triggering multimedia photos and videos of crisis and criminal situations, increasing the level of stress that they are likely to face. This has the potential to be both personally harmful and professionally detrimental in terms of job performance and productivity.[71] 911 professionals will also need to undergo training to comprehend time-sensitive data from media forms other than voice calls and convey that information to first responders.[72] Furthermore, transitioning to the NG911 system will likely require organizational challenges that have the potential to cause staff resistance.[73]

Although the NG911 system is capable of data sharing and connecting different ECCs and enables callers to use VoIP devices to contact emergency services from any internet access point, those calls are routed to the ECC associated with the subscriber's home; if the caller is contacting 911 from a different location, then the call must be rerouted. [74] Rerouting which wastes precious time and allows for human error in identifying the correct ECC.[75]

How can we build in resilience and prevent NG911 systems from being overloaded?
NG911's main drawback is that it will collapse under a faulty internet connection, the odds for which increase during the heavy traffic disaster situations when the system is most critical. In response, researchers have proposed developing a single protocol level which can integrate remote media control system with the VoIP-based NG911 system. This combined system can then switch between multimedia messages and voice only systems (during high emergency and traffic situations). This integration can happen with the help of a smartphone option of enabling and disabling remote media control (RMC).[76]

Reverse 911 systems are another mechanism through which 911 automated calls are sent out to people in areas affected by emergency situations. This process preempts community members placing a high volume of 911 calls by proactively providing warnings and information through recorded or automated

[68] Grace and Kropczynski, "Communicating NG911."
[69] 911.gov, "NG911 Guide for Telecommunicators," accessed November 16, 2021, https://www.911.gov/project_ng911publicsafety/telecommunicators/index.html
[70] Janet Baseman et al., "Impact of New Technologies on Stress, Attrition and Well-Being in Emergency Call Centers: The NextGeneration 9–1-1 Study Protocol," *BMC Public Health* 18, no. 1 (2018): 1-9, https://link.springer.com/content/pdf/10.1186/s12889-018-5510-x.pdf.
[71] Baseman et al., "Impact of New Technologies."
[72] Oorni and Goulart, "eCall and Beyond."
[73] Baseman et al.," Impact of New Technologies."
[74] Guerlain and Algiere, "IP-Enabled WAN EMS System."
[75] Anthony Daniel Salerni, "IP-Enabled WAN EMS System," Worcester Polytechnic Institute Interactive Qualifying Projects (2013), https://digital.wpi.edu/concern/student_works/7p88ch066.
[76] Vikram Chandrasekaran et al., "Socio-Technical Aspects of Remote Media Control for a NG9-1-1 System," *Multimedia Tools and Applications* 62, no. 3 (2013): 733-759, https://doi.org/10.1007/s11042-011-0875-1.

messages.[77] Reverse 911 usefully curates messages and warnings for specific populations, and is effective in communicating instructions, such as directing the evacuation of a disaster area.[78]

When setting up a landline, users are prompted to provide a valid address within their country of purchase.[79] In the United States, this address and number is accessible to local 911 services and can be used to notify individuals of crisis situations with reverse 911.[80] More recently, the VoIP-based NG911 system has brought reverse 911 to cell phones, making it an even more powerful tool. Authorities are no longer confined to alerting individuals solely at their home addresses. They are now able to share more precise warnings and instructions no matter where people are. This is especially useful for those who are unhoused and do not have regular access to a landline. However, since cell phones are wireless, can be carried anywhere, and are not tied to specific addresses, residents are responsible for registering their cell phone numbers with their county in order to receive alerts.[81] This additional step of registration may act as an unintended barrier for certain populations, specifically the elderly and disabled, who may not have the capacity to register for such services, and people living under unstable conditions who may not have continuity in phone service.

How can advanced 911 technology improve accessibility and equity within the emergency response system?

Most attention around accessibility and equity in 911 call technology focuses on deaf and hard of hearing users, and text-to-911 is the 911 technological innovation perhaps most frequently touted as a tool to improve access for these users.[82] A simulation pilot study in King County, WA, found that 911 call-takers were able to provide CPR instructions via text to ten deaf and hard of hearing participants, all of whom then successfully completed CPR on a practice mannequin.[83] Recently, researchers have suggested integrating NG911, voice-to-text captioning, and third-party video calls directly into mobile dialer systems, rather than requiring separate apps or workarounds for these services, to provide deaf and hard of hearing users with an experience akin to that of auditory phone users.[84]

As of this writing, there is little public awareness or clarity around new services like text-to-911. One content analysis of text-to-911 public education information across Texas found that local government entities and ECCs provided minimal and inconsistent information about the availability and use of text-to-911.[85] Information about text-to-911 availability is itself sometimes inaccessible for deaf and hard of hearing populations, as well as being vague or minimally descriptive. A Houston-Galveston Area Council video announcing new text-to-911 availability, for example, has inaccurate automatic closed captioning and no subtitles or in-video text, and advises that if you don't get a text back from 911 (no

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77 Lesley Strawderman et al., "Reverse 911 as a Complementary Evacuation Warning System," *Natural Hazards Review* 13, no. 1 (2012): 65-73, https://ascelibrary.org/doi/abs/10.1061/(ASCE)NH.1527-6996.0000059.

78 Strawderman et al., "Reverse 911."

79 Ooma, "Calling 911 From Landline Phones, VOIP Phones, and Cell Phones," Ooma FAQ, https://www.ooma.com/home-phone-service/faqs/calling-911-from-a-landline-phones-voip-phones-and-cell-phones/.

80 Maricopa County, "Community Emergency Notification System (CENS)," https://www.maricopa.gov/1755/CENS.

81 Douglas County, NV Sheriff, "Reverse 911," https://sheriff.douglascountynv.gov/services/reverse_911.

82 e.g., 911.gov, "Ensuring Access." This page on 911.gov states in a paragraph about deaf and hard of hearing callers that text-to-911 "is a great benefit for this community and others."

83 Priyanka Gautom, "Text-to-9-1-1: Testing CPR Instructions for the Deaf and Hard of Hearing Population in King County, WA." (Master's thesis, University of Washington, 2019, https://digital.lib.washington.edu/researchworks/handle/1773/44314.

84 Gary Behm et al., "Equivalent Telecommunications Access on Mobile Devices," in *the 23rd International ACM SIGACCESS Conference on Computers and Accessibility*, pp. 1-3. 2021, https://doi.org/10.1145/3441852.3476535.

85 Rob Grace and Sierra Sinor, "How to text 911: A content analysis of text-to-911 public education information," in *the 39th ACM International Conference on Design of Communication* (2021): 135-14, https://dl.acm.org/doi/abs/10.1145/3472714.3473633.

specific timeframe was given), you should call.[86] This "call if texting doesn't work" approach has been documented by other scholars, who are concerned about the effective rollout of text-to-911 for individuals with disabilities.[87]

Rural and tribal communities may encounter challenges to 911 access due to lack of phone network coverage,[88] among other factors like distance to emergency services and hospitals or outright lack of a local ECC. Scholars have identified cellular coverage and other dispatch issues within American Indian reservations and other tribal communities as an area needing further research.[89]

Users who do not speak English fluently may also have difficulty using 911, though little research exists in this area. NG911's potential to send photos and video footage could help overcome language barriers, but further research should be conducted into technology to support language interpreters or automated translation. While no evaluations have been published on Smart911 to date, this technological tool is designed to assist users with language and verbal differences to access and communicate with 911 and associated first responders.

911 technology is particularly relevant in the move to expand the use of alternative three-digit (988, 311, 211) hotlines and helplines, as research finds that many calls for services that are suitable for alternatives to police response are nonetheless placed to 911.[90] Advances in 911 technology should include the exploration of the most efficient re-routing of such calls and of considerations surrounding location-finding capabilities for alternative hotlines to ensure that they are fully employed when appropriate and generate the information needed to direct emergency medical services if necessary.

What other innovations have been proposed by researchers?
Many public safety communication systems use the land mobile radio system (LMRS), which is a wireless communication system that uses portable and mobile devices to allow for two-way digital radio communications.[91] LMRS, however, is unable to support high data rate applications, thus is lacking during situations with high broadband requirements.[92] To overcome the challenges of LMRS, long-term evolution (LTE) is the emergent technological network which will allow for increased capacity and for large volumes of data to be exchanged over wireless networks. Currently, the FirstNet network is in development under a public-private partnership between the US government and AT&T as an LTE-based broadband network for supporting public safety communications.[93] FirstNet will help in enabling group calls, talker identification, emergency alerting, and improving audio quality.[94] Unmanned aerial vehicles (UAVs) are the other LTE-based wireless communication systems which can be used during

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[86] Houston-Galveston Area Council, "Text To 9-1-1," accessed November 22, 2021, https://www.h-gac.com/gcrecd/text-to-9-1-1.
[87] Elizabeth Ellcessor, "Call If You Can, Text If You Can't: A Dismediation of US Emergency Communication Infrastructure," *International Journal of Communication* 13 (2019).
[88] 911.gov, "Ensuring Access."
[89] Kathryn Quick et al., "Emergency Medical Services in American Indian Reservations and Communities: Results of a National Survey," Center for Transportation Studies, University of Minnesota (2019), https://conservancy.umn.edu/handle/11299/203396.
[90] Jessica W. Gillooly, "“Lights and Sirens”: Variation in 911 Call-Taker Risk Appraisal and its Effects on Police Officer Perceptions at the Scene," *Journal of Policy Analysis and Management* (2021), https://doi.org/10.1002/pam.22369; Cynthia Lum et al., "Constrained Gatekeepers of the Criminal Justice Footprint: A Systematic Social Observation Study of 9-1-1 Calltakers and Dispatchers," *Justice Quarterly* 37, no. 7 (2020): 1176-1198, https://doi.org/10.1080/07418825.2020.1834604; Lorraine Mazerolle et al., "Managing Citizen Calls to the Police: The Impact of Baltimore's 3-1-1 Call System," *Criminology & Public Policy* 2, no. 1 (2002): 97-124.
[91] Kumbhar et al., "A Survey on Public Safety Technologies."
[92] Kumbhar et al., "A Survey on Public Safety Technologies."
[93] Kumbhar et al., "A Survey on Public Safety Technologies."
[94] Kumbhar et al., "A Survey on Public Safety Technologies."

emergency situations. They have the advantages of easier deployment than traditional towers and the ability to send out quicker communications during crisis situations.[95]

Researchers have also proposed improvements to the CAD system. A team in Australia has suggested an "agent-based" CAD system for automatic deployment of resources, using interconnected visual interfaces to facilitate communication between dispatch, responders (e.g., police departments, fire stations), and mobile units.[96] On the consumer side of technology, researchers are exploring social media's dedicated SOS features (e.g., Facebook's Safety Check[97]), and organic use of social media for emergency outreach (e.g., frequent use of social media to ask for help during natural disasters that have caused network outages[98]), as well as potential ways to harness these networks for formal emergency response. With the proliferation of social media in emergency communication, researchers have proposed frameworks for detecting SOS messages/posts/tweets and actionable information on social media[99,100] and using a "public safety bot" to triage and escalate requests for help.[101]

Researchers have proposed that the effectiveness of fire emergency response systems could be improved by adopting an Internet of Things (IoT)-based system which can automatically determine the source of fire in a building and share that information with the responding fire department. This can be useful in reducing response time and managing the evacuations.[102]

Finally, there has been some preliminary exploration of computer algorithms and artificial intelligence/machine learning to assist in triage of 911 calls,[103] particularly for identifying medical emergencies. One recent study of machine learning triage for out-of-hospital cardiac arrest found that machine learning alerts alone had a significantly higher sensitivity than dispatchers without machine learning. Given this pattern, the machine learning triage had a lower rate of false negatives but a higher rate of false positives than a dispatcher.[104] Similarly, an algorithm employed in New York City, NY, to divert COVID-19-related 911 calls to hospital-based hotlines staffed by physician assistants and/or nurses reduced the proportion of calls resulting in ambulance response and increased the more appropriate allocations of EMS resources.[105]

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[95] Arvind Merwaday, et al., 'Improved Throughput Coverage in Natural Disasters,' IEEE, 2016.
[96] Jihang Zhang et al., "Enable Automated Emergency Responses Through an Agent-Based Computer-Aided Dispatch System," in *Proceedings of the 17th International Conference on Autonomous Agents and MultiAgent Systems* (2018): 1844-1846.
[97] Kate Sangwon Lee, "Explicit Disaster Response Features In Social Media: Safety Check And Community Help Usage On Facebook During Typhoon Mangkhut," in *Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services* (2019): 1-12, https://doi.org/10.1145/3338286.3340140.
[98] Chaudhry and Yuksel, "Social Media for Public Safety."
[99] Jess Kropczynski et al., "Identifying Actionable Information on Social Media For Emergency Dispatch," *Proceedings of the ISCRAM Asia Pacific* (2018).
[100] Chaudhry and Yuksel, "Social Media for Public Safety."
[101] Chaudhry and Yuksel, "Social Media for Public Safety."
[102] Chang-Su Ryu, "IoT-based Intelligent for Fire Emergency Response Systems," *International Journal of Smart Home* 9, no. 3 (2015): 161-168, http://dx.doi.org/10.14257/ijsh.2015.9.3.15.
[103] Marcos Orellana et al., "A Methodology to Predict Emergency Call High-Priority: Case Study ECU-911," in *2020 Seventh International Conference on eDemocracy & eGovernment (ICEDEG)* (2020): 243-247.
[104] Stig Nikolaj Blomberg et al., "Effect of Machine Learning on Dispatcher Recognition of Out-Of-Hospital Cardiac Arrest During Calls to Emergency Medical Services: A Randomized Clinical Trial," *JAMA Network Open* 4, no. 1 (2021): e2032320-e2032320.
[105] W. Haussner et al., "49 911 Call Diversion to Telemedicine During the COVID-19 Pandemic in New York City: Call Characteristics, Outcomes and 48-Hour Follow-Up at a Single Academic Center," *Annals of Emergency Medicine*, August 1, 2021, https://doi.org/10.1016/j.annemergmed.2021.07.050.

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Questions for Inquiry and Action

As described above, the lack of centralized, publicly available data makes it difficult to get a full picture of what technology is currently in use – and much more difficult to study the capabilities of these technologies to promote more equitable access to 911 services and streamline the diversion of calls to alternative hotlines and responders. Questions for researchers to explore in the future include:

- How can technology provide better 911 and alternative hotline access for users who are nonverbal, hearing impaired, or who do not speak English fluently? How well does text-to-911 serve their needs?

- To what degree does Smart911 improve the speed and effectiveness of 911 services and responses? Does Smart911 result in improved communications and better-quality services, particularly to those who are nonverbal, hearing impaired, have cognitive or developmental disabilities, or do not speak English fluently?

- How can existing and NG911 technologies be improved to promote more seamless and efficient rerouting from 911 to alternative hotlines and helplines?

- To what degree do call-taking and triaging facilitation and automation technologies yield more consistent and equitable responses and more effective service delivery? Are technologies development in partnership with ECC professionals more or less effective than those developed without practitioner input?

- How can technology needs be assessed objectively in a manner that informs the actual needs of the 911 profession and community rather than guided by the introduction of new applications promoted vendors?

- What can we learn from tracking ECC migration to NG911 to better understand technological barriers and what factors support successful migration? Are some ECCs better equipped to make the transition to NG911based on the entity in which they are housed (e.g., police, fire/EMS) or the governance structure under which they operate?

- What has the impact of the NG911 grant program been in facilitating migration to 911? What are the remaining gaps in technical assistance and resource needs among ECCs nationwide?

- How do different communication types (call, text, multimedia) affect performance indicators like call outcome and response time? Do they have any impact in promoting more or less equitable and less harmful responses to request for emergency services?

- How does lack of cellular network coverage affect 911 accessibility in rural and tribal areas?

- To what degree does the underlying 911 technological infrastructure reduce or exacerbate the under- or over-triaging of calls to 911? Can changes to 911 technology reduce the over-triaging of calls pertaining to people of color?

- How is CAD best structured to support optimal outcomes for call-taking, triaging, assessment, dispatch, response, and follow-up? How might different CAD user interfaces or dashboards influence triaging decisions?

- How can emergency communications systems be fortified against outages, network overload, and cyberattacks?

- What are the most efficient ways to detect and handle false alarms and accidental calls?

- How can lags and lapses in service during the transition to NG911 be prevented or mitigated?

- How could 911 technology infrastructure better support standardized data collection around volume and type of 911 calls, responses, and associated outcomes?

- How can machine learning assist 911 professionals to provide appropriate responses to medical and other emergencies?

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