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Conventional and Cognitive Radio Based Disaster Response Networks, A Comparative Study

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Abstract

The need for the deployment of reliable and efficient telecommunication systems in extreme emergency scenarios such as disaster response networks imposes a set of emerging unusual communication and routing challenges and obstacles that questions the performance of existing traditional and commercial telecommunication systems and networks in such scenarios, the revolution of telecommunication and networks industry witnessed the development of enormous telecommunication and networking services and systems that shaped their implementations in various domains of applications , in this paper, we study most of these communication standards in terms of their pros and cons, we also analyze the potentials of these standards in for Disaster Response networks in comparison with Cognitive Radio technology that has distinct capabilities and functionalities that enabled such a technology to be highly applicable for such harsh and unexpected scenarios.

Keywords: Cognitive radio, disaster response networks, communication standards.

1. Introduction

Existing radio communication systems such Zigbee, Bluetooth, WiFi and others have been implemented for disaster-like emergency networks, these technologies operate in the $2.4GHZ$ license-free ISM (industrial, scientific and medical) frequency band [1], the harsh electromagnetic interference from devices operating in this band along with link disruptions resulting from disaster occurrence degrade the wireless channel conditions, the radio frequency interference that results from multiple devices sending and receiving within the same regional distance in the ISM band in along with potentially multiple technologies operating in different frequency bands trying to gain access to the network resources for performing network-based activities including sending and receiving data to

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and from other communicating parties connected to the same network or even to other networks will probably influence reliable DRN communication, the collection and transmission of large volumes of data related to electrical energy poses a significant challenge for existing communication networks, therefore. Section 2 illustrates the existing communication technologies that have been implemented in disaster-like and emergency scenarios, the illustration summarizes the capabilities and limitations of these technologies and their potential in DRNs application scenario.

In order to overcome the challenges and limitations and insufficiency of traditional communication systems in DRNs, Cognitive radio (CR) is proved by [2] to be highly potential solution in the scenario of DRNs, CR is an important technology that will shape the future wireless communication industries [3]. An important capability of CR is spectrum efficiency which acts an obstacle in all other existing technologies, this capability enabled network nodes to utilize unused available spectrum known as TV white space (TVWS) in an efficient manner. In order to efficiently utilize and benefit from the licensed radio frequency bands that are exclusively assigned to authorized and licensed users referred to as PUs who have the legal authorization and license to access that band in which they are operating. Spectrum efficiency and other distinguishing capabilities of CR technology (outlined in section 4)enabled this technology to provide a reliable solution in future DRNs, Dynamic Spectrum Access (DSA) is considered the key feature of CR, but there are many other potentials in which CR can be applied to DRNs, after disaster occurrence, the DRN will be considered as a Secondary User (SU) while the partially disabled existing network will be considered as the Primary User provided that the newly deployed SU maintains minimum levels of interference with PU [2].

Routing remains the core challenge in all communication systems, the efficiency of the communication system is directly determined by a number of factors among which routing algorithm is a key one. Both decisions related to spectrum management along with decisions related to the routing of data packets over the network [4] make routing a primary concern in in CRNs due to the variations in availability of network resources in terms of time and location [5]. Furthermore, the primary user activities are influenced by the availability of spectrum. In case of multi-hop routing which is highly applicable in DRNS; the route establishment process is controlled and maintained by SUs' receiving and sending nodes through other set of nodes known as intermediate or relay nodes, this process also involves the selection of the intermediate relay node as well as the frequency to be used on each link of the communication route. So, DRNs routing algorithm design encounters all the challenges of traditional multi-hop, multi-channel and mesh networks with many extra challenges due to the highly variable routing requirements in DRNs specially the consideration of PU activity [6].

In this paper, we study the post disaster scenario and outline the consequences of disaster occurrence on existing communication systems, we also identify the key requirements for routing in CR-DRNs and introduce a survey on the existing CR-based routing protocols and their potentials and limitations in CR-DRNs from perspective of key routing requirements to determine how satisfactory these routing protocols are, furthermore, we highlight the challenges and future research directions towards reliable and efficient routing in CR-DRNs.

2. Existing communication technologies in DRNs

The deployment of advanced and modern reliable telecommunication systems is required for various usual and unusual application scenarios including extreme emergency networks such as DRNs, the performance of these technologies is directly proportional to a set of factors including the number of users and their devices, the type of data to be transmitted over this network, the architecture of this network, the communication environment conditions and status of the existing communication systems, the existing traditional communication systems can variably handle the distinct routing requirements of disaster area up to different extents that determines whether these technologies can properly cope with these routing requirements, in this section, we summarize the general capabilities of the existing communication systems so that we conclude whether or not these technologies are applicable for DRNs.

Table 1: Advantages and disadvantages of existing communication systems.

Standard	dAdvantages	Disadvantages
ZigBee [7]	16 5 MHz communication channels operating in the band of 2.4 GHz, low power usage, not complex, deployment costs are low.	Powered by limited battery power, short transmission range, in sufficient data rates, processing power is low, high interference with IEEE802.11 WLANS, Wi-Fi, Bluetooth and microwave devices.
Bluetooth [8]	Consumes less device power.	Short transmission range, low throughput rates, insufficient security, high interference with IEEE802.11 WLAN.
Broadband Access [9]	Sufficient bandwidth, allows high user mobility, low latency.	Acceptable data rates, un-reliable infrastructure, high deployment cost.
Microwave [10]	High data rates, wide coverage range.	communication links may be to precipitated, multi-link interference, less data rates due to strict security.
WLAN [11]	Robust, high speed P-P and P-multipoint comm., minimized interference to network users who are out-of-band, high data rates, simple installation, less cost.	Slow data rates, high interference, not available on industrial wireless LAN devices, complex designs when availability and reliability are highly required.

WiMAX [12]	High throughput ranges, wide coverage range.	Performance negatively affected with increasing distance, high power is consumed in licensed spectrum, expensive equipment, frequencies of higher bands don't cope with transmission obstacles, lower frequency bands are required to be licensed.
Wi-Fi [12]	Provides convenient access to variety of devices, supports users with high mobility, easy configuration, low cost.	Insufficient for outdoor connectivity, prone to security threats, limited transmission range, subject to wide variety of interference sources, propagation issues, low transmission rates.
Cellular Comm. [13]	Extensive coverage, improved QoS, continuously growing.	Range depends on service availability, connection establishment causes transmission delay, call drops produces large data exchange, expensive service and subscription.
Powerline [14]	High speed, low cost, minimum latency, availability	Harsh medium conditions, topology determines signal quality, requires more wiring and network devices, low bandwidth, sensitive to disturbances.
DSL [15]	High speed, low cost, less transmission latency, high channel capacity, high throughput, wide coverage, network availability.	QoS is determined by distance between user and next telephone exchange, standardization is insufficient, new connections require high installation costs, maintenance is regularly required, not feasible in low-density area due to high installation costs.
Optical Networks [16]	High transmission rates, sufficient bandwidth, reliability, wide coverage.	High cost, interoperability.
CR-WRAN [17]	High transmission rates, wide coverage, immune to interference, acceptable power levels.	May be disrupted by PU activity, security is not a primary concern, network is interoperable.

3. Limitations of Existing communication technologies in DRNs

The deployment of infrastructure networks is considered to be unreliable for disaster management mainly because after disaster there is a high potential for power outage and wired media dysfunctionality, considering that the communication system infrastructure is not thoroughly dysfunctional, network traffic problems and network congestion may result in network dysfunctionality and makes the communication over this network virtually unreliable, attempting to repair the network infrastructure could be time wasting, expensive and lead to unnecessary loss of lives and properties.
The arrival of Mobile Ad Hoc networks has partially solved the problem of infrastructure network insufficiency for DRNs specially the issue of power outage and link failure [18], but this networking paradigm was not fully functional in DRNs due to the distinct characteristics imposed by post disaster circumstances like rapid deployment, existing network utilization, interoperability with heterogeneous technologies, reliability and robustness, self-organization, supporting the emergent services based on (2G/3G/4G/5G) mobile systems with different technologies and the most important characteristic which is the efficient spectrum utilization, in traditional networks [19], these circumstances may arise individually and network design is required to consider few of these characteristics, what makes DRNs different and distinct is that these circumstances arrive all together at the same time, specifically in the same few hours.
According to the comparison in table (1), we conclude that each of the existing communication technologies has its strengths and weaknesses based on the area of application, the services it provides and the constraints upon network deployment, the environmental and operational circumstances imposed by disaster make a particular technology which is favored in usual conditions unfavored in post disaster scenario, such as:

1. Traditional communication systems that are based on mobile broadband service providing are efficient communication systems but their service provision is limited only to licensed users.

2. 2. In uncivilized districts where population is much less than major cities and towns, traditional communication systems are not feasible, sine the cognitive solutions are beyond licensed solutions, service providers may replace their cellular communication systems in those areas with cognitive radio based solutions to save the charges of spectrum licensing and also help in reducing the problem of spectrum scarcity [20].

3. The layers of emergency networks such as DRNs each has its own functional requirements such as routing requirements and conditions of the surrounding environment, this renders the network adaption to a single technology or standard logically impossible. WLAN and other broadband access standards are capable of providing sufficient transmission and coverage ranges guaranteeing reliable and high transmission rates and operate on both licensed as well as unlicensed spectrum bands. However, these standards are able to partially cover the DRN layers and application areas [12].
   In uncivilized districts where population is much less than major cities and towns, traditional communication systems are not feasible, sine the cognitive solutions are beyond licensed solutions, service providers may replace their cellular communication systems in those areas with cognitive radio based solutions to save the charges of spectrum licensing and also help in reducing the problem of spectrum scarcity [20].

4. At disaster time, normally the DRN's power systems are distributed and hence; these systems cover large geographical areas, which may be governed by certain strict spectrum rules and regulations [21].

5. Powerline communications (PLC) is characterized with its high speed, but its performance is badly degraded by the disastrous hard and unusual communication environment resulting from disaster occurrence [14].

6. Digital subscriber line also supports and is aligned with IEEE 802.22 WRAN and compliant technologies in many aspects, DSL's application area covers almost each layer of the DRN architecture but it supports only licensed users [1].

4. Potentials of CR technology for DRNs

Different from all other technologies, Cognitive Radio technology is able to cope with the above communication and routing obstacles, this fact is inspired from its definition provided by FCC which defines CR technology as "A cognitive radio is a radio that can change its transmitter parameters based on interaction with the environment in which it operates." , it is marked with its capability to acquire information by sensing this information from its surrounding radio frequency environment along with its re-configurability capability where the radio to be dynamically programmed according to the radio environment , these two distinguishing capabilities enable CR-based networks like CR-DRNs to perform better and cope with all the challenges and issues of providing reliable and efficient routing in DRNs [22].

1. In post disaster scenarios, CR can help to sufficiently accumulate and send large amounts of data keeping the spectrum utilization at maximum levels, the architectures of CR networks may cover home, neighborhood and wide areas, their intelligent nature with reconfigurability ability and awareness can help to manage the communication across various disaster area ranges [23].

2. The utilization of TVWS by CR technology can provide reliable low-latency communication channels for time constrained communication in disaster area [24], this could also reduce the congestion in ISM band and provided better data transmissions as compared to unlicensed 2.4 GHz band.

3. The CR-based networks may reduce power consumption, this result from their ability to sense the surrounding radio environment and dynamically reconfigure the transmission power levels, the power consumption of these networks is low at the lower frequencies of the TVWS [25]. this also can reduce the overall cost of network deployment.

4. The establishment of CR-based communication links in disaster area with devices operated by IEEE standards such as 802.11 and 802.22 don't need high budgets and investments in the licensed spectrum like the investments needed for IEEE 802.22 Wireless regional area networks WRANs that support long ranges (up to 100 km), this in turn reduces the number of base stations required for traditional communication systems, CR WAN architectures can also readily support for DRNs reliable data collection.

5. The ability of CR-based networks and communication systems fits with almost all DRN network layers of the DRN architecture and a wide range of network application areas [26,27].

6. CR can flexibly support DRN service applications regardless of certain spectrum utilization issues and regulations, e.g., by communication over recently sensed spectrum holes, CR networks are also capable of utilizing and sharing the spectrum portions available in multiple networks around[21].

7. After the occurrence of disaster, it is possible that PU's authorized access to network services is degraded due to the occurrence of disasters or a security breach, DRN's data is hence transmitted over CRNs utilizing the spectrum holes known as TV white spaces TVWS.

8. Software defined radios (SDR) can be exploited using PCs or embedded computers and devices to implement CR communications, these radios can reliably change their routing parameters in the disaster area through software upgrades.

Conclusion

Conventional telecommunication systems are able to provide a wide range of services to their subscribers in usual circumstances, but the occurrence of disastrous events renders these networks virtually dysfunctional, this imposes the implementation of intelligent networking and telecommunication solutions that can adapt its transmission parameters and configurations dynamically in such harsh and noisy situations, the major issue of such harsh scenarios is the spectrum scarcity problem, the arrival of CR has made a considerable attempt to resolve the issue of spectrum scarcity through dynamic spectrum access DSA which efficiently utilizes the available radio frequency spectrum.

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References

[1] A. A. Khan, M. H. Rehmani, and M. Reisslein, "Cognitive radio for smart grids: Survey of architectures, spectrum sensing mechanisms, and networking protocols," IEEE Commun. Surv. Tutorials, vol. 18, no. 1, pp. 860–898, 2016, doi: 10.1109/COMST.2015.2481722.

[2] A. K. N. B. SAIM GHAFOOR, PAUL D. SUTTON, CORMAC J. SREENAN, "Cognitive radio for Disaster Response networks, Survey, potential, and Challenges," Ieee Wirel. Commun., no. February, pp. 104–111, 2010, doi: 10.1109/MWC.2009.5361183.

[3] I. F. Akyildiz, W. Y. Lee, M. C. Vuran, and S. Mohanty, "NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey," Comput. Networks, vol. 50, no. 13, pp. 2127–2159, 2006, doi: 10.1016/j.comnet.2006.05.001.

[4] H. Kumar and D. Sarma, "Routing Protocols for CRAHN: A Comparative Evaluation," Proc. 3rd Natl. Conf. CCB, 2018, vol. 99, pp. 3–11, 2018.

[5] N. Dutta, H. K. D. Sarma, and Z. Polkowski, "Cluster based routing in cognitive radio adhoc networks: Reconnoitering SINR and ETT impact on clustering," Comput. Commun., vol. 115, pp. 10–20, 2018, doi: 10.1016/j.comcom.2017.09.002.

[6] N. Dutta and H. K. D. Sarma, "A probability based stable routing for cognitive radio adhoc networks," Wirel. Networks, vol. 23, no. 1, pp. 65–78, 2017, doi: 10.1007/s11276-015-1138-2.

[7] A.-K. Chandra-Sekaran, A. Nwokafor, L. Shammas, C. Kunze, and K. D. Mueller-Glaser, "A Disaster Aid Sensor Network using ZigBee for Patient Localization and Air Temperature Monitoring," Int. J. Adv. Internet Technol., vol. 2, no. 1, pp. 68–80, 2009, [Online]. Available: http://www.thinkmind.org/index.php?view=articlearticleid=inttech$_v 2_n 1_2 009_6 . F. Alvarez, L. Almon, H. Radtki, and M. Hol$ $Mediating Post-disaster Communication Systems using the Internet of Things and Bluetooth Mesh, pp. 18, 2020, doi:$ 10.1109/$ghtc$46095.2019.9033063.

[8] E. Seeman, J. Kleckley, and J. E. Holloway, "Data Management , Technology , and Public Policy," J. Inf. Policy, vol. 8, no. 2018, pp. 472–496, 2018.

[10] S. Gaikwad and D. C. Anastasiu, "Optimal constrained wireless emergency network antenna placement," 2017 IEEE SmartWorld Ubiquitous Intell. Comput. Adv. Trust. Comput. Scalable Comput. Commun. Cloud Big Data Comput. Internet People Smart City Innov. SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI 2017 - , pp. 1–6, 2018, doi: 10.1109/UIC-ATC.2017.8397562.

[11] J. Cai, "A time-threshold-based emergency preemption scheme for vertical handoff in cellular/WLAN interworking," Proc. IEEE Int. Conf. Softw. Eng. Serv. Sci. ICSESS, vol. 2017-Novem, pp. 414–417, 2018, doi: 10.1109/ICSESS.2017.8342944.

[12] I. M. Haider M. Turki Al-Hilfi, Mustafa Mohammed, "WiMAX and WiFi Network Integration as Backhaul on Emergency Communications," IEEE, vol. 18, no. february 20-24, 2018.

[13] P. V. Klaine, J. P. B. Nadas, R. D. Souza, and M. A. Imran, "Distributed Drone Base Station Positioning for Emergency Cellular Networks Using Reinforcement Learning," Cognit. Comput., vol. 10, no. 5, pp. 790–804, 2018, doi: 10.1007/s12559-018-9559-8.

[14] L. Wang, C. Huo, F. Gao, and B. Li, "Link awareness based networking scheme of power line carrier and wireless converged communications," Int. Conf. Commun. Technol. Proceedings, ICCT, vol. 2019-Octob, pp. 716–720, 2019, doi: 10.1109/ICCT.2018.8599971.

[15] M. Y. Adwitiya, R. Vinayaka, and P. Akshay Kumar, "A Multi-Tiered Alert Mechanism for Intrusion and Disaster Prevention in a Smart Home Scenario," Proc. 2019 3rd IEEE Int. Conf. Electr. Comput. Commun. Technol. ICECCT 2019, pp. 1–5, 2019, doi: 10.1109/ICECCT.2019.8869320.

[16] E. Tego et al., "A Measurement Plane for Optical Networks to Manage Emergency Events," Fiber Integr. Opt., vol. 36, no. 6, pp. 227–241, 2017, doi: 10.1080/01468030.2017.1408164.

[17] K. Ali, H. X. Nguyen, P. Shah, Q. T. Vien, and N. Bhuvanasundaram, "Architecture for public safety network using D2D communication," IEEE Wirel. Commun. Netw. Conf. WCNC, vol. 2016-Septe, no. ComExCon, 2016, doi: 10.1109/WCNC.2016.7564671.

[18] J. Bauer and Y. Lin, "Transition Paths to Next-Generation Wireless Services," … /Quello. Msu. Edu/Wp/Wp-04 …, pp. 1–29, 2004, [Online]. Available: http://quello.msu.edu/sites/default/files/pdf/wp-04-04.pdf.

[19] S. A. I. M. G. Ghafoor, P. A. U. L. D. S. Utton, C. O. J. S. Reenan, and K. E. N. B. Rown, "a Ccepted From O Pen C All C Ognitive R Adio for D Isaster R Esponse N Etworks : S Urvey , P Otential , and C Hallenges," no. October, pp. 70–80, 2014.

[20] M. Erol-Kantarci and H. T. Mouftah, "Energy-Efficient Information and Communication Infrastructures in the Smart Grid: A Survey on Interactions and Open Issues," IEEE Commun. Surv. Tutorials, vol. 17, no. 1, pp. 179–197, 2015, doi: 10.1109/COMST.2014.2341600.

[21] V. C. Gungor and D. Sahin, "Cognitive Radio Networks for Smart Grid Applications," IEEE Veh. Technol. Mag., no. June, pp. 41–46, 2012.

[22] P. Kaur, "Cognitive Radio: Need, Capabilities, Standards, Applications and Research Challenges," Int. J. Comput. Appl., vol. 30, no. 1, pp. 31–38, 2011.

[23] R. Yu, Y. Zhang, S. Gjessing, C. Yuen, S. Xie, and M. Guizani, "Cognitive radio based hierarchical communications infrastructure for smart grid," IEEE Netw., vol. 25, no. 5, pp. 6–14, 2011, doi: 10.1109/MNET.2011.6033030.

[24] R. C. Qiu, Z. Hu, Z. Chen, N. Guo, and R. Ranganathan, "Cognitive Radio Network for the Smart Grid: Experimental System Architecture, Control Algorithms, Security, and Microgrid Testbed," IEEE Trans. Wirel. Commun., vol. 31, no. 1, pp. 1–6, 2016, doi: 10.1109/TVT.2010.2043124.

[25] P. Ferrari, E. Sisinni, A. Flammini, and A. Depari, "Adding accurate timestamping capability to wireless networks for smart grids," Comput. Networks, vol. 67, pp. 1–13, 2014, doi: 10.1016/j.comnet.2014.03.005.

[26] Seryasat, O. R., Haddadnia, J. (2018). Evaluation of a new ensemble learning framework for mass classification in mammograms. Clinical breast cancer, 18(3), e407-e420.

[27] T. M. Chiwewe and G. P. Hancke, "Cognitiva - A cognitive industrial wireless network protocol: Protocol design and testbed implementation," Proc. IEEE Int. Conf. Ind. Technol., vol. 2016-May, pp. 2042–2047, 2016, doi: 10.1109/ICIT.2016.7475082.