Radio Frequency Coordination at the Democratic National Convention

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The 2016 Democratic National Convention (DNC) was a historic political event that gathered worldwide press and media interest. As part of the ongoing coverage for this event, the media relied on wireless communications to ensure timely delivery of content to the worldwide audience. In such large gatherings, radio frequency (RF) interference often becomes a major obstacle for maintaining quality of service, and various interference management techniques have been applied to proactively avoid loss of signal quality. In this article we detail the RF coordination and enforcement process at the DNC that we observed first-hand through our volunteer activities. We employed a traditional, low-overhead RF coordination technique that divides the available frequency spectrum into orthogonal bands and allocates them to different media organizations, ranging from national news networks to local television stations. The overall RF coordination process was considered a success, with only minor interference incidents that arose sporadically and handled promptly. The effectiveness as well as drawbacks of the traditional RF coordination procedure are analyzed to further motivate development of future RF coordination approaches.

1 Introduction

The 2016 Democratic National Convention (DNC) took place in Philadelphia, Pennsylvania, from July 25 through 28, 2016. This event gathered delegates of the Democratic Party, selected previously through a preceding series of primaries and caucuses, to nominate the party’s candidate for president and vice president in the 2016 United States presidential election. In this historic political event, former Secretary of State Hillary Clinton became the first female nominee of a major party for president. Her accomplishments attracted major national and global media interest both before and during the convention. The DNC opened at the Wells Fargo Center amidst tremendous coverage from all major news networks, including MSNBC, CNN, Fox News Channel, CBS News, among others.

For an event of this scale, live newscasting and commentaries from the convention floor are indispensable for timely coverage. Reliable wireless transmission of live content streams directly from the video cameras roaming the convention floor to the production backend, often situated on the elevated suite level, becomes a first-class priority for broadcasters. Since frequency spectrum is a scarce resource, the number of transmitting devices that can be active concurrently in a given frequency band and geographic area is limited. Uncoordinated transmissions from different transmitters can therefore collide in time and frequency, resulting in a phenomenon called interference, which severely impacts the signal integrity and quality of service at the receivers. To ensure harmonious operations among various news and television networks, frequency spectrum coordination is necessary as a centralized management approach.

This article describes in details the RF coordination and enforcement process that was carried out at the DNC this year. Wireless coordination and enforcement was primarily handled by Broad Comm [1], a New York-based advanced broadcast solutions and frequency coordination services company, with the help of student volunteers from Drexel University and Delaware Tech Community College. As part of this team of volunteers, we experienced first-hand the major engineering effort that went on behind the scene and assisted closely RF coordination personnel—Howard Fine of Broadcast Services at Pacific Television Center and Louis Libin of Broad Comm, as well as Rich Paleski from WCBS-TV in New York City—in enforcing compliance and resolving interference issues as they came up. This event represents a distinct transition from our RF theory acquired in the classroom to an actual deployment and management of wireless technologies at scale.

The remaining of this article is organized as follows. Sec. 2 discusses the background and motivation for frequency coordination, as well as some existing approaches for multiple access. The specific details of our RF coordination and enforcement process at the DNC are described in Sec. 3. Sec. 4 discusses the DNC RF coordination outcomes and several student testimonials. Sec. 5 gives an overview of the directions to go forward for RF coordination services at major events. Finally, we conclude the article in Sec. 7.
2 Background and Motivation

2.1 The Need for Frequency Coordination

To make wireless communications possible, information is modulated onto electromagnetic signals, which in turn are conditioned into specific slivers (bands) of the frequency spectrum for over-the-air transmission. If multiple transmitters attempt to utilize the same spectrum band concurrently, their signals will collide, resulting in a phenomenon called interference. In such cases, depending on the relative strengths of the individual signals to each other, some or all of them may appear undecodable at their intended receivers. In outdoor settings, if multiple transmitter-receiver (Tx-Rx) links are separated sufficiently far apart, interference can be overcome, and the frequency band can be reused for transmission. Achieving the frequency and spatial reuse in indoor application scenarios, however, is decidedly more challenging. Due to the rich-scatter environment and chaotic device deployment, the multipath channel and interference conditions become unpredictable and more varied, leading to severe performance loss for unmanaged transmissions.

The broadcasting of a political convention is unlike most other major events. The DNC took place in an indoor setting inside the Wells Fargo center and had approximately 2,000 registered wireless devices, all contending for a frequency slice in a tight space where radio waves were scattered all around, causing tremendous interference. In this challenging wireless environment, encoded video streams at high bit rates need to be wirelessly and reliably transmitted from the video cameras to the production backend for subsequent on-air broadcast. Quality of Service for these video streams needs to be guaranteed and maintained at all times. Besides video cameras, all other wireless devices, such as wireless microphones, cellular and WiFi devices, as well as equipment used by emergency and law enforcement personnel, also need regular channel access. All of these demands pose further interference likelihood to broadcasters, making the task of frequency coordination more critical.

The purpose of frequency coordination is to ensure seamless, interference-free spectrum access for registered wireless devices. Frequency coordination forms a centralized reservation-based system that can allocate exclusive spectrum usage in the coordinated bands to certain users. Given the quality of service requirement of live broadcast services, we restrict the number of allowed users on a particular monitored spectrum band to one. This enables high-fidelity broadcast to proceed harmoniously among a large number of broadcasters, ranging from national news networks to local TV stations.

2.2 Coordination Approaches

Considering that the radio frequency spectrum is scarce, communication channels need to be utilized efficiently. Multiple access techniques are employed to allow for channel resource sharing between different users in spread locations [7]. Allocation may be decided based on frequency, time, code, or space divisions. Frequency-division multiple access (FDMA) splits the available bandwidth between users, while allowing them to each use the channel over all time. Time-division multiple access (TDMA) permits users to use the entire bandwidth during different assigned time slots. In both FDMA and TDMA there exists a guard interval between users over the respective division scheme. Code-division multiple access (CDMA) uses spreading codes to allow users to utilize the full channel bandwidth over all time slots. In addition, Space-division multiple access (SDMA) separates users geographically by using beamforming and directional antennas, allowing for different users to transmit on the same frequency at the same time. The key requirement of the multiple access schemes described in this section is that the allocated channel resource for a given user is orthogonal to other users of the channel. Orthogonality occurs from the use of guard intervals to achieve the minimum distance required in TDMA and FDMA, selection of codes used in CDMA, and separation in physical space in SDMA. Asynchronous CDMA uses pseudo-noise sequences with low correlation between codes for practical implementations, when perfect orthogonal code sets may not be used [8].

3 RF Coordination Procedure at the DNC

A large scale event such as the DNC receives widespread national and international coverage. Media teams use various equipment to broadcast live video and coordinate amongst themselves. Some of these equipment have wireless capabilities such as microphones, video transmitters and two-way radios. These equipment have to be manually tuned to specific frequencies within their operating range for communication between transmitters and
receivers. Due to the manual nature of this process, the event of various teams stepping on each other’s radio frequency is extremely likely. This can result in broadcast interruptions and can affect quality of service. In order to avoid this, a wireless enforcement team was established to coordinate frequencies for wireless broadcast equipment at the DNC.

The following subsections explain the wireless enforcement process at the DNC and the steps taken to ensure smooth operation. Please note that wireless equipment mentioned here do not include devices that follow wireless standards such as WiFi & Bluetooth.

3.1 Frequency coordination prior to start of convention

Before the start of the convention, media personnel were asked to contact the DNC wireless enforcement team to be allocated frequencies for all radio frequency transmissions. Radio frequencies in the 470 MHz to 698 MHz and 7 GHz to 7.5 GHz ranges were allocated to media teams, and a list of all allocated frequencies was approved by the wireless enforcement group. This pre-coordination of frequencies served two purposes. First, it allowed media teams to use wireless equipment without service or quality disruption due to other teams stepping on their frequencies. Second, pre-allocation prevented the usage of frequencies outside the approved frequency range, preventing them from stepping on first responder communications as well as cellular communication networks.

Only teams that were allocated frequencies prior to the start of the convention were allowed to use wireless equipment. No additions to the approved list of frequencies were made during the convention. Media teams that did not coordinate frequencies were required to switch off all wireless transmitters and receivers and use wired alternatives.

3.2 Tagging of Devices

At the convention, antennas on all wireless equipment were tagged with a convention-approved wireless coordination sticker. Media teams with allocated frequencies were tagged with a white colored sticker, and teams that did not have allocated frequencies were tagged with a yellow colored sticker. These tags were placed on the top-most tip of antennas for high visibility, making it easier for monitoring personnel to detect unauthorized wireless operations. Personnel from the wireless enforcement team were stationed at the media workspace center and the media entrance to the convention center. All equipment with antennas entering these locations were tagged based on the convention’s list of approved frequencies.

3.3 Frequency Counter

A frequency counter was used to ensure that wireless equipment was tuned to its allocated frequency. The wireless enforcement team used a YAEGE FC-1 portable frequency counter with a frequency range of 50 MHz to 6 GHz.

3.4 Floor Sweeps to Monitor Authorized Usage

Apart from being stationed at the media entrance and workspace locations, personnel from the wireless enforcement team also carried out sweeps of the convention floor, broadcast media suites, and the general convention perimeter to monitor wireless equipment use. Media teams utilizing unauthorized wireless operation of devices (indicated by yellow sticker) were asked to immediately halt wireless transmission and switch to wired operation after photographs of their credentials were recorded. Non-cooperative teams were reported to members of the FCC stationed at the convention.

4 Conference RF Operation Outcomes

4.1 RF Operation Outcomes

Except for one incident, we had no major interference issue during our enforcement time window through the entire convention. The only interference incident reported was a severe loss of video quality for the Associated Press (AP) floor correspondents, which happened on the first day of the conference (Monday). We investigated the issue by monitoring the frequency band in the 7 GHz range using a hand-held spectrum analyzer. After
observing the usual interference pattern for some time, we decided to seek out other licensed users in adjacent bands and asked to check their equipment’s active frequency band. The retune process of all equipment using nearby frequency bands was able to suppress the concerned interference. The inspection and retuning procedure successfully resolved the interference issue.

In other minor incidents, we spotted unauthorized wireless transmitters (indicated by the yellow tags, as explained in Sec. 3.2) being utilized for ad hoc broadcasts, and politely asked for them to be turned off. Another case involved a local TV station whose wireless gears were not tagged before they got on the floor. We resolved such situations by cross-checking the RF allocation database and tagging devices on the spot during our regular floor sweeps.

Overall, regarding RF coordination and enforcement, we consider our operations to be a success for DNC 2016.

4.2 Testimonials

This section lists our individual testimonials for our volunteer activities at the DNC.

**Danh’s Remarks:** It was my pleasure and great learning experience volunteering in the RF coordination and enforcement team at the DNC this year. I got to experience first-hand much of the RF theories I have learned over the years, most notably the concepts of RF interference and spectrum multiple access. We had to be quick on our feet to resolve interference issues and assure many broadcasters the quality of service they were previously promised. This experience adds tremendously to our perception of the growing wireless field and further motivates us to pursue research activities that will enhance users’ quality of experience through innovations.

**Marko’s Remarks:** Volunteering at the DNC as a member of the communications team was an excellent experience for me. I was exposed to different aspects of the broadcast industry that were all foreign to me, from video cameras to the control switch and even observing all of the various roles that people took to support support such a major event. Working with the communications team was at times fascinating. Not only was it impressive to see the amount of effort that went into frequency coordination, but observing how the members responded to live issues during the convention was truly remarkable. Whenever there were events of unauthorized frequency use, the team would be able to isolate the source and resolve the issue despite the large number of people at the convention. In addition, the members of the team made a strong effort to teach us fine details about our responsibilities and equipment that we would encounter and use ourselves. I found the overall experience to be very rewarding, as I was exposed to the real issues and considerations that are faced in industry. Reflecting on what I saw and did during my time as a volunteer helped to inspire me in determining what type of research in wireless communication may be useful for the future of the industry.

**Ilhaan’s Remarks:** Volunteering at DNC 2016 for wireless enforcement was a great learning experience. Witnessing a congested wireless environment that needed to be coordinated using a simple method of tagging devices and maintaining a list of allocated frequencies convinced me that there is an immediate need for innovation in efficient spectrum sharing. The advent of the Internet of Things has made this an even more pressing issue, as more devices gain wireless capabilities and new devices enter the gadget ecosystem.

Working with the enforcement team and watching them respond to time-sensitive issues in a crowded arena and solve problems on their feet was a highly rewarding experience. Members of the team also made sure to take their time to teach all student volunteers about various broadcast technologies and introduced us to engineering staff from various television networks. It was fascinating to learn about all the technologies and processes involved in bringing live television programming to a national audience. Watching television does not make apparent the immense efforts behind the camera required to ensure high quality undisrupted programming, especially for live events.

One observation from this experience that I will cherish forever is how engineers across various television networks helped each other. There were no signs of network rivalry or affiliations when engineers assisted their counterparts from media outlets across the country. Even members of the wireless enforcement team made sure that media teams without allocated frequencies had the wires necessary to carry out their broadcasts. A lot of technical issues can arise at a large scale event such as the DNC, and all engineering staff at the event supported each other however they could.

This experience has given me some insight in research directions for wireless communications and has inspired me to learn more about cognitive radios and dynamic spectrum sharing.
5 Future Approaches for Coordination / Enforcement

5.1 Software Defined Radio, Cognitive Radio, and Dynamic Spectrum Access

The use of Software Defined Radio (SDR) would enable broadcasters and coordinators to have more control over the signal characteristics used in video and audio transmissions. As implied by its name, SDR drives many functions of the radio transmit and receive chain into software. A software implementation allows for high flexibility with regards to signal parameters selected, in comparison to a conventional radio [2]. Users have greater control over modulation and coding rates, guard interval length, channel selection, occupied bandwidth, transmit power, and various other parameters. Depending on the restrictions of the event and the surroundings of the user, different radio configurations may easily be selected. The use of SDRs also enables for Cognitive Radios to be implemented.

Cognitive Radio (CR) is a type of radio that adapts itself dynamically based on its environment. The key goal of a CR is to maintain quality of service for communication while efficiently utilizing the radio spectrum [6]. Static assignments of time or frequency slots result in underutilization of the spectrum, as users will not constantly be using their allocated slot. In the case of the DNC, users were statically assigned frequency channels for the full geographical area of the event grounds and stadium. Broadcasters were not transmitting at all possible time slots, and did not cover or need to encompass the entirety of the space. As a result, there were many spectrum holes, in which a frequency band was available at a particular moment in time and location. Dynamic Spectrum Access (DSA) is an essential requirement of CR, in which a user will opportunistically access the channel based on the activity it detects from other users in its environment [10]. The intelligence of the radio from the algorithms it implements will determine the best time and frequency to transmit based on the policies considered, while minimizing interference to other users. The use of an SDR platform allows for the parameters of the radio to be easily modified, while the learning capabilities of the CR enables for DSA based on its environment. In relation to a major event such as the DNC, in which radio spectrum is scarce, technologies such as SDR and CR allow for the optimization of resources. A greater number of broadcasters would be able to use wireless technologies in a cooperative fashion, which would help both the coordination and enforcement tasks.

5.2 Exploring Underutilized Higher Frequency Bands

An area of active research lies in formulating the design and characterizing practical considerations of the unlicensed 60 GHz band, due to its large amount of available spectrum and its capability to support high data rates by using bandwidth on the level of 1 GHz. Ongoing discussion exists regarding waveform selection, compensation of front-end distortion, and correcting for channel effects [12]. 60 GHz systems suffer from extreme attenuation and path loss, as expected when compared to 2.4 GHz and 5 GHz unlicensed bands. As a result, many have argued that a line-of-sight (LOS) communication link may be necessary for practical implementation, which motivates the use of highly directional antennas. In addition, reconfigurable antennas which may adjust the radiation pattern may be used with learning algorithms to improve non-LOS communication [3]. For wireless microphones, communication channels typically are characterized by a short distance of propagation and a dominant LOS link, the use of a 60 GHz system with a highly directional antenna may be a feasible solution in the future to combat the scarcity of radio spectrum. In addition, the use of reconfigurable antennas may enable communication between cameras and production teams by determining the optimal antenna state in non-LOS communication. Overall, future work in the 60 GHz unlicensed spectrum may alleviate some of the challenges present for broadcasters during highly congested indoor events.

5.3 Alternate Device Identification Methods

The colored stickers used at the DNC can be enhanced with various contemporary technologies that are easy to implement. Two such technologies have been presented below. These technologies will help improve the efficiency and effectiveness of wireless enforcement. They will also allow for time limited frequency allocation to media teams. For example, after the start of daily events at the DNC, media teams were given forty-five minutes of access to the convention floor, where speaking events took place. Media teams broadcasting beyond their allocated broadcast times can be detected with ease using the technologies discussed below.
5.3.1 RFID

The colored stickers used to differentiate between authorized and unauthorized wireless equipment can be enhanced with RFID tags. These would allow device labels to store frequencies allocated to teams, making it possible to easily identify incorrectly tuned wireless equipment. Media team names, network affiliation and wireless transmission purpose (such as audio/video transmitter or two-way radio) can also be stored in RFID tags.

EPC Gen2 UHF RFID operates in the 902 MHz to 928 MHz range in the United States [5] and has a read range of up to 12 m. UHF RFID tags are small in size and are passive, allowing them to be integrated in stickers without the addition of a battery. These tags can be read using smartphone RFID readers such as the UGrokit\(^1\) mobile UHF RFID reader.

Wireless enforcement personnel carrying out floor sweeps can carry a smartphone RFID reader to scan wireless equipment and determine authorized radio frequency utilization without having to interrupt media teams. This in addition to a frequency counter or spectrum analyzer can be extremely useful for wireless enforcement at a large scale event such as the DNC.

In order to ensure media teams do not tamper with their RFID tags to allocate themselves a frequency, RFID chips can be write-locked using a 32-bit password [4]. A read-lock can also be implemented if deemed necessary.

5.3.2 Quick Response (QR) Codes

While RFID tags will improve wireless enforcement efficiency in a convenient manner, the use of radio frequency in an already congested wireless environment may pose difficulties and raise concern. QR codes are two dimensional barcodes that can store small amounts of data. They can provide the same benefits as RFID mentioned in sec. 5.3.1 in terms of data storage. However, the read range of a QR code is proportional to its print size [11]. Printing stickers in a convenient size may not provide a read range as large as that of UHF RFID. However, several applications capable of reading QR codes using built-in cameras are available free of cost on all smartphone platforms, making QR code implementation cheaper than RFID which would require the purchase of smartphone RFID readers.

Integrating digital signatures into QR codes can improve security and make them tamper proof [9]. However, digital signatures will reduce the amount of data that can be encoded in a QR code. Additional anti-phishing techniques can be implemented in QR code reader software to detect tampered codes.

6 Acknowledgment

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7 Conclusion

In this article we have described the motivation and necessity for RF coordination and enforcement at major broadcast events. We provide anecdotal examples of the RF coordination and enforcement process that went on at the DNC 2016. In addition, we also survey the emerging technologies in wireless communications that can benefit greatly future RF coordination efforts. DNC 2016 was a great learning experiences for all the volunteers of the RF coordination team. It provided the much needed impetus to transition wireless research from the lab to tackle real wireless problems in the field, especially at an event of this scale.

\(^1\)https://www.ugrokit.com/
References


