Transmission of Live Detection Data Based on Modified D2D

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Abstract. While the standardization of live detection process helps ensure safe operation of substation equipment significantly, data transmission between detection equipment and the handheld tablet is still a great challenge. In this article, we propose a communication method for live detection in substations with D2D in licensed band and unlicensed band. Firstly, we analyze the scenario of live detection in substation and compare various near field communication methods. Secondly, we study the key technologies of D2D mainly including spectrum resource management and channel access mechanism. Finally, we perform system level simulation on D2D in licensed and unlicensed band, whose results show that modified D2D can achieve high quality communication between detection equipment and the handheld tablet.

1. Introduction

Live detection is an important way to ensure the safe operation of substation equipment and its detection methods commonly used now mainly include gas insulated system (GIS) ultrasonic detection [1], GIS ultra-high frequency (UHF) detection[2], infrared temperature measurement and so on. However, detection points for traditional live detection are not standardized, resulting in inaccurate measurement results and low efficiency. Therefore, a power company has carried out the work of standardizing the live detection process, which is shown in figure 1.

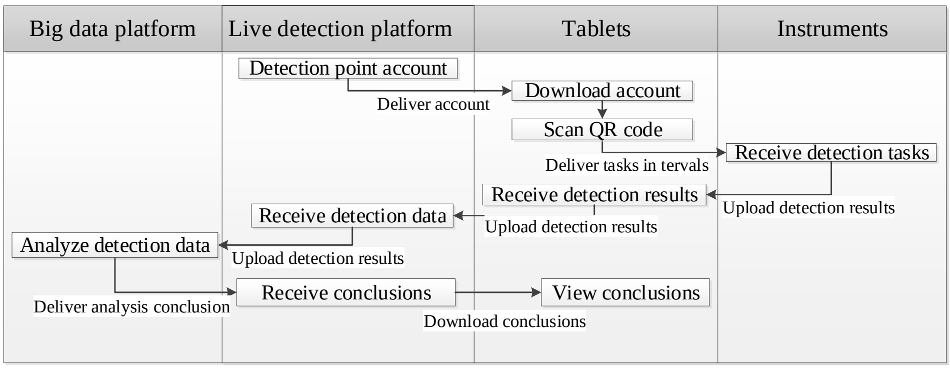

Figure 1. Standard live detection process.

From figure 1 we can see that accounts of standard detection points are stored in live detection platform and we need to download the account of current substation when detecting a substation. After that, we need to scan QR code attached to interval of GIS when detecting one interval. Whenever detection task is finished, detection data is delivered to the big data platform which can analyse current detection results automatically and deliver the final results to handheld tablets. The scheme above can help avoid bad test results caused by missing test points and manual judgment error. Corresponding to the detection process in figure 1, the data transmission process is as shown in figure 2.

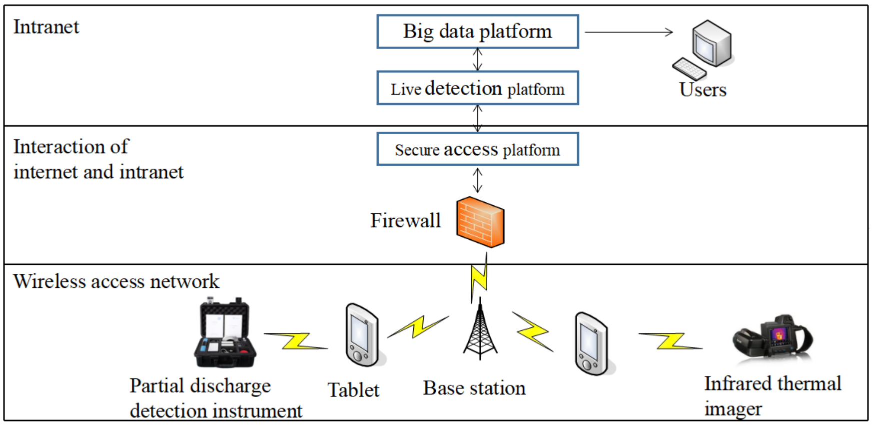

Figure 2. Data transmission process in standardized operation of live detection.

In field application, the communication between the partial discharge instrument, the infrared instrument and the mobile terminal communicates via Wi-Fi or Bluetooth [3][4]. The use of Wi-Fi violates the security regulations of the grid company and the transmission speed of traditional Bluetooth is relatively low, resulting in a large delay in the transmission of infrared spectrum data.

Device to device (D2D) is a direct communication technology between devices[5]. When the two mobile terminals are close to each other, the air interface data transmission can be directly performed without forwarding through the base station. By making use of single-hop gain, adjacent gain, and reuse gain, the cost, power and delay of communication between mobile terminals can be reduced effectively. We propose a live detection data transmission method based on D2D in both licensed band and unlicensed band in this paper. Firstly, we analyze the scenario of live detection in substation and compare various near field communication methods. Secondly, we study the key technologies of D2D mainly including spectrum resource management and channel access mechanism in unlicensed band. Finally, we perform system level simulation whose results show that our method can meet the requirements of field application in substations.

2. Related Works

2.1. Application scenario

Communications between tablets and partial discharge detection instruments or infrared thermal imagersare shown in figure 3, where user equipment (UE) does not establish a connection through the base station but communicates directly.

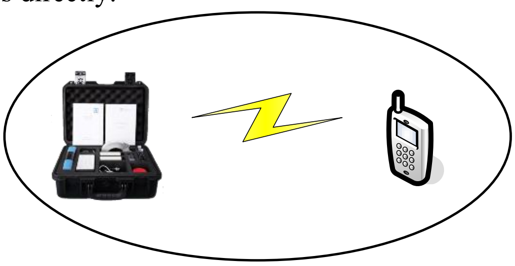

Figure 3. Application scenario of D2D in substation.

2.2. Comparison of various near field communication methods

Comparison of various near field communication methods are shown in table 1.

Table 1. Comparison of various communication methods.

	Band	Speed	Effective distance	Safety
Bluetooth	2.4GHz	24Mbps	8-10m	High
Wi-Fi	2.4/5GHz	60Mbps	20-35m	Prohibited in substations
Lora	433/470/868MHz	30kbps	>100m	Middle

From the table above we can see that the transmission speed of Lora is relatively low and it cannot meet the requirements of data transmission. In addition, the transmission distance of Bluetooth is too close to meet the requirements of field application and Wi-Fi is prohibited in substation acceptable due to its shortcomings on security.

2.3. Characteristics of D2D

The short-distance communication characteristics and direct communication methods of D2D technology are a great change to the traditional communication method, whose advantages are shown as follows.

(1) Compared with cellular communication, single-hop transmission can achieve higher transmission rate, lower delay and lower transmission power consumption.

(2) D2D can adapt to the local data sharing requirements of services such as wireless P2P, and provide flexible data services.

(3) D2D communication does not access the cellular communication core network, which can greatly reduce the network load.

However, D2D communication has the following disadvantages.

(1) If the scanning discovery method is used between the D2D devices, it takes a long time for the two UEs to discover each other, which will cause a large delay.

(2) When D2D is introduced into the cellular network and its spectrum is not orthogonal to the cellular spectrum, it will cause certain spectrum interference problems, and more D2D links may cause large interference and affect the communication quality.

(3) Orthogonal spectrum can help avoid the interference problem but cause low spectrum resource utilization. So it is the key to achieve a balance between interference and spectrum resource utilization.

In order to modify D2D for application in standardization of live detection, we mainly cared about resource management and interference avoidance.

3. Modification of D2D for deployment in substations

3.1. Resource management

Since causes of partial discharge are different, spectrum of UHF partial discharge signals are also various, which are shown in table 2.

Table 2. Spectrum of various UHF partial discharge signals.

Defect	Tip	Suspended	Particulate	Air gap
Frequency/MHz	100～250	200~900	300~900	150~1500

From table 2 we can see that UHF signal caused by partial discharge are lower than 1.5GHz. In order to reach high upload speed and low interference to 4G network, we use unlicensed band 5GHz for data transmission and 1.8GHz for signalling transmission[6].

3.2. Channel access.

In order to avoid influence on other communication devices deployed at 5 GHz, we need to adopt appropriate channel access mechanism which is shown in figure 4.

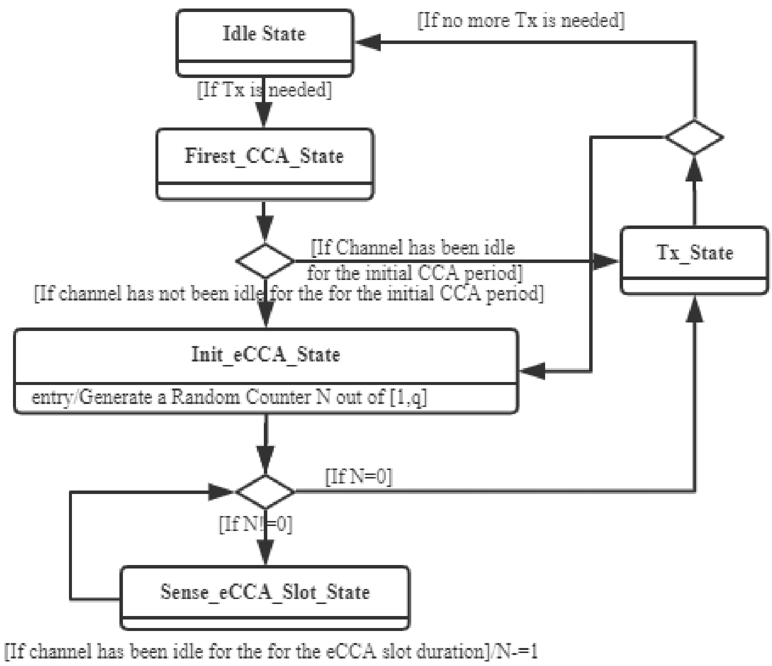

Figure 4. LBT mechanism using variable contention window

From figure 4 we can see that the general process of LBT Category 3 is as follows[7]:

1) The first CCA detection is performed only when the current UE has a service waiting for transmission.

2) If the channel is idle during the first CCA query time, the UE enters the sending state. And if the first CCA query channel is busy, the UE performs extended CCA detection, which means randomly select the back off step length N between [1, q], and enter a back off state, where q represents the size of the contention window.

3) For the retreat step length N, the UE detects the channel for eCCA slot of each step. If the channel remains idle during the eCCA slot time, then N is assigned to N-1, and if N is equal to 0, the UE enters the transmission state.

4) When the transmission time is used up and there is no data to be transmitted, then the UE enters the idle state. But if there is still service to be transmitted, the back off step length N is randomly selected again, and then re-enter the back off state.

3.3. Channel model for D2D data transmission in unlicensed band

After the analysis of electromagnetic environment of the substations, channel models in this paper are shown in table 3.

Table 3. Channel model of D2D.

Scenario	Path Loss	Shadow Fading
Indoor	$PL_{\mathrm{Los}} = 89.5 + 16.9 * \lg(d/1000)$	3
	$PL_{\mathrm{NLos}} = -1.0 * (147.4 + 43.3 * \lg(d/1000))$	4
Outdoor	$PL_{Los} = \max(46.4 + 20\lg d + 20\lg(f_c/5), 27 + 20\lg f_c + 22.7\lg d)$	7
	$\mathrm{PL}_{\mathrm{NLos}} = \max(46.4 + 20\lg d + 20\lg(f_c/5), 13.38 + (44.9 - 6.55\lg h_{\mathrm{ue1}}) * \lg d + 5.83\lg h_{\mathrm{ue1}} + 23\lg f_c)$	7

In addition, LOS probability of UEs indoor and outdoor is shown in table 4.

Table 4. LOS Probability.

Scenario	LOS Probability
Indoor	$P_{LOS}=\begin{cases}1, & d\le 18\\ \exp(-(d-18)/27), & 18<d<37\\ 0.5, & d\ge 37\end{cases}$
Outdoor	$P_{LOS}=\min(18/d,1)\cdot(1-\exp(-d/63))+\exp(-d/63)$

4. Simulation and discussion

4.1. Configuration

This simulation uses the FTP service for system-level performance evaluation. The specific simulation parameter configuration adopted is shown in table 5:

Table 5. Configuration of simulation parameters.

Parameters	D2D	Wi-Fi
Topology	1 cell 3 sector	
Single carrier bandwidth	20MHz	
Number of carriers	1	
Number of UEs in each cluster	4UE	4UE
Modulation	16QAM/64QAM/256QAM	
CCA detection threshold	-72 dBm for CCA-ED	-82 dBm for CCA-CS
LBT competition window setting	CWS = {15, 31, 63}.	
Maximum channel occupancy time	MCOT=8ms	TXOP = 8ms.
UE uplink channel access mode	LBT Category 3	LBT Category 3
Main performance evaluation indicator	User perceived throughput(UPT):Mbps Latency: ms	

4.2. Simulation results

Since there are both outdoor equipment and indoor equipment in the substation, this part uses the FTP service model in the D2D system for outdoor scenarios and indoor scenario. In each scenario, low-to-high-load conditions are evaluated.

Simulation results of UEs in indoor scenario and outdoor scenario are respectively shown in figure 5 and figure 6.

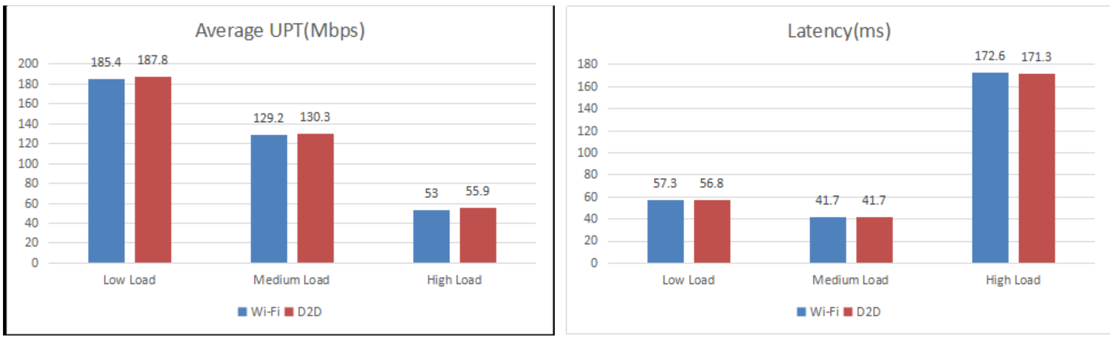

Figure 5. Simulation results of cross-carrier scheduling in outdoor scenario.

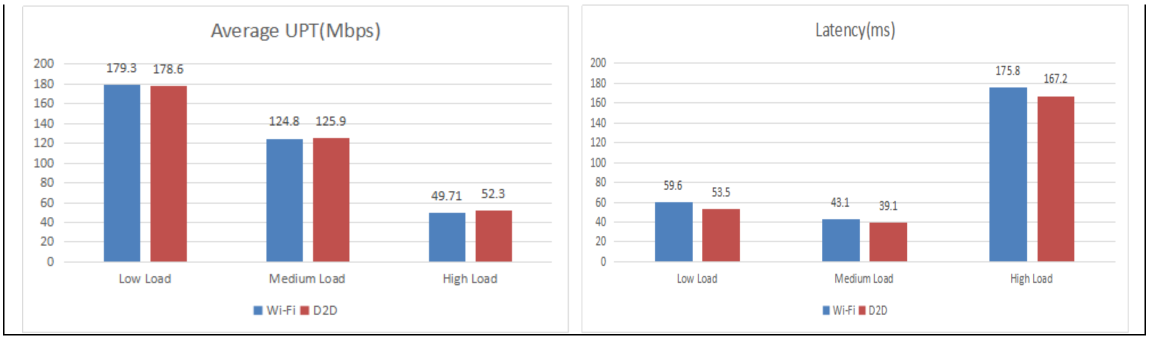

Figure 6. Simulation results of cross-carrier scheduling in indoor scenario**.**

From figure 5 and figure 6 we can see that D2D has little affection on Wi-Fi, and the speed of D2D in low load scenario reach about 180Mbps, which meet the requirements perfectly. In addition, UPT in outdoor scenario is higher than that in indoor scenario and latency in outdoor scenario is a lower than that in indoor scenario, which is caused by the complex electromagnetic environment in indoor environment.

5. Conclusions

In this paper, we firstly analyze the scenario of live detection in substation and compare various near field communication methods. Secondly, we study the key technologies of D2D mainly including spectrum resource management and channel access mechanism. Finally, we perform system level simulation in indoor and outdoor scenario, whose results show that modified D2D in unlicensed band can achieve high quality communication between detection equipment and the handheld tablet.

Acknowledgments

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