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The Study of WLAN Cell Radius for Outdoor Coverage in Wireless Digital City Deployment

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Abstract

Firstly, the technical features and frequency characteristics of IEEE802.11x protocol in wireless local area network (WLAN) are introduced. The functional relationship of path loss and coverage distance in dense urban and suburb is shown in figures. The uplink and downlink radio power budget of current WLAN outdoor coverage is calculated. Secondly, calculation and comparison of WLAN pass loss, link budget and cell coverage radius is done for dense urban and suburb. Thirdly, hot spot area WLAN outdoor coverage signal strength is simulated in dense urban for several situations by using simulation software. The results of simulation validate the accuracy of the calculation for uplink/downlink power budget, path loss in WLAN 2.4GHz band and WLAN cell coverage radius. The cell coverage radius for dense urban and suburb is 300~500m and 1000~1200m respectively. Finally, a valuable hot spot area WLAN outdoor coverage deployment suggestion is given: high power WLAN BTS/AP and high gain antenna with 4 sectors deployment will improve the uplink/downlink power budget; enlarge radio coverage in hot spot area. The analysis in this paper is significant for the deployment of wireless digital city.

Keywords-WLAN cell coverage radius; wireless digital city; path loss; WLAN link budget; WLAN propagation model;

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1. Introduction

Wireless digital city deployment is the indispensable way of city informatization. Wireless digital city refers to the city with wireless network coverage, which can provide safe, convenient, quick, efficient wireless broadband service to citizen, enterprise, visitor, government in any time, any place.

Wireless broadband data service can be realized by GPRS/EDGE/TD-SCDMA/WCDMA/CDMA2000 network combined with WLAN coverage. WLAN outdoor coverage is primary part of wireless digital city deployment.

The cell coverage radius is the key factor for BTS/AP deployment in WLAN outdoor coverage. To get the signal coverage range in 2.4GHZ band, WLAN space channel fading model, link budget/link balance, and coverage simulation will give strong help for WLAN BTS/AP outdoor coverage radius analysis.

By using WLAN channel fading model, WLAN path loss, link budget/link balance are calculated and compared for WLAN outdoor coverage in dense urban and suburb scenarios. The simulation of outdoor coverage BTS signal strength in dense urban validates the WLAN cell coverage radius calculation. It will give guidance basis for WLAN outdoor coverage cell radius analysis and WLAN outdoor coverage planning and optimization. It is primary part of wireless digital city deployment.

2. The technical features and frequency characteristic of WLAN standard

WLAN is wireless local area network which meets the IEEE802.11x standard. The IEEE802.11x standard series include IEEE802.11b, IEEE802.11a and IEEE802.11g etc. With its high maturity of technology, stability of communication quality and transmission bandwidth, these standard series have become primary standard in WLAN and have been used widely.

Its main application scenarios have indoor distribution, indoor coverage and outdoor coverage. The advantages of indoor distribution/coverage are good coverage and signal stability. But its installation workload is big, expense is high and cycle time is long. In some special scenarios such as shopping street, school and plaza, the outdoor coverage mode may be the only mode to deliver. So it is important to analysis WLAN radio transmission .The study of WLAN propagation model/path loss become more and more important, WLAN space channel fading model, link budget/link balance, and coverage simulation will give guidance basis for WLAN outdoor coverage planning and optimization.

In this paper, WLAN path loss, power budget and uplink/downlink balance are analyzed for WLAN space channel fading model under several conditions, especially for dense urban. The signal strength simulation of campus area WLAN outdoor coverage is given. This provides guidance basis of WLAN outdoor coverage planning and optimization. It is significant for wireless digital city deployment.

WLAN includes IEEE802.11b/a/g standard mainly. The frequency bandwidth is 83.5MHz, 325MHz and 83.5MHz respectively; the frequency range is 2.400-2.483GHz, 5.150-5.350GHz (5.725-5.850GHz) and 2.400-2.483GHz respectively; the maximum data rate is 11Mbps, 54Mbps and 54Mbps respectively; the modulating method is CCK/DSSS, OFDM and CCK/OFDM respectively.

IEEE802.11b/g is mainly used in high speed data transmission between AP (Access Point) and STA (Sta-tion). IEEE802.11a is used in bridging connection between point to point etc. The frequency band of data transmission between AP and STA is 2.4GHz whose frequency characteristics are mainly concerned in the following outdoor coverage path loss analysis.

3. Analysis of WLAN path loss

To determine WLAN outdoor BTS/AP cell radius, WLAN space channel fading model, path loss model, and link budget/link balance in 2.4GHZ band will be analyzed firstly.

When 2.4GHz frequency is used in IEEE802.11b/g standard, COST231 Hata correction model is used as propagation mode in dense urban and suburb.

$$PL(dB)=46.3+33.9\log_{10}f-13.82\log_{10}Ht-\alpha(Hr)+(44.9-6.55\log_{10}Ht)\log_{10}d + Cm$$

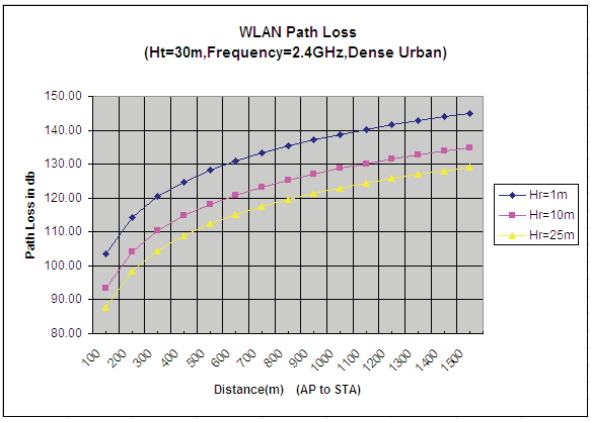

Figure 1.WLAN Path Loss
(Ht=30m, Frequency=2.4GHZ, Dense Urban)

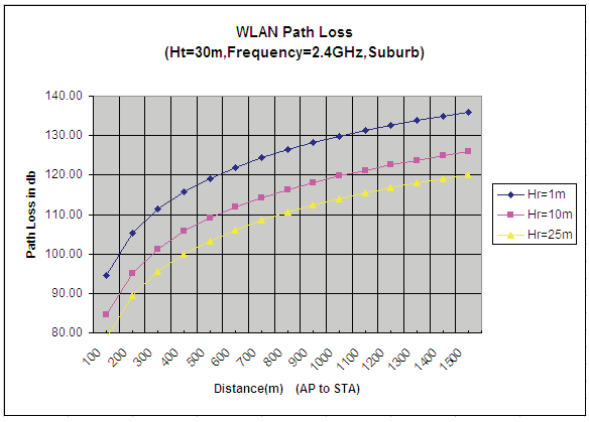

Figure 2. WLAN Path Loss
(Ht=30m, Frequency=2.4GHZ, Suburb)

Where α(Hr)=3.2(log1011.75Hr)2-4.97

f (MHz):working frequency；

Ht (m): virtual height of BTS/AP antenna, which is defined as the difference between BTS/AP antennas actual height and the average altitude height within the propagation scope of antenna.

Hr (m): virtual height of terminal/STA antenna, which is defined as above surface height of terminal/STA antenna

d (km): horizontal distance between BTS/AP antennas and terminal/STA antenna ；

α (Hr): effective antenna correction factor, It is the function of coverage scope. It is related to its radio environment.

Cm：correction factor, its values are shown as follow:

Dense Urban:-3 Urban:-6 Suburb:-12 Rural：-20

Figure 1 shows WLAN path loss in dense urban area with AP's antenna height Ht=30m, STA's antenna height Hr is 1m、10m、25m respectively. The distance d changes from 100m to 1500m.Figure 2 shows WLAN path loss in suburb area with AP's antenna height Ht=30m, STA's antenna height Hr is 1m 、10m、25m respectively. The distance d changes from 100m to 1500m. From comparison of Figure.1 and Figure.2.WLAN path loss in dense urban is bigger than in suburb. The coverage scope in dense urban is smaller than that in suburb.

4. Analysis of WLAN link budget and cell coverage radius

The WLAN wireless link budget can determine maximum allowed path loss between BTS/AP and terminal/STA to guarantee the coverage quality, uplink and downlink budget are included. The wireless link budget can guide cell radius setting, required number calculation and layout analysis of BSC/AP

The uplink and downlink power budget for WLAN outdoor coverage typical application in dense urban and suburb area are shown in Table 1 and Table 2 respectively.

Table 1.WLAN outdoor coverage link budget (dense urban)

Downlink (AP to STA)	Antenna pattern 1	Antenna pattern 2	Uplink (STA to AP)	Antenna pattern 1	Antenna pattern 2
AP Tx power	27dBm (500mw)	27dBm (500mw)	STA Tx power	17dBm (50mw)	17dBm (50mw)
Feeder loss	0.2 dB(12.5db/100m)	0.2 dB(12.5db/100m)	STA antenna gain	2dBi	2dBi
AP antenna gain	19dBi	14dBi	Total EIRP	19dBm	19dBm
Total EIRP	45.8dBm	40.8dBm			
			AP Rx Sensitivity	-95dBm	-95dBm
STA Rx Sensitivity	-90dBm	-90dBm	AP antenna gain	19dBi	14dBi
STA antenna gain	2	2	Diversity gain	4dB	4dB
Fading margin(90% coverage)	11	11	Fading margin(90% coverage)	11	11
Interference margin	3	3	Interference margin	3	3
Allowed Pathloss	123.8dB	118.8dB	Max. Allowed Pathloss	123	118

Table 2. WLAN outdoor coverage link budget (suburb)

Downlink (AP to STA)	Antenna pattern 1	Antenna pattern 2	Uplink (STA to AP)	Antenna pattern 1	Antenna pattern 2
AP Tx power	27dBm (500mw)	27dBm (500mw)	STA Tx power	17dBm (50mw)	17dBm (50mw)
Feeder loss	0.2 dB(12.5db/100m)	0.2 dB(12.5db/100m)	STA antenna gain	2dBi	2dBi
AP antenna gain	19dBi	14dBi	Total EIRP	19dBm	19dBm
Total EIRP	45.8dBm	40.8dBm			
			AP Rx Sensitivity	-95dBm	-95dBm
STA Rx Sensitivity	-90dBm	-90dBm	AP antenna gain	19dBi	14dBi
STA antenna gain	2	2	Diversity gain	4dB	4dB
Fading margin(90% coverage)	6	6	Fading margin(90% coverage)	6	6
Interference margin	1	1	Interference margin	1	1
Max. Allowed Pathloss	130.8	125.8	Max. Allowed Pathloss	130	125

According to table 1, in dense urban area, the uplink maximum allowed path loss is 123dB or 118dB (19dBi or 14dBi BTS/AP antennas). The downlink maximum allowed path loss is 123dB or 118dB (19dBi or 14dBi BTS/AP antennas).The uplink and downlink path is balance basically. From the consideration of signal coverage, the data rate can achieve the service grade of 1 Mb/s at least in WLAN outdoor coverage area while the signal transmission distance or WLAN cell coverage radius is 300~500m. (Refer to figure 1)

According to table 2, in suburb area, the uplink maximum allowed path loss is 130dB or 125dB (19dBi or 14dBi base station antennas). The downlink maximum allowed path loss is 130.8dB or 125.8dB (19dBi or 14dBi base station antennas).The uplink and downlink path loss is balance basically. From the consideration of signal coverage, the data rate can achieve the service grade of 1 Mb/s at least in WLAN outdoor coverage area while the signal transmission distance or WLAN cell coverage radius is 1000~1200m. (Refer to figure 2)

Figure 1 and 2 show that: in dense urban, WLAN path loss is 120dB with BTS/AP's antenna height Ht=30m, STA's antenna height Hr is 1m (coverage scope is street or lower floor building), while the transmission distance is 300m. WLAN path loss is 130dB while the distance is 500m.That is to say, when the allowed path loss is 123dB (or 118dB), WLAN outdoor coverage cell radius is limited in 300m~500m.

In suburb, WLAN path loss is 130dB with BTS/AP's antenna height Ht=30m, STA's antenna height Hr is 1m (coverage scope is street or lower floor building), while the transmission distance is 1000m. WLAN path loss is 135dB while the distance is 1500m.That is to say, when the allowed path loss is 130dB (or 125dB), WLAN outdoor coverage cell radius expands to 1000m~1200m.

5. Signal strength simulation of WLAN outdoor coverage

For wireless digital city deployment, two manners may be adopted, subarea deployment manner and whole area deployment manner. When subarea deployment manner adopted, the wireless network will be deployed subarea by subarea, hot spot deployment to whole area deployment will be arranged in deferent phase. So, it is important in wireless digital city deployment to plan wireless coverage of hot spot area, like campus area, plaza, Commercial Street and high technology district. Commercial Street deployment

is dense urban application scenario, while high technology district is suburb application scenario. They are all important for wireless digital city deployment.

From the calculation and analysis above, in dense urban, if the maximum allowed path loss between AP and STA is 120dB, for link balance, the WLAN cell coverage radius will be limited to 300~500m.In suburb, the WLAN cell coverage radius is 1000~1200m.

In hot spot, the signal strength simulation can validate whether WLAN BTS/AP outdoor coverage radius can reach theoretical value or not. Because the coverage in dense urban is more important, so the signal strength simulation in dense urban is shown as follow.

Figure 4~6 show WLAN signal strength simulation in dense urban. WLAN propagation models, antenna patterns and simulation parameters can be adjusted through system simulation software with precise 3-dimensions digital map. High precision simulation maps can be worked out by simulation software, which would benefit to the analysis of WLAN outdoor coverage, planning and optimization and WLAN cell coverage radius.

Simulation parameters are listed below:

Frequency f: 2400MHz. Propagation model: COST231 Hata correction model. WLAN BTS/AP antenna height Ht: 30m.Antenna parameters: Gain 19/14dBi; Horizontal Beam width 70dgree; Vertical Beam width 12dgree.Transmit Power: 27dBm.Terminal/STA Receiver Sensitivity: -95dBm.

Figure 3 is BTS location map in simulation.

Figure 4 is the WLAN signal strength simulation map, WLAN BTS/APs antenna height Ht=30m, antenna gain 19dBi, 3 sectors deployment.

Figure 5 and 6 are the WLAN signal strength simulation maps. WLAN BTS/APs antenna height Ht=30m, 50m respectively, antenna gain 14dBi, 4 sectors deployment.

Figure 3. WLAN Simulation BTS Location Map

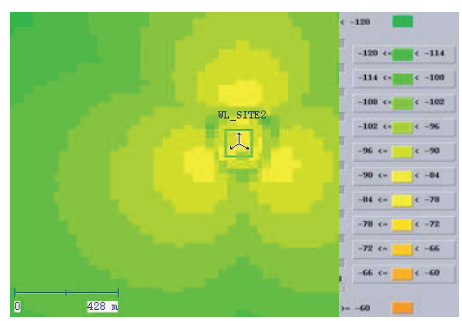

Figure 4.WLAN Signal Strength Simulation Map
(Ht=30m, antenna gain 19dBi, 3 sectors)

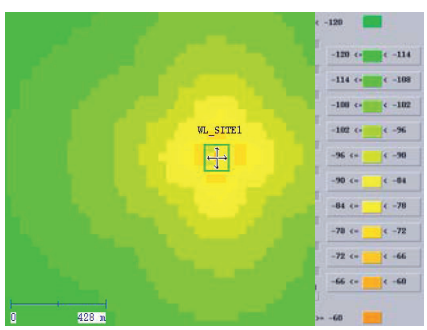

Figure 5.WLAN Signal Strength Simulation Map

(Ht=30m, antenna gain 14dBi, 4 sectors)

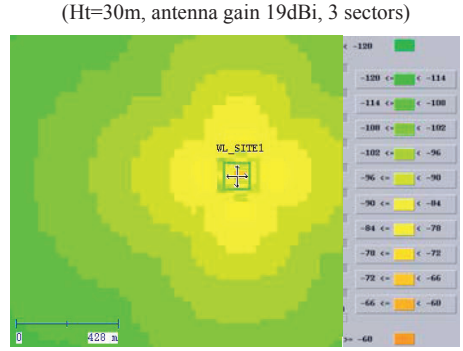

Figure 6.WLAN Signal Strength Simulation Map

(Ht=50m, antenna gain 14dBi, 4 sectors)

From Figure 4 to 6, the results of WLAN outdoor coverage signal strength simulation validate the accuracy of the calculation for uplink/downlink power budget, path loss and cell coverage radius in WLAN 2.4GHz band, the transmit distance can reach 300~500m range in dense urban. WLAN cell coverage radius increases with the increase of STA's antenna height in dense urban. A valuable hot spot area WLAN outdoor coverage deployment suggestion is given: high power WLAN BTS/AP and high gain antenna with 4 sectors deployment will improve the uplink/downlink power budget and enlarge cell coverage radius in dense urban area. It is appropriate for using high gain antenna (antenna pattern 2) to increase coverage radius in directional coverage. It is good for using higher gain, wider vertical beam with 4 sectors antenna (antenna pattern 1) in omni coverage.

6. Summary

In this paper, firstly, the technical features and frequency characteristics of IEEE802.11x protocol in wireless local area network (WLAN) are introduced. The functional relationship of path loss and coverage distance in dense urban and suburb is shown in figures. The uplink and downlink radio power budget of current WLAN outdoor coverage is calculated. Secondly, calculation and comparison of WLAN pass loss, link budget and cell coverage radius is done for dense urban and suburb. Thirdly, hot spot area WLAN outdoor coverage signal strength is simulated in dense urban for several situations by using simulation software. The results of simulation validate the accuracy of the calculation for uplink/downlink power budget, path loss in WLAN 2.4GHz band and WLAN cell coverage radius. The cell coverage radius for dense urban and suburb is 300~500m and 1000~1200m respectively. Finally, a valuable hot spot area WLAN outdoor coverage deployment suggestion is given: high power WLAN BTS/AP and high gain antenna with 4 sectors deployment will improve the uplink/downlink power budget; enlarge radio coverage in hot spot area. The analysis in this paper is significant for the deployment of wireless digital city.

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