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WiMax 與現階段區域性無線網路異質連結佈建之研究

A study of heterogeneous network deployment for WiMax and current wireless LAN

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摘要

台灣在佈建複雜異質連結的無線區域網路的 BS 點，實做皆以試誤法決定位置，這種做法有高度的不確定性及高成本的付出，本研究依據現有 WiFi 設定信號需求，以階層分群法在 SPSS 的分析中，佐以加入權重值方式，計算出 LOS 及 NLOS，其數值與原先試誤法比較，以降低佈建極少量 BS 點，即達到全區域性的涵蓋範圍。

Keywords：WiMax、異質無線網路佈建。

一、 簡介

1.1 前言

WiMAX(Worldwide Interoperability for Microwave Access，全球互通微波存取)，是基於IEEE 802.16 的無線通訊技術，同時也是近年來相當被看好的無線網路技術，不少人也認為WiMAX將是演進至4G 的代表技術之一。目前的市場上的WiMAX設備主要規格有兩種，分別為IEEE 在2004 年制訂的802.16-2004 標準，其前身為802.16d，又稱Fixed WiMAX，顧名思義就是固定式的WiMAX；另外一種是IEEE 在2005年制訂的802.16-2005，前身為802.16e，又稱為Mobile WiMAX，可支援行動式的相關無線應用。

Fixed WiMAX一般應用於骨幹或橋接用途，可使用免執照頻段，例如大樓之間的網路連接，避免實體佈線的麻煩；或是作為WiFi環境的回程線路，臨時網路的架設等等[1]。

過去一般都市佈建的實體以有線ADSL或光纖網路為主，近幾年開始慢慢佈建無線網路，以802.11為主，未來也可能部份改採用Fixed WiMAX 來接取，以節省實體光纖線路佈建成本。Mobile WiMAX的終端則主要是一般個人用戶，Mobile WiMAX提供了相似3G 技術的行動通訊能力，以及WiFi環境的親和力，除了長程傳輸能力、高傳輸頻寬的特點外，還能夠支援現有的IP 相關應用，因此Mobile WiMAX也是被各界所看好的一塊大餅[2]。

1.2 研究目的

現行 WiMAX 網路系統面臨的問題，包含電信業者獲得的頻譜有限、建築物屏障限制形成覆蓋缺陷、資料流量不均、新興地區有線網路架構不足等因素，因此電信業者須找出強化資料傳輸率及網路覆蓋範圍的解決辦法。目前電信業者主要採用置放功率中繼站(Repeater)或增加基地台(Base Station, BS)數量改善問題。表 1 為使用功率放大器、增加基地台個數及使用中繼站(Relay Station)等 WiMAX 網路系統解決辦法的優缺點比較。

表 1：佈建方案之比較

現行 WiMAX 網路系統佈建方案之比較		
	優點	缺點

功率放大器	設備價格最便宜。 佈建快速。	干擾訊號一併放大。 佈建範圍不完整。
基地台	功能完備。 佈建範圍完整。	設備價格貴。
中繼站	設備價格較便宜。 佈建快速。 佈建範圍完整。 Auto Configuration。	系統複雜度增加。

然而增加功率放大器將出現干擾訊號一併放大的副作用，反觀若增加基地台佈放密度，則面臨昂貴的備援(Redundant)設備、備用電源(Backup Power)設備及高價的骨幹網路維運成本等問題。從另一個角度來說，透過增加基地台個數，能使每個基地台的有效覆蓋半徑降低，資料密度提高，不過在佈建上將面臨基地台架設限制及新興地區有線寬頻網路基礎建設不佳等環境限制。

本研究著重於802.16/802.11異質網路之無縫漫遊(seamless inter system roaming / hand off)機制，過去研究異質連結，著重在QOS服務品質保證與行動管理上，我們採用已有的IEEE 802.11系列搭配IEEE 802.16g的整合型網路，提出在這個整合型無線通訊環境裡如何維持相對的服務品質的研究。針對實際佈建WIMAX基地台，以低成本而不失去服務品質與行動管理，目的則能減少基地台的佈建數為主。

異質性無線網路技術的整合是近年來具有相當價值的研究議題，以現階段最具發展潛力的無線整合的系統包含了: Internet、3G、GPRS、WiMAX（802.16）、以及WiFi（802.11）。因為系統上的差異，如何讓使用者可以從一個系統不斷線漫遊(seamless roaming)到另一系統，並且維持一定的服務品質(Quality of Service)就是非常重要的課題。

二、文獻與背景探討

2.1 無線區域網路Qos之MAC整合

談到WiMAX 眾人的印象不外乎就是範圍廣，頻寬大的一種無線網路技術，就建置架構上來看，似乎比起現行的WiFi 環境或者是WiFi Mesh 似乎來得更容易管理。

無線網路上的服務品質保證一向是一個重要的議題，尤其是跨越了不同的無線網路，例如：802.11 網路和802.16 網路；MS(Mobile Station)經由802.11 網路連結到802.16的網路，從使用者的角度來看，服務品質要求都是一樣的，但是對應到802.11網路與802.16網路上的MAC 層參數不見得相同，當使用者針對802.11發出相關的服務品質要求，同時傳給相對的服務品質要求參數，然而802.11網路收到後，因為必須跟後端網路802.16作連線要求，所以必須把802.11的參數格式轉為802.16的參數格式，轉換的過程中，必需

考量不同網路間頻寬的差異，資源獲得的方式不同，例如：在802.11使用的是競爭模式，然而在802.16使用的是【請求/同意】機制。

更進一步來說，兩者所使用的MAC 不同，互相協調配合勢必是個非常重要的研究

議題，因此本計畫擬研究整合IEEE 802.11與IEEE 802.16的MAC 協調運作，以求在此異質網路中能發揮完善的效能[3]。

2.2 公共無線網路

公共無線區域網路的提供方式主要可分為四類：(一)Private WISP、(二)Community WISP、(三)Hotsopt WISP 以及(四)Wide area WISP 四類。

(一)Private WISP：

係指包括如學校、家庭、企業、社區用戶內部自行方想寬頻網路非開放式，特點是僅供且免費供私人用途。

(二)Community WISP：

係指推廣WLAN傳輸技術應用的非營利團體組織，通常會在若干特定地點佈建AP，提供過往民眾或是附近商家的WLAN頻寬使用。

(三)Hotspot WISP：

是由場地業主在自有建築內架設WLAN設備，提供其消費者WLAN服務，此類的服務業者以率管、咖啡廳、餐廳等小型場地為主，佈建也以室內為主，藉以提供額外的服務，增加營運的競爭力。

(四)Wide Area WISP：

與Hotspot不同在於此類服務業者的Hotsopt的據點分佈範圍廣泛，服務範圍分為區域性或是全國性，通常有能力提供此類的服務的業者以大型WISP業者或是電信業者為主，其服務特點在於其具有完整網路管理機制，提供認證與安全機制，可確保無線上網的傳

輸品質，同時也提供業者之間或是跨國的漫遊服務。

2.3 集群分析

集群分析（Cluster Analysis）是將資料檔中的觀測值或變數加以歸類在各個集群內，也就是把沒有分群的個體按相似程度歸於同一群。

集群分析分群的方法有兩大形式，分層法（Hierarchical）與非分層法（Non-hierarchical），結合兩種方法的集群分析則稱為兩階段法（Two Step）。

分層法以個體間某項量測的距離或相似性將個體連結，但是事前並不知道分群的個數，通常可表示成樹型圖。

非分層法則是於事前依據其他研究或主觀認定，決定要將群體分成幾群，其中以 K 平均值法（K-Means）為代表。

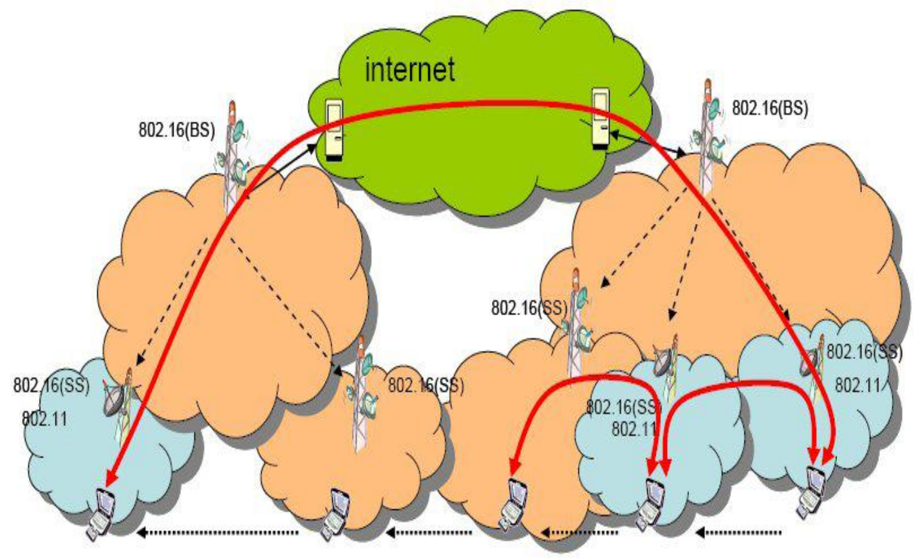
集群分析使在同一集群內的事物具有高度的同質性（homogeneity），而不同集群的事物具有高度的異質性（heterogeneity）。亦即將樣本分成幾群互相沒有交集的群組。因素分析是將同質性高的變數（variables）集成一群；而集群分析則是將變數相似性高的觀察值（cases）集成一群。集群分析的大部分應用都屬於探索性研究，最終結果是產生研究對象的分群。

三、研究方法

本研究的目標為整合無線WiMAX (802.16)及WiFi (802.11)異質網路，並以提供端至端網路服務品質保證為研究主軸。

在無線網路的部份同時考慮使用者行動時在跨過相同網系統、以及跨越異質系統的

過程中的網路服務品質控制。本研究預期建立的平台如圖一所示，以差異式網路架構建立具有服務品質保證之主幹網路，接取端網路則以WiMAX 及WiFi 做為主要的無線接取網路。



圖一、WiMAX/WiFi 整合網路

3.1 集群分析選擇

集群分析至少都應該包括以下四個步驟：

Step1：根據研究的目的選擇合適的分群變數。

Step2：計算相似性衡量。

Step3：選定集群方法進行集群。

Step4：加入權重值。

Step5：對結果進行分析和驗證。

當所有節點都已加入網路後，我們提出集合的概念(clustering)來判斷網路上可同時傳輸的節點。

3.2 沃德法(Ward's)

本研究採用分層法中的沃德法(Ward's)其定義為 $D_{pq}=n_p\cdot\left\|\bar{x}_p-\bar{\bar{x}}\right\|^2+n_q\cdot\left\|\bar{x}_p-\bar{\bar{x}}\right\|^2$ ，將 WiFi 的所有節點帶入網路中，其基本想法是同一群內觀察值的變異數和應該較小，不同群之間觀察值的變異數和應該較大，群間距離 d_{pq} 為變異數分析中所謂的組間平方和，公式 $d_{pq}=SSB=\sum_{i=1}^{2}n_i\left(\bar{x}_i-\bar{\bar{x}}\right)'\left(\bar{x}_i-\bar{\bar{x}}\right)$，其中 n_i 為第 i 群的個數，$\bar{x}_i$ 為第 i 群的中心點，$\bar{\bar{x}}$ 為全體中心。

要求觀察值之間的距離必須採用歐氏平方距離法最為恰當。最小變異數和法和平均連結法一樣，是分群效果較好，在社會科學領域應用較廣泛的集群方法。

3.3 研究架構

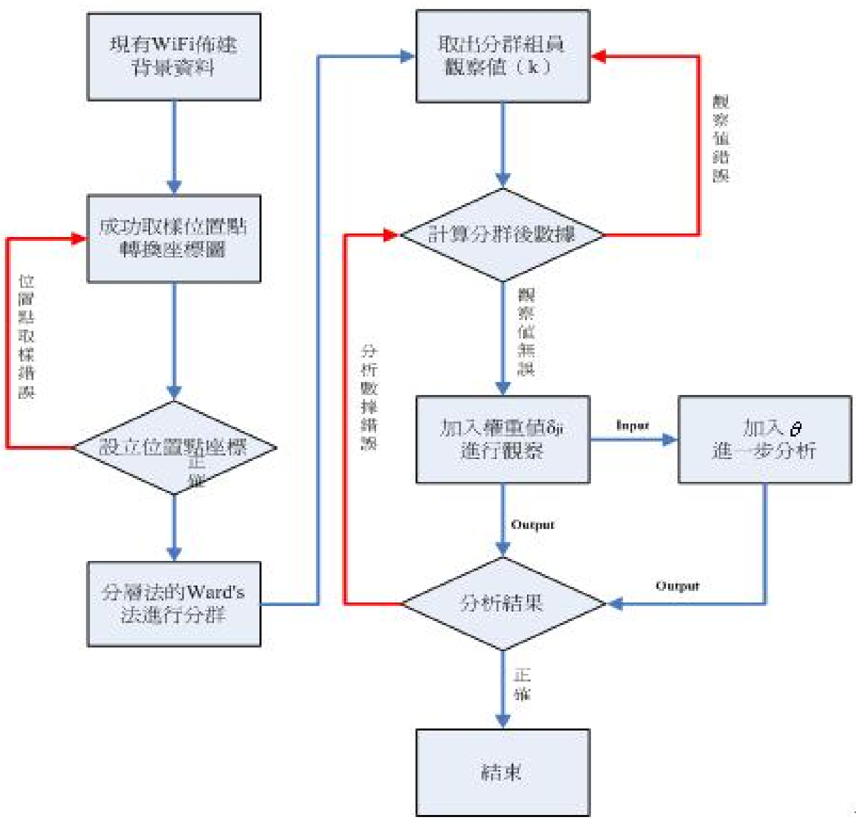


圖 2.研究流程圖

四、實驗分析

在這一節中，將詳細說明本研究所提出的基地台佈建機制。

我們的目標是在滿足使用機能的條件下，以佈建最少量的BS，達到最大涵蓋熱區面積。首先我們依照WiFi密度高，先決定熱區，區分如表1。

表1　熱區使用率與WiFi佈建密度關係

熱區	密度	使用率
絕對	WiFi佈建密度高	[illegible]
必須	WiFi佈建密度中	[illegible]
不必	WiFi佈建密度低	[illegible]

進行實驗分析所使用的參數代號如表2。

表2　參數說明

參數	說明
[illegible]	存取點佈建數量
[illegible]	存取點位置之二維座標
[illegible]	行動點位置之二維座標
[illegible]	行動點*j* 與存取點*i*
[illegible]	連結建立，有連結為1，無連結為0
[illegible]	熱區權重值
θ	熱區因變素
[illegible]	距離影響率

此為中台灣地區WiFi佈建狀況(圖2)，採用亂數佈建，本研究之所以用亂數佈建原因，在於使用802.11密度高的區域必定是人口密集的地方，但WiFi在密度高的區域卻以企業或私人所佈建，無法確認WiFi確定位置，只能確認無線網路使用率的高低。

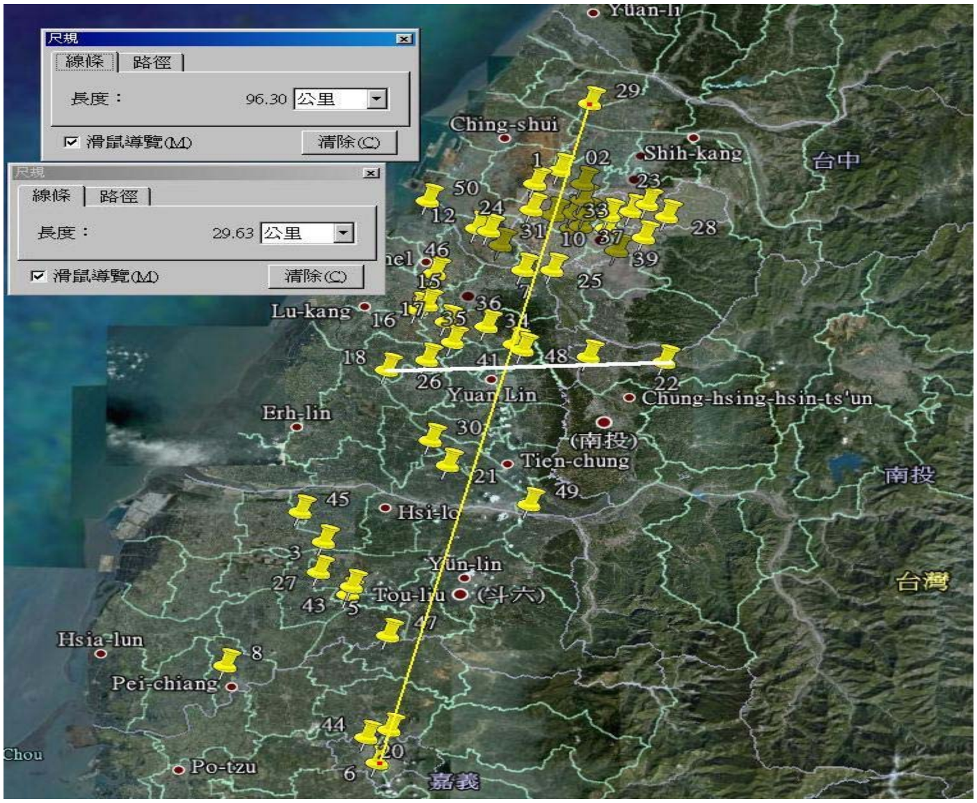


圖3、WiFi佈建圖

依據IEEE802.16協定中，沒有受到任何阻礙訊號傳送的理想狀況(LOS) 為30~50km，考慮NLOS的情況，訊號傳送約為4~9km，本研究依最遠距離法則，縱軸取29及6兩點觀測點計算，兩點直線最短距離為96.30km，其橫軸取18及22兩點觀測點計算，兩點直線最短距離為29.63km(圖三)。

採用試誤法計算，公式為 $d = (\overline{x_1 + x_2})'(\overline{y_1 + y_2})/Ds$ 佈建BS數達14個，為降低佈建數，本研究將先圖轉換為座標圖，進行分析研究，如圖二。

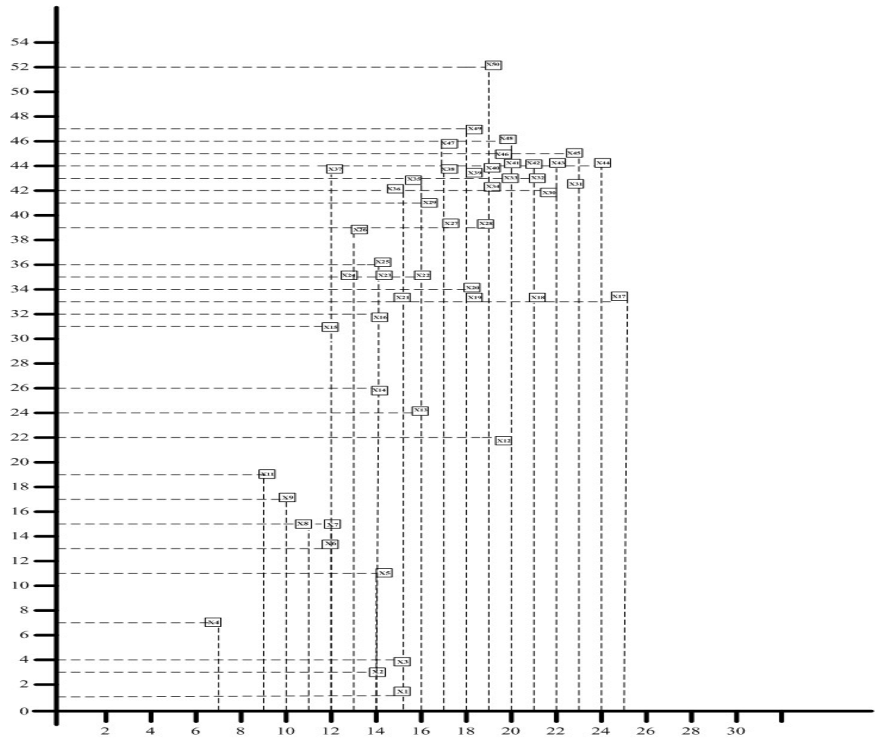


圖 4、設立座標圖

將此座標圖設立之後，利用階層集群分析法，進行分析，進而得到的結果(表 4)

表 4.群數凝聚過程

階段	組合集群		係數	先出現的階段集群		下一階段
	集群1	集群2		集群1	集群2	
1	49	47	0.5	0	0	19
2	41	42	1	0	0	17
3	39	40	1.5	0	0	19
4	31	32	2	0	0	17
5	22	24	2.5	0	0	8
6	18	19	3	0	0	28
7	7	8	3.5	0	0	21
8	22	23	4.333	5	0	24
9	46	48	5.333	0	0	31
10	43	44	6.333	0	0	29
11	37	38	7.333	0	0	22
12	34	35	8.333	0	0	16
13	29	30	9.333	0	0	25
14	15	20	10.333	0	0	27
15	2	3	11.333	0	0	26
16	28	34	13	0	12	30
17	31	41	15	4	2	25
18	26	27	17	0	0	34
19	39	45	19.5	3	1	31
20	9	10	22	0	0	39
21	6	7	24.833	0	7	32
22	33	37	27.833	0	11	30
23	12	13	31.833	0	0	35
24	21	22	36	0	8	33
25	29	31	40.333	13	17	29
26	1	2	44.667	0	15	41
27	14	15	50.333	0	14	38
28	17	18	56.5	0	6	36
29	29	43	65.167	25	10	42
30	28	33	74.833	16	22	34
31	39	46	85.667	19	9	40
32	5	6	98.083	0	21	39
33	21	25	110.583	24	0	38
34	26	28	131	18	30	37
35	11	12	153.667	0	23	45
36	16	17	180.75	0	28	43
37	26	36	209.111	34	0	44
38	14	21	239.319	27	33	43
39	5	9	276.403	32	20	45
40	39	49	314.498	31	0	42
41	1	4	372.665	26	0	46
42	29	39	435.236	29	40	44
43	14	16	556.444	38	36	47
44	26	29	696.125	37	42	47
45	5	11	915.014	39	35	46
46	1	5	1477.7	41	45	48
47	14	26	2290.83	43	44	48
48	1	14	9440.94	46	47	0

依據數據分析，擬聚係數透過SPSS的分層法進行計算分群如下：

表5. 凝聚分群關係

觀察值	10集群	9集群	8集群	7集群	6集群	5集群	4集群	3集群	2集群
X1	1	1	1	1	1	1	1	1	1
X2	1	1	1	1	1	1	1	1	1
X3	1	1	1	1	1	1	1	1	1
X4	2	2	1	1	1	1	1	1	1
X5	3	3	2	2	2	2	2	1	1
X6	3	3	2	2	2	2	2	1	1
X7	3	3	2	2	2	2	2	1	1
X8	3	3	2	2	2	2	2	1	1
X9	3	3	2	2	2	2	2	1	1
X11	3	3	2	2	2	2	2	1	1
X12	4	4	3	3	3	3	2	1	1
X13	4	4	3	3	3	3	2	1	1
X14	4	4	3	3	3	3	2	1	1
X15	5	5	4	4	4	4	3	2	2
X16	5	5	4	4	4	4	3	2	2
X17	6	6	5	5	4	4	3	2	2
X18	6	6	5	5	4	4	3	2	2
X19	6	6	5	5	4	4	3	2	2
X20	6	6	5	5	4	4	3	2	2
X21	5	5	4	4	4	4	3	2	2
X22	5	5	4	4	4	4	3	2	2
X23	5	5	4	4	4	4	3	2	2
X24	5	5	4	4	4	4	3	2	2
X25	5	5	4	4	4	4	3	2	2
X26	5	5	4	4	4	4	3	2	2
X27	7	7	6	6	5	5	4	3	2
X28	7	7	6	6	5	5	4	3	2
X29	7	7	6	6	5	5	4	3	2
X30	8	8	7	7	6	5	4	3	2
X31	8	8	7	7	6	5	4	3	2
X32	8	8	7	7	6	5	4	3	2
X33	8	8	7	7	6	5	4	3	2
X34	7	7	6	6	5	5	4	3	2
X35	7	7	6	6	5	5	4	3	2
X36	7	7	6	6	5	5	4	3	2
X37	7	7	6	6	5	5	4	3	2
X38	7	7	6	6	5	5	4	3	2
X39	7	7	6	6	5	5	4	3	2
X40	9	9	8	7	6	5	4	3	2
X41	9	9	8	7	6	5	4	3	2
X42	8	8	7	7	6	5	4	3	2
X43	8	8	7	7	6	5	4	3	2
X44	8	8	7	7	6	5	4	3	2
X45	8	8	7	7	6	5	4	3	2
X46	9	9	8	7	6	5	4	3	2
X47	9	9	8	7	6	5	4	3	2
X48	9	9	8	7	6	5	4	3	2
X49	9	9	8	7	6	5	4	3	2
X50	10	9	8	7	6	5	4	3	2

分群出來的數據由 2 集群至 10 集群 , 依照環境限制 我們將外在因素將數學公式加入權

重值 $d_{pq} = SSB = \sum_{i=1}^{2} n_i \left(\overline{x_i} - \overline{\overline{x}}\right)' \left(\overline{x_i} - \overline{\overline{x}}\right) * \delta_{ji}$ ，權重值帶入 SPSS 中，集群分析得參考資料數據如下

表 6.加權過後擬聚分群

觀察值	10集群	9集群	8集群	7集群	6集群
X1	1	1	1	1	1
X2	1	1	1	1	1
X3	1	1	1	1	1
X4	2	2	1	1	1
X5	3	3	2	2	2
X6	3	3	2	2	2
X7	3	3	2	2	2
X8	3	3	2	2	2
X9	3	3	2	2	2
X11	3	3	2	2	2
X12	4	4	3	3	3
X13	4	4	3	3	3
X14	4	4	3	3	3
X15	5	5	4	4	4
X16	5	5	4	4	4
X17	6	6	5	5	4
X18	6	6	5	5	4
X19	6	6	5	5	4
X20	6	6	5	5	4
X21	5	5	4	4	4
X22	5	5	4	4	4
X23	5	5	4	4	4
X24	5	5	4	4	4
X25	5	5	4	4	4
X26	5	5	4	4	4
X27	7	7	6	6	5
X28	7	7	6	6	5
X29	7	7	6	6	5
X30	8	8	7	7	6
X31	8	8	7	7	6
X32	8	8	7	7	6
X33	8	8	7	7	6
X34	7	7	6	6	5
X35	7	7	6	6	5
X36	7	7	6	6	5
X37	7	7	6	6	5
X38	7	7	6	6	5
X39	7	7	6	6	5
X40	9	9	8	7	6
X41	9	9	8	7	6
X42	8	8	7	7	6
X43	8	8	7	7	6
X44	8	8	7	7	6
X45	8	8	7	7	6
X46	9	9	8	7	6
X47	9	9	8	7	6
X48	9	9	8	7	6
X49	9	9	8	7	6
X50	10	9	8	7	6

受到 δ_{ji} 影響的數據得知，經過分群方式，接近 LOS 情況為 6 集群相差比 42.85%，則 NLOS 為 10 集群，相差比為 71.43%，BS 佈建數從 14 個降為 10~6 個。依照熱區的密度設為因變數 θ ，屏除密度低的熱點，其屏除熱點 X_4、X_{12}、X_{17}、X_{37}、X_{50}，共五點，可由 RS 接替。如表 7

表 7.加入 θ 分群關係

觀察值	10集群	9集群	8集群	7集群	6集群
X1	1	1	1	1	1
X2	1	1	1	1	1
X3	1	1	1	1	1
X5	3	3	2	2	2
X6	3	3	2	2	2
X7	3	3	2	2	2
X8	3	3	2	2	2
X9	3	3	2	2	2
X11	3	3	2	2	2
X13	4	4	3	3	3
X14	4	4	3	3	3
X15	5	5	4	4	4
X16	5	5	4	4	4
X18	6	6	5	5	4
X19	6	6	5	5	4
X20	6	6	5	5	4
X21	5	5	4	4	4
X22	5	5	4	4	4
X23	5	5	4	4	4
X24	5	5	4	4	4
X25	5	5	4	4	4
X26	5	5	4	4	4
X27	7	7	6	6	5
X28	7	7	6	6	5
X29	7	7	6	6	5
X30	8	8	7	7	6
X31	8	8	7	7	6
X32	8	8	7	7	6
X33	8	8	7	7	6
X34	7	7	6	6	5
X35	7	7	6	6	5
X36	7	7	6	6	5
X38	7	7	6	6	5
X39	7	7	6	6	5
X40	9	9	8	7	6
X41	9	9	8	7	6
X42	8	8	7	7	6
X43	8	8	7	7	6
X44	8	8	7	7	6
X45	8	8	7	7	6
X46	9	9	8	7	6
X47	9	9	8	7	6
X48	9	9	8	7	6
X49	9	9	8	7	6

由原先佈建數 10~6 個降為 8~6 個，LOS 為 42.85%則 NLOS 為相差比 57.13%

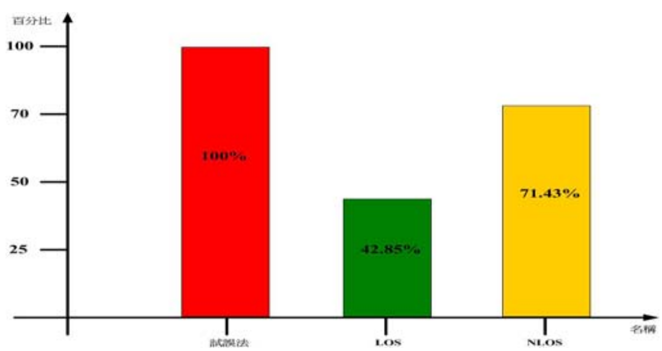


圖 5.加入 δ_{ji} 三者比較圖

另外我們加入 θ，如圖 6 所示，屏除了不必要服務區熱點，可將 LOS 及 N LOS 的比值更為接近。

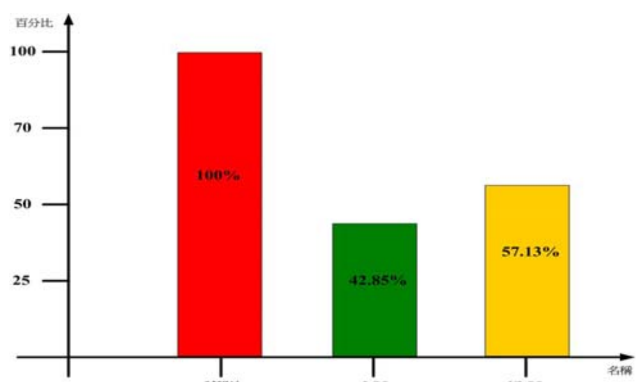


圖 6.加入 θ 三者比較圖

五、結論

在佈建異質網路中，若是由施工人員現場以試誤法決定佈建無線區域網路的BS點的佈建位置，無法判斷其佈建位置的有效性與合理性結果是否良好。因此，本研究提供亂數WiFi熱點利用階層分析模擬方法，依據座標數據進行近似的分析模擬，達到能夠滿足全區域性範圍的條件下，佈建最少的BS點，達到最大涵蓋熱區面積。我們的模擬法與實作法比較的結果顯示這是一種經濟且效果良好的模擬分析。

目前我們的分析僅限於二維平面，因此結果可能不是最經濟的佈建法，未來我們將修改模擬數據及參數值，先進行因素分析，使三維因素亦能考慮，達到更精準之結果。

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有關作者

劉柏伸在於畢業於國立台灣大學資訊工程學系，在2006年於僑光技術學院資訊科技系任職，專長為網路工程、排隊理論(效能分析)、無線網路、多媒體網路、多媒體系統、網路安全與管理。

薛景峰目前就讀於僑光技術學院，為劉柏伸的老師的學生，擅長是無線網路規劃佈建。

Abstract

About Taiwan's complex heterogeneous BS deployment of wireless local area network links, the reality does all tries method to decide the position by mistake. This procedure has the high uncertainty and high cost payout. This research based existing WiFi hypothesis signal demand, by the social stratum group method in the SPSS analysis, with the weight value way, calculates LOS and NLOS. Our deployment method reduces the number of BS spots, achieves the entire regional covering and scope

Keyword： WiMax, heterogeneous wireless network deployment.

A study of heterogeneous network deployment for WiMax and current wireless LAN

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Abstract

In Taiwan, Trial-and-error method is adopted in practice in the Base Station (BS) deployment of complex heterogeneous wireless local area network, which is subject to high uncertainty and high cost. Based on existing WiFi hypothesis signal demand, the author utilizes hierarchical clustering method in the SPSS analysis, and combines with different weights, to calculate the LOS and NLOS. The outcomes show that the new method can cover the entire area with less number of BS.

Keywords：WiMax、heterogeneous wireless network deployment

1. Introduction

1.1 Preface

WiMAX(Worldwide Interoperability for Microwave Access), which is based on the IEEE 802.16 wireless communication technology, is highly recognized in recent years and is also popularly expected to be a representative technology when the communication technology is evolving to 4G. There are two main specifications in present WiMAX equipment market: 802.16-2004 Standard and 802.16-2005 Standard. The former one is constituted by IEEE in 2004, and its previous version is 802.16d – also known as Fixed WiMAX. The latter one is constituted by IEEE in 2005, and its previous version is 802.16e, which is known as Mobile WiMAX and has the advantage to support related wireless application that required mobility. Fixed WiMAX is mainly used in backbone and bridge with license-free frequency, such as network among buildings. Hence it has the advantage of avoiding the troubles arisen in the entities network deployment. It also can be used as backhaul line in the WiFi environment, or used to establish the temporary network, and so on [1].

In the past, wired ADSL or cable network was the common entities used in the city network establishment. Recently, wireless network, represented by 802.11, was gradually used; and in the future, part of this technology will be probably replaced by the Fixed WiMAX to reduce the cost of establishing cable network. Mobile WiMAX terminal commonly caters to individual users. It provides mobile communication ability, which is similar to 3G technology. In addition, it is also environmentally friendly, and has the characteristics of long distance transmission ability, high transmission frequency bandwidth, and the compatibility with existing IP-related application. Therefore, Mobile WiMAX is also esteemed as a promising big cake by all works of life [2].

1.2 Research Objective

The major problems faced present WiMAX network system include limited spectrum certificated to telecommunication industry, coverage deficit due to building barriers, inequality of data stream, insufficient wired network entities in emerging areas, and so on. Hence telecommunication entrepreneur have to find a way to enhance data transmission speed and to address the network coverage problem. Presently, main solutions are to place the Repeater or to increase the number of Base Station. Table 1 shows the advantages and disadvantages of using power amplifier, increasing more Base Stations, or employing Relay Station to address the problems in the WiMAX network system.

Table1: Comparison of Different Deployment Schemes

Comparison of Existing WiMAX Network System Deployment Schemes		
	Advantages	Disadvantages
PA	Equipment is cheapest. Express deployment.	Interfering signals will be amplified too. Deployment coverage is incomplete.
Base Station	Fully functional. Deployment coverage is complete.	Equipment is expensive.
Relay Station	Equipment is relatively cheap. Express deployment. Deployment coverage is complete. Auto Configuration.	Increase the complexity of systems.

As shown in the Table 1, if the number of PA is increased, the interfering signals will be amplified too; if the number of Base Station is increased, the cost will rise due to expensive redundant equipments and Backup Power equipments, and costly Backbone network maintenance expanse. On the other hand, increasing the number of Base Stations will strengthen the data density at the cost of smaller effective coverage radius. In addition, when it comes to how to deploy the Base Stations, there will be other problems rising from Base

Station establishment, environmental restriction due to poor infrastructure construction in wired broadband network, and so on.

The objective of this paper focuses on the seamless inter-system roaming / hand off mechanism in 802.16/802.11 heterogeneous network, while the past research paid more attention to the QOS (Quality of Service) guarantee and Mobility Management. In this paper, we develop an integrated network by combining IEEE 802.16g with present IEEE 802.11 series, and propose an idea of how to maintain relatively better QOS in this integrated wireless communication environment. As how to deploy WiMAX Base Stations in the practice, our principle is to reduce the number of Base Stations so as to reduce the overall cost under the condition of maintaining certain degree of QOS and Mobility Management.

The integration of heterogeneous wireless network technologies is a rather valuable research topic recently. Presently, the most promising integrated wireless systems include Internet, 3G, GPRS, WiMAX(802.16), and WiFi(802.11). Due to the discrepancies among systems, it is an important research topic of how to develop a system that can enable the user to seamlessly roam from one system to another, and meanwhile maintain certain degree of QOS.

2. Literature Review

2.1 MAC Integration in Wireless LAN QOS

WiMAX is well-known as a wireless network technology with broad coverage and bandwidth, and is perhaps easier to be established than present WiFi or WiFi Mesh.

QOS of wireless network is always an important research topic, especially in inter-systems wireless environment, such as 802.11 network and 802.16 network. When the Mobile Station (MS) links to 802.16 network through 802.11 network, the quality of service requires from user's perspective is the same. But due to the different parameters in MAC layers in the corresponding 802.11 network and 802.16 network, when user sends certain relevant requirements of quality of service under 802.11 which transmit into corresponding QOS parameters, 802.11 network after receiving the requirements has to convert original parameter format into 802.16 format because it has to link with the back-end 802.16 network. During the conversion process, the bandwidth discrepancies between different network and the different ways of resources procurement should be carefully considered. For example, Competition Mode is used in 802.11 network, while Request/Transmission Policy in 802.16.

Furthermore, due to different MAC used, how to better coordinate poses a significant research topic. Therefore, this paper proposes a scheme to achieve MAC coordinate operation in the integrated IEEE 802.11 and IEEE 802.16 network, so as to enhance the efficiency of the heterogeneous network [3].

2.2 Public Wireless Network

There are major four types of internet service provider in the public wireless network: (1) Private WISP, (2) Community WISP, (3) Hotspot WISP, and (4) Wide area WISP.

(1) Private WISP:

Private WISP is a non-open broadband network set up and shared by individuals in schools, families, enterprises, communities and so on. Its characteristic is that the service is only confined to and free to internal users for their own private purposes.

(2) Community WISP：

Community WISP is sponsored by non-government organizations that advocate the application of WLAN transmission technology. These NGOs always deploy AP in several specific locations to provide WLAN to passengers, and shops nearby.

(3 Hotspot WISP：

Hotspot WISP is established by business runners in their operation sites. They set up the WLAN equipments and provide WLAN service to their consumers. These sites usually have small size and are operated indoor, like coffee bars, restaurants, and so on. The operators enhance their operation competitiveness through value-added service.

(4) Wide Area WISP：

Unlike to Hotspot WISP, Wide Area WISP hotspots span broader, from local area to national wide. Usually such kind of service providers that has the ability to provide such a huge project is always largish WISP operators or telecommunication operators. It is characterized as wholesome network management mechanism with Authentication and Security Mechanism, so as to ensure transmission quality in the wireless network, even to provide inter-countries roaming service between service providers.

2.3 Cluster Analysis

Cluster Analysis is a method to classify the cases and variables in the data file into each cluster, in other words to sort the non-clustered individuals into groups according to their similarities.

There are two types of Cluster Analysis, Hierarchical and Non-hierarchical method. And it is called Two Step method to integrate both of the methods.

Hierarchical Cluster Analysis is to link individuals according to their similarities or the distance between their certain measurements when the number of implied groups is unknown. It always can be presented as a Tree.

Non-hierarchical Cluster Analysis is to separate the individuals into groups in advance according to relevant research or objective hypothesis. The typical way is K-Means.

Cluster Analysis ensures the elements in the same group have high homogeneity, while elements from different groups have high heterogeneity; in other words, the samples are divided into clusters with no intersection set. Element Analysis is to cluster variables with high homogeneity, while Cluster Analysis is to cluster observations with high variable similarity. Most of the applications of the Cluster Analysis are subjected to exploratory research. The ultimate results are used to produce clusters under research.

3. Research Methodology

The objective of this paper is to integrate the heterogeneous networks between WiMAX(802.16) and WiFi(802.11) under the pivot of securing end-to-end network quality of service.

The wireless integrated network systems take the quality of service into consideration when users move between homogeneous/heterogeneous network systems. The platform expected to be developed in this paper is shown in Figure 1, including a Backbone network with guaranteed QOS established by heterogeneous network frame, and an Access network which is mainly set up by WiMAX and WiFi.

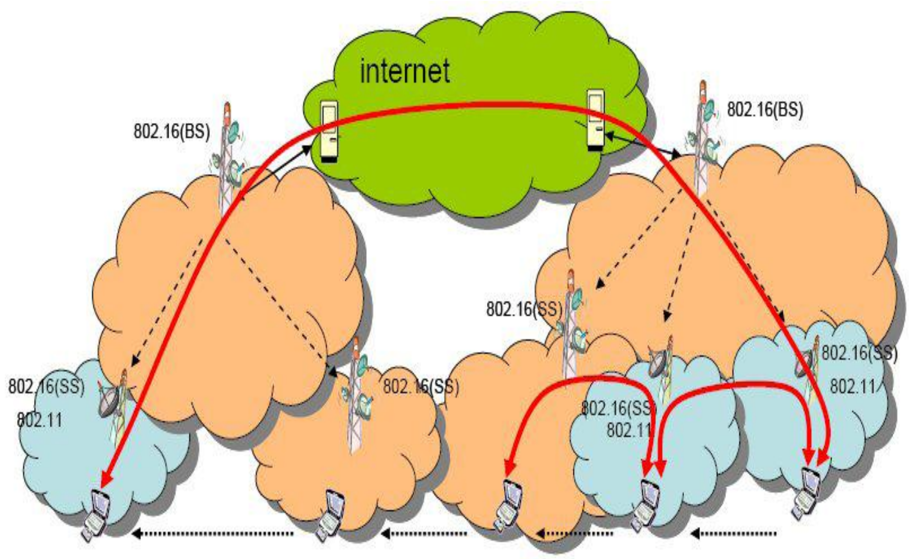

Figure 1. WiMAX/WiFi Integrated Network

3.1 Cluster Analysis

Cluster Analysis should at least include the following 5 steps:

Step1: Select appropriate cluster variables according to the research objective.
Step2: Calculate similarity measurement.

Step3: Cluster variables by selected clustering method.

Step4: Incorporate the weights.

Step5: Analyze and examine the results.

When all the WiMAX/WiFi nodes are positioned in the network, we use the clustering method to decide available nodes that are ready to transmit in the same time in the integrated network.

3.2 Ward's Method

The Hierarchical clustering method used in this paper is Ward's Method, which is defined as $D_{pq} = n_p \cdot \left\| \bar{x}_p - \bar{\bar{x}} \right\|^2 + n_q \cdot \left\| \bar{x}_p - \bar{\bar{x}} \right\|^2$. The fundamental principle to deploy all the WiFi nodes in the network is to keep relatively low sum of variation of observations in the same cluster, and relatively high sum of variation in the different cluster. The distance between clusters d_{pq} , is the so called Between Groups Sum of Squares in the ANOVA. The formula is $d_{pq} = SSB = \sum_{i=1}^{2} n_i \left(\bar{x}_i - \bar{\bar{x}}\right)' \left(\bar{x}_i - \bar{\bar{x}}\right)$, where n_i is the number of elements in the ith cluster, and $\bar{x}_i$ is the center point of the ith cluster, and $\bar{\bar{x}}$ is the center point of the sample.

The most appropriate method to calculate the distance between observations is Squared Euclidean Distance Method. Minimum Variance Method and Average Linkage Method are two kinds of cluster methods that are widely used in the social science realm with the advantage of better clustering performance.

3.3 Research Structure

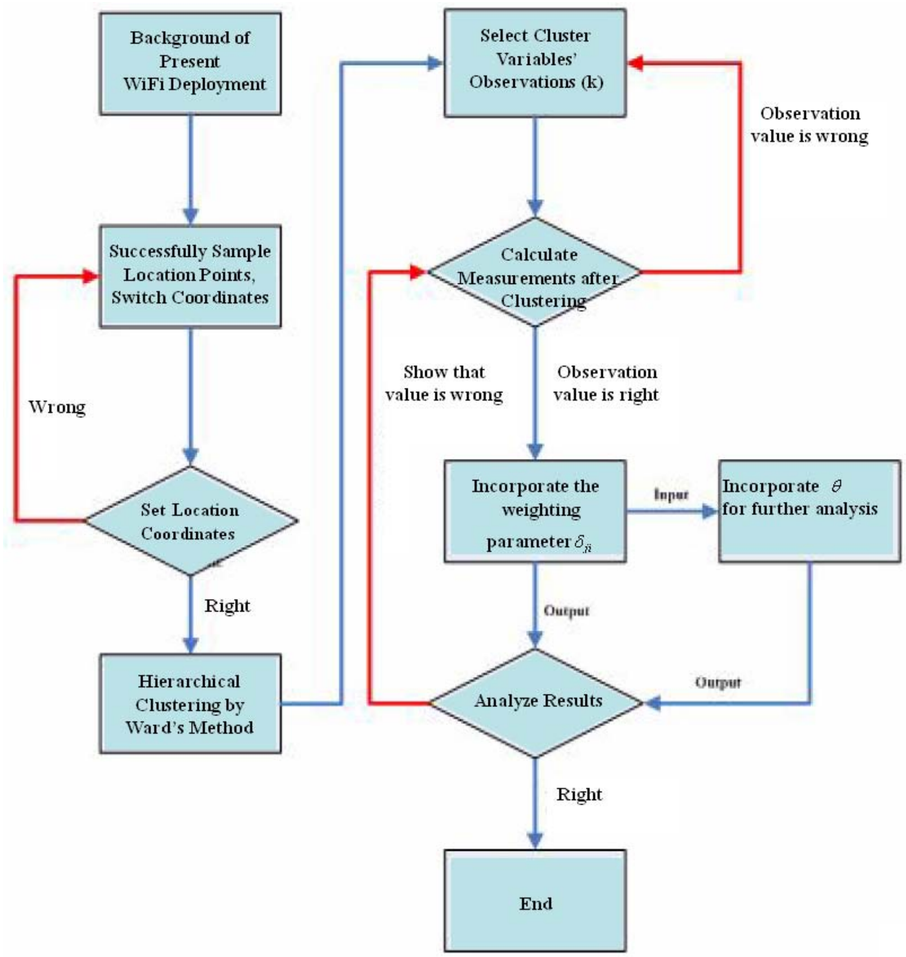

Figure 2. Research Structure

4. Experiment

In this section, we will detailedly introduce the Base Station deployment mechanism proposed in this paper.

Our objective is to deploy minimum BS to achieve maximum hot-zone coverage under the condition of satisfying certain usage. First of all, we decide the hot-zone based on WiFi density, as shown in Table 2.

Table2. Relationship between Hot-zone Usage and WiFi Deployment Density

Hot-zone	Density	Usage
Absolute	High WiFi deployment density	80%≥
Necessary	Median WiFi deployment density	>80%, 20%≥
Unnecessary	Low WiFi deployment density	>20%

The parameter denotes in the experiment are shown in Table 3.

Table 3. Parameter Denotes

Parameters	Note
X_n	The number of access point deployed.
AP_i	Two-dimensional coordinates of access point location.
MS_j	Two-dimensional coordinates of mobile station location.
p_{ji}	Mobile station *j* and access point *j*.
L_{ji}	Binary variable to indicate the link status; if linked, the value is 1, otherwise 0.
δ_{ji}	Weight of each hot-zone.
θ	Hot-zone dependant variable.
Ds	Distance factor.

Figure 3 shows the WiFi deployment illustration in Taiwan region by random deployment method. Random deployment method is used because the area with high 802.11 density always locates in the area with high population density, while WiFi in high density area is always set up by enterprises or private individuals. Hence it is difficult to identify the WiFi locations, but only to confirm the usage in the network.

According to IEEE 802.16 protocol, the LOS under ideal situation with unobstructed wave propagation is 30~50km, and the NLOS is 4~9km. The Maximum Distance Rule is used in this paper; point 29 and 6 with lineal measure of 96.30km are selected to determine the vertical axis, and point 18 and 22 with distance of 29.63km are selected to determine the horizontal axis, as shown in Figure 3.

By Trial-and-error method, according to $d = \left(\overline{x_1 + x_2}\right)'\left(\overline{y_1 + y_2}\right)/Ds$, we calculate the number of required BS is 14. In order to reduce the BS amount, we convert the locations in the figure into two-dimensional coordinates, as shown in Figure 4.

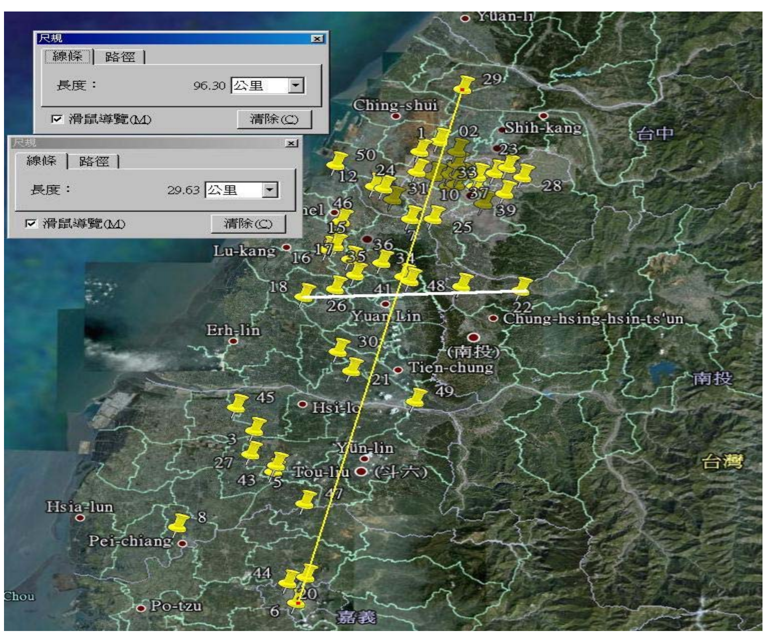

Figure 3. WiFi Deployment Illustration

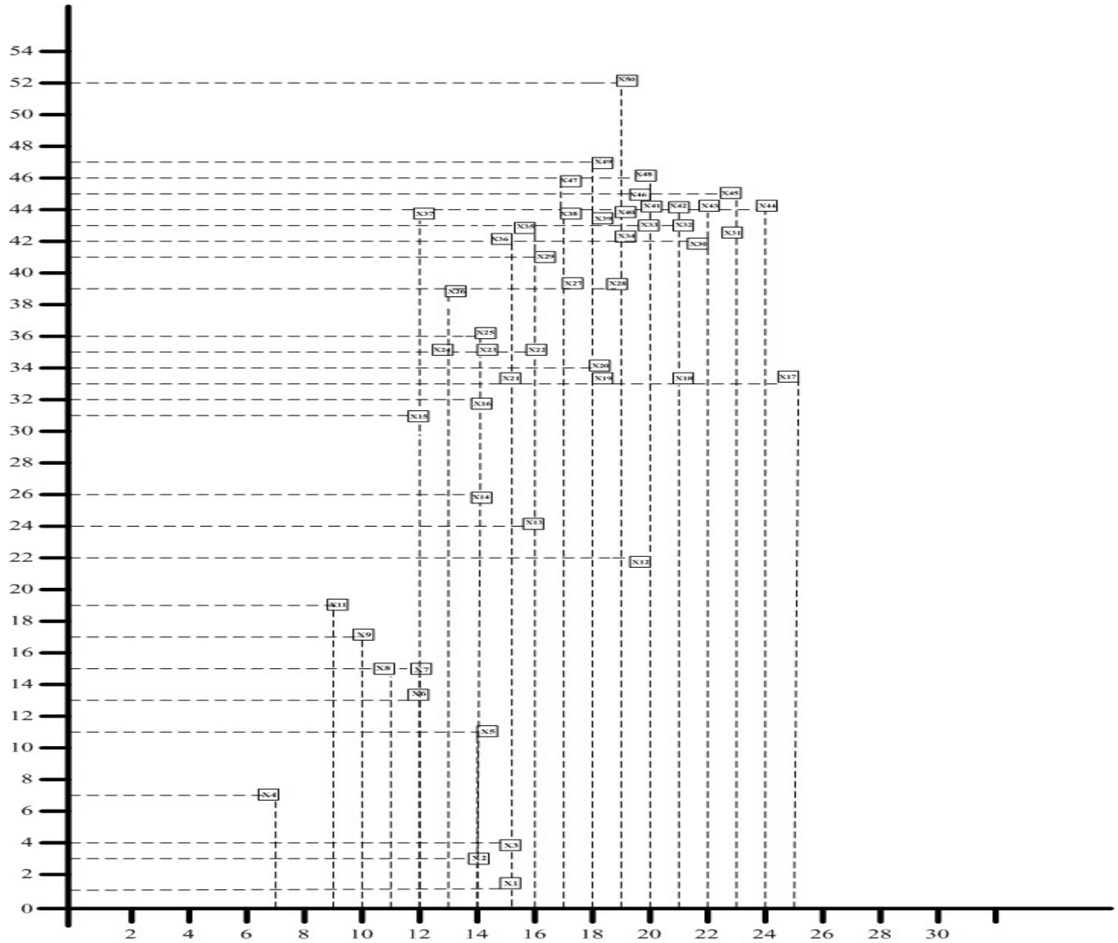

Figure 4. Corresponding Coordinates

When coordinates are set readily, Hierarchical Cluster Analysis is employed for further analysis and calculation. The result is shown in Table 4.

Table 4. Agglomerative Clustering Schedule

Stage	Combined Cluster		Coefficient	Early appeared Hierarchical Cluster		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	49	47	0.5	0	0	19
2	41	42	1	0	0	17
3	39	40	1.5	0	0	19
4	31	32	2	0	0	17
5	22	24	2.5	0	0	8
6	18	19	3	0	0	28
7	7	8	3.5	0	0	21
8	22	23	4.333	0	0	24
9	46	48	5.333	0	0	31
10	43	44	6.333	0	0	29
11	37	38	7.333	0	0	22
12	34	35	8.333	0	0	16
13	29	30	9.333	0	0	25
14	15	20	10.333	0	0	27
15	2	3	11.333	0	0	26
16	28	34	13	0	12	30
17	31	41	15	4	2	25
18	26	27	17	0	0	34
19	39	45	19.5	3	1	31
20	9	10	22	0	0	39
21	6	7	24.833	0	7	32
22	33	37	27.833	0	11	30
23	12	13	31.833	0	0	35
24	21	22	36	0	8	33
25	29	31	40.333	13	17	29
26	1	2	44.667	0	15	41
27	14	15	50.333	0	14	38
28	17	18	56.5	0	6	36
29	29	43	65.167	25	10	42
30	28	33	74.833	16	22	34
31	39	46	85.667	19	9	40
32	5	6	98.083	0	21	39
33	21	25	110.583	24	0	38
34	26	28	131	18	30	37
35	11	12	153.667	0	23	45
36	16	17	180.75	0	28	43
37	26	36	209.111	34	0	44
38	14	21	239.319	27	33	43
39	5	9	276.403	32	20	45
40	39	49	314.498	31	0	42
41	1	4	372.665	26	0	46
42	29	39	435.236	29	40	44
43	14	16	556.444	38	36	47
44	26	29	696.125	37	42	47
45	5	11	915.014	39	35	46
46	1	5	1477.7	41	45	48
47	14	26	2290.83	43	44	48
48	1	14	9440.94	46	47	0

According to the data analysis, agglomerative coefficients are calculated by SPSS' hierarchical clustering method; the clustering result is shown in Table 5.

Table 5. Agglomerative Clusters Relationship

Observation	Cluster 10	Cluster 9	Cluster 8	Cluster 7	Cluster 6	Cluster 5	Cluster 4	Cluster 3	Cluster 2
X1	1	1	1	1	1	1	1	1	1
X2	1	1	1	1	1	1	1	1	1
X3	1	1	1	1	1	1	1	1	1
X4	2	2	1	1	1	1	1	1	1
X5	3	3	2	2	2	2	2	1	1
X6	3	3	2	2	2	2	2	1	1
X7	3	3	2	2	2	2	2	1	1
X8	3	3	2	2	2	2	2	1	1
X9	3	3	2	2	2	2	2	1	1
X11	3	3	2	2	2	2	2	1	1
X12	4	4	3	3	3	3	2	1	1
X13	4	4	3	3	3	3	2	1	1
X14	4	4	3	3	3	3	2	1	1
X15	5	5	4	4	4	4	3	2	2
X16	5	5	4	4	4	4	3	2	2
X17	6	6	5	5	4	4	3	2	2
X18	6	6	5	5	4	4	3	2	2
X19	6	6	5	5	4	4	3	2	2
X20	6	6	5	5	4	4	3	2	2
X21	5	5	4	4	4	4	3	2	2
X22	5	5	4	4	4	4	3	2	2
X23	5	5	4	4	4	4	3	2	2
X24	5	5	4	4	4	4	3	2	2
X25	5	5	4	4	4	4	3	2	2
X26	5	5	4	4	4	4	3	2	2
X27	7	7	6	6	5	5	4	3	2
X28	7	7	6	6	5	5	4	3	2
X29	7	7	6	6	5	5	4	3	2
X30	8	8	7	7	6	5	4	3	2
X31	8	8	7	7	6	5	4	3	2
X32	8	8	7	7	6	5	4	3	2
X33	8	8	7	7	6	5	4	3	2
X34	7	7	6	6	5	5	4	3	2
X35	7	7	6	6	5	5	4	3	2
X36	7	7	6	6	5	5	4	3	2
X37	7	7	6	6	5	5	4	3	2
X38	7	7	6	6	5	5	4	3	2
X39	7	7	6	6	5	5	4	3	2
X40	9	9	8	7	6	5	4	3	2
X41	9	9	8	7	6	5	4	3	2
X42	8	8	7	7	6	5	4	3	2
X43	8	8	7	7	6	5	4	3	2
X44	8	8	7	7	6	5	4	3	2
X45	8	8	7	7	6	5	4	3	2
X46	9	9	8	7	6	5	4	3	2
X47	9	9	8	7	6	5	4	3	2
X48	9	9	8	7	6	5	4	3	2
X49	9	9	8	7	6	5	4	3	2
X50	10	9	8	7	6	5	4	3	2

According to the environmental limitation, we incorporate the weights (δ_{ji}) indicating the

$$d_{pq} = SSB = \sum_{i=1}^{2} n_i \left(\overline{x_i} - \overline{\overline{x}}\right)' \left(\overline{x_i} - \overline{\overline{x}}\right) * \delta_{ji}$$

external factors into the original formula for cluster 2 to cluster 10 based on the abovementioned result. The formula now changes to . Then the weights are added into SPSS, and the calculated outcomes through cluster analysis show in Table 6.

Table 6. Weighted Agglomerative Clusters

Observation	Cluster 10	Cluster 9	Cluster 8	Cluster 7	Cluster 6
X1	1	1	1	1	1
X2	1	1	1	1	1
X3	1	1	1	1	1
X4	2	2	1	1	1
X5	3	3	2	2	2
X6	3	3	2	2	2
X7	3	3	2	2	2
X8	3	3	2	2	2
X9	3	3	2	2	2
X11	3	3	2	2	2
X12	4	4	3	3	3
X13	4	4	3	3	3
X14	4	4	3	3	3
X15	5	5	4	4	4
X16	5	5	4	4	4
X17	6	6	5	5	4
X18	6	6	5	5	4
X19	6	6	5	5	4
X20	6	6	5	5	4
X21	5	5	4	4	4
X22	5	5	4	4	4
X23	5	5	4	4	4
X24	5	5	4	4	4
X25	5	5	4	4	4
X26	5	5	4	4	4
X27	7	7	6	6	5
X28	7	7	6	6	5
X29	7	7	6	6	5
X30	8	8	7	7	6
X31	8	8	7	7	6
X32	8	8	7	7	6
X33	8	8	7	7	6
X34	7	7	6	6	5
X35	7	7	6	6	5
X36	7	7	6	6	5
X37	7	7	6	6	5
X38	7	7	6	6	5
X39	7	7	6	6	5
X40	9	9	8	7	6
X41	9	9	8	7	6
X42	8	8	7	7	6
X43	8	8	7	7	6
X44	8	8	7	7	6
X45	8	8	7	7	6
X46	9	9	8	7	6
X47	9	9	8	7	6
X48	9	9	8	7	6
X49	9	9	8	7	6
X50	10	9	8	7	6

As shown in Table 6, the results impacted by δ_{ji} indicate that the cluster close to LOS status is Cluster 6 with 42.85% difference, and that close to NLOS is Cluster 10 with 71.43% difference, which reduce the number of BS deployed from 14 to 10~6. Then according to hot-zone density dependant variable θ, we remove the hotspots with low density, which are the five points of X_4, X_{12}, X_{17}, X_{37}, and X_{50}, and replace them with RS. The results show in Table 7.

Table 7. Cluster Relationship after Incorporating Hot-zone Density Factor θ

Observation	Cluster 10	Cluster 9	Cluster 8	Cluster 7	Cluster 6
X1	1	1	1	1	1
X2	1	1	1	1	1
X3	1	1	1	1	1
X5	3	3	2	2	2
X6	3	3	2	2	2
X7	3	3	2	2	2
X8	3	3	2	2	2
X9	3	3	2	2	2
X11	3	3	2	2	2
X13	4	4	3	3	3
X14	4	4	3	3	3
X15	5	5	4	4	4
X16	5	5	4	4	4
X18	6	6	5	5	4
X19	6	6	5	5	4
X20	6	6	5	5	4
X21	5	5	4	4	4
X22	5	5	4	4	4
X23	5	5	4	4	4
X24	5	5	4	4	4
X25	5	5	4	4	4
X26	5	5	4	4	4
X27	7	7	6	6	5
X28	7	7	6	6	5
X29	7	7	6	6	5
X30	8	8	7	7	6
X31	8	8	7	7	6
X32	8	8	7	7	6
X33	8	8	7	7	6
X34	7	7	6	6	5
X35	7	7	6	6	5
X36	7	7	6	6	5
X38	7	7	6	6	5
X39	7	7	6	6	5
X40	9	9	8	7	6
X41	9	9	8	7	6
X42	8	8	7	7	6
X43	8	8	7	7	6
X44	8	8	7	7	6
X45	8	8	7	7	6
X46	9	9	8	7	6
X47	9	9	8	7	6
X48	9	9	8	7	6
X49	9	9	8	7	6

The number of BS further reduces from 10~6 to 8~6, and results in 42.85% difference comparing with LOS, and 57.13% difference with NLOS, as shown in Figure 5.

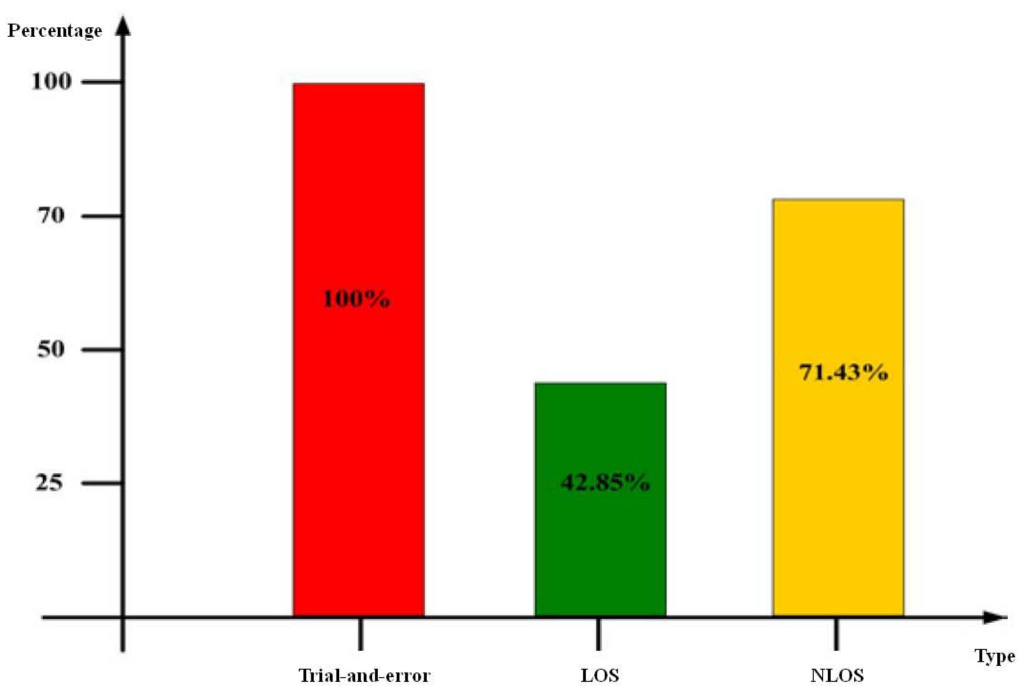

Figure 5. Comparison among Trial-and-error, LOS, and NLOS, after Incorporating δ_{ji}

In addition, when considering θ , we remove unnecessary hotspots, so as to further reduce the difference between LOS and NLOS, as shown in Figure 6.

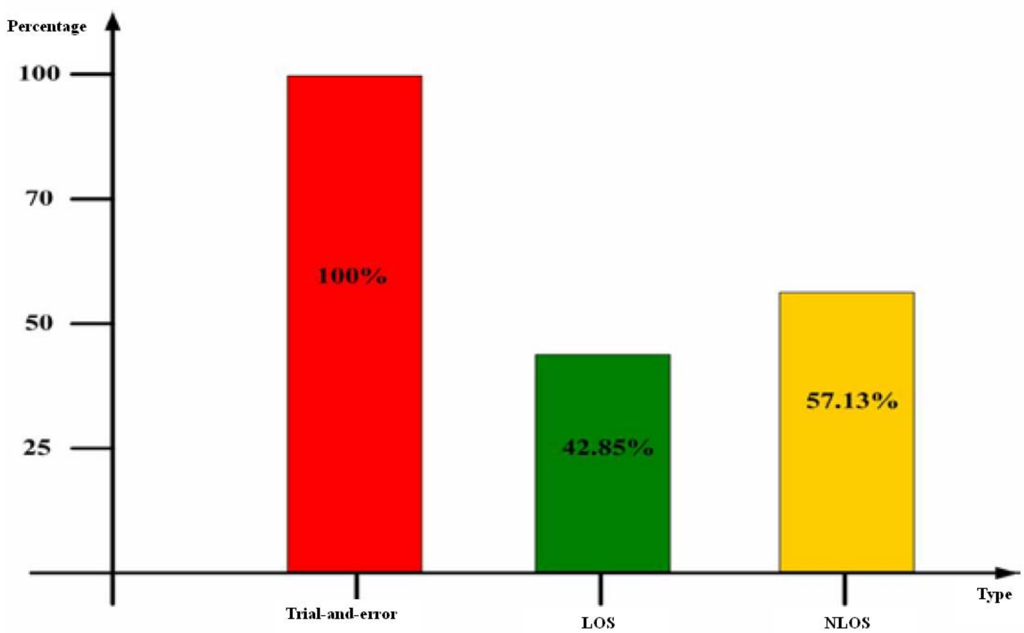

Figure 6. Comparison among Trial-and-error, LOS, and NLOS, after Incorporating θ

5. Conclusion

In deploying the heterogeneous network, if the construction staff decide the BS location in the wireless local area network on-site by Trial-and-error method, it is impossible to decide whether it is efficient or reasonable enough based on this BS deployment layout. Hence, in this paper we develop a WiFi hotspot random deployment method and convert the points into coordinates; then based on Hierarchical clustering analysis method, we conduct the simulated experiment to analyze the deployment schedule. Our research result shows that the deployment can achieve the maximum hot-zone coverage by minimum Base Stations under the condition that the whole area is covered. The comparison between our simulation and experiment indicates that our method is a cost-effective and efficient simulation analysis.

So far our analysis only focuses on two-dimensional plane. Hence the results may not be the most economy deployment scheme. Our future research will adjust the simulated data and parameters and perform the Factor Analysis in the first place so as to make three-dimensional plane analysis available to achieve more accurate results.

6. References

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Biography

Bo-Shen Liou graduated from Department of Information Engineering in National Taiwan Univerity. Since 2006, he worked in Department of Information Technology in OCIT, with expertise in network engineering, queuing theory (performance analysis), wireless networks, multimedia networks, multimedia systems, network security and management.

Ching-Feng Heng, student of Dr. Liou, is currently perusing his Master's Degree in OCIT. He is good at deployment schedule for wireless networks.

Appendix