行政院國家科學委員會專題研究計畫 成果報告

隨機幾何圖和隨機扇圖上子圖機率之研究
研究成果報告(精簡版)

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中 文 摘 要 ： 無線電網路的重要性和普及性日益劇增，因此其相關的圖形理論，開始吸引著世界各地學者的目光，並且不斷地投入時間進行基礎的研究。例如，最近幾年來，一個全新的圖學模型：隨機幾何圖(random geometric graphs) 被學者先後提出來。隨機幾何圖及隨機扇圖上有一個共同的基本問題：計算子圖出現的機率。我們注意到，若能準確地估算子圖出現的機率，無線電網路的許多基本問題，將會有一個統一的且有效的量化分析平台。直到最近 Yu[41]第一個提出一個系統化的典範(方法)來精確計算隨機幾何圖上的子圖機率。可惜的是，Yu[41]所提的方法雖然可以計算出隨機幾何圖上的任意子圖機率。但是當該子圖的點集合(vertex set)變大(由其是遠大於 5 以上)時，他們的方法需要相當複雜且費時的計算，幾乎為一般人力無法達成。而當一般的網路問題牽涉的規模較大時，其所需要考慮到子圖的點集合也會變大。另外，當運用隨機幾何圖上的任意子圖機率來計算隨機幾何圖上的任意子圖出現的次數時，目前並不存在一個系統性的方法。本計劃的目的即是研究如何更有效率地精確計算(或估計)大型子圖的機率及次數。

中文關鍵詞： 隨機幾何圖, 子圖機率, 隨意網路

英 文 摘 要 ：

英文關鍵詞：

行政院國家科學委員會補助專題研究計畫 □ 成 果 報 告 □期中進度報告

隨機幾何圖和隨機扇圖上子圖機率之研究

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計畫主持人：俞征武
共同主持人：
計畫參與人員：陳逸寧、林臻義、黃信文、彭棟賢

成果報告類型(依經費核定清單規定繳交)：√精簡報告　□完整報告

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執行單位：中華大學資訊工程學系
中　華　民　國 2011 年 10 月 31 日

摘要

無線電網路的重要性和普及性日益劇增，因此其相關的圖形理論，開始吸引著世界各地學者的目光，並且不斷地投入時間進行基礎的研究。例如，最近幾年來，一個全新的圖學模型：隨機幾何圖(random geometric graphs) 被學者先後提出來。隨機幾何圖及隨機扇圖上有一個共同的基本問題：計算子圖出現的機率。我們注意到，若能準確地估算子圖出現的機率，無線電網路的許多基本問題，將會有一個統一的且有效的量化分析平台。直到最近 Yu[41]第一個提出一個系統化的典範(方法)來精確計算隨機幾何圖上的子圖機率。可惜的是，Yu[41]所提的方法雖然可以計算出隨機幾何圖上的任意子圖機率。但是當該子圖的點集合(vertex set)變大(由其是遠大於 5 以上)時，他們的方法需要相當複雜且費時的計算，幾乎爲一般人力無法達成。而當一般的網路問題牽涉的規模較大時，其所需要考慮到子圖的點集合也會變大。另外，當運用隨機幾何圖上的任意子圖機率來計算隨機幾何圖上的任意子圖出現的次數時，目前並不存在一個系統性的方法。本計劃的目的即是研究如何更有效率地精確計算(或估計)大型子圖的機率及次數。

關鍵字: 隨機幾何圖, 子圖機率, 隨意網路

1. 前言

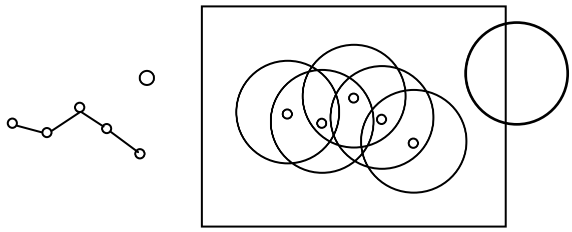
無線電網路的重要性和普及性日益劇增，因此其相關的圖形理論，開始吸引著世界各地學者的目光，並且不斷地投入時間進行基礎的研究。例如，最近幾年來，一個全新的圖學模型：***隨機幾何圖(random geometric graphs)***[22] 被學者先後提出來。隨機幾何圖有相當多的不同的定義，我們採用以下的定義[22]：

(1)有 n 個點(node) uniformly randomly 分佈於已知的幾何空間中。令 X_0, X_1, …, X_{n-1} 爲此 n 點{0, 1, 2, …, n-1}的座標，則皆可視爲獨立的隨機變數(independent random variable)。注意此幾何空間有相當多的可能性；有學者定義爲爲方形，矩形，圓形，一維線段，或高於二維，或無邊界，或一個封閉空間。

(2)一個隨機幾何圖 $G=(V, E)$，其中 V 是由上面 n 個點={0, 1, 2, …, n-1}所組成，而如果任 V 中的兩個點(node) i 和 j 的距離小於 r 則(i, j)之間存在一個 edge。也就是說如果 $d(X_i, X_j)\le r$ 則 $(i, j)\in E$，此處 d 函數代表兩個 node 之間的歐基里德距離(Euclidean distance)。

隨機幾何圖的應用相當廣，包含通訊網路(communication networks)、隨意網路(ad hoc networks)、感測網路(sensor networks)、分類技巧(classification)、空間統計(spatial statistics)、流行病學(epidemiology)、天文物理學(astrophysics)、和類神經網路(neural networks)等[22]。

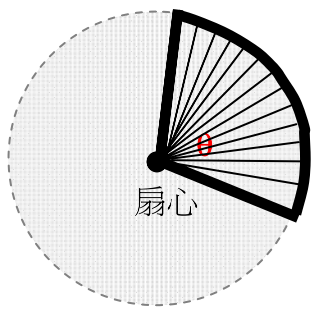
乍看之下，隨機幾何圖好像十分合適於表示所有無線電網路系統。例如將一個無線網路佈置在一個矩型的活動會場上，此會場可視爲出現在前面定義中的一個幾何上的空間。每個點視爲一個無線電收發器(transceiver)，而其收發功率範圍(power range)皆爲 *r*。任兩點有一條線(edge)代表此兩個收發器可相互直接通訊。整個會場一共有 *n* 個收發器隨機 uniformly 地分配於活動會場上。簡言之，此一個無線網路系統 N=(n, r, l, m)代表有 *n* 個傳輸半徑爲 *r* 的無線電收發器，此設備是獨立且 uniformly 分配在一個長爲 *l* 寬爲 *m* 的空間中。一個隨機幾何圖合適於代表一個無線電網路其隨機部署(如感測網路)或隨意移動(如隨意網路)的動態本質。在圖一中，左圖代表右邊無線網路系統的一個隨機幾何圖。



圖一、隨機幾何圖及其代表的無線網路系統。

隨機幾何圖的缺點是，在於它的定義並不能表示配備方向性天線的無線網路。一般用一個圓來代表一個無線電收發器(transceiver)時，是假設它配帶的是一個全方向性的天線(omni-directional antennas)，但是在實際應用時，有可能配帶的是一個方向性的天線(directional antennas)。當一個方向性的天線因爲其訊號的涵蓋範圍不是圓形時，隨機幾何圖便不適用於此類的網路。

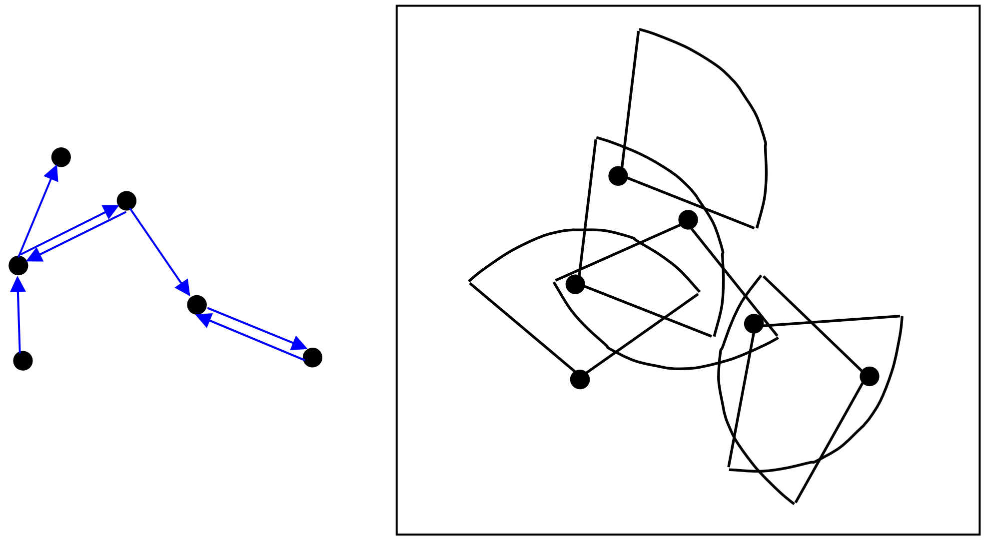
採用方向性的天線原因有很多，包含增強訊號及網路頻寬、降低電量的消耗、提升空間的使用率、減少co-channel干擾的情形、增加傳送的距離[42-44]。但是，爲了充分利用方向性天線的優點，必須重新設計合適的通訊協定，故許多使用方向性天線的MAC協定相繼被提出。攜帶方向性天線的無線感測網路[43]，期望比傳統的無線感測網路有更大的頻寬，更可以有效地傳送監控的環境影像。但是，同時方向性天線的無線感測網路，也影響了整體網路被覆蓋的狀況。因此，不同於隨機幾何圖的圖學理論也開始受到重視。如Josep Diaz [45]等人開始討論random scaled sector graphs上的chromatic numbers和clique numbers及和隨機幾何圖的關係。



圖二、一個角度θ的圓扇(circular sector)代表一個攜帶方向性天線的收發器。

爲彌補隨機幾何圖不易代表方向性天線收發器的缺點，我們定義一個新的圖，稱爲隨機扇圖(random circular sector graphs, 簡稱RSG)如下。

一個***隨機扇圖***$G=(V, E, A, \theta)$，其中V是由n個相同大小及相同角度θ的圓扇(circular sector)(圖二)隨機分佈(uniformly randomly)於已知的幾何空間A中。如果任一個V中的一個扇i(node)涵蓋到另一個扇j (node)的扇心，則(i, j)之間存在一個有方向的線(directed edge)，也就是說$[i, j]\in E$。從網路的功能來考量時，每個扇可代表一個攜帶方向性天線的收發器，扇心是收發器的位置而圓扇的區域就是其有效傳遞範圍。扇i涵蓋到另一個扇j的扇心，即是代表收發器i可直接傳訊息與收發器j。圖三是一個隨機扇圖的範例。



圖三、隨機扇圖及其代表的方向性天線無線網路系統。

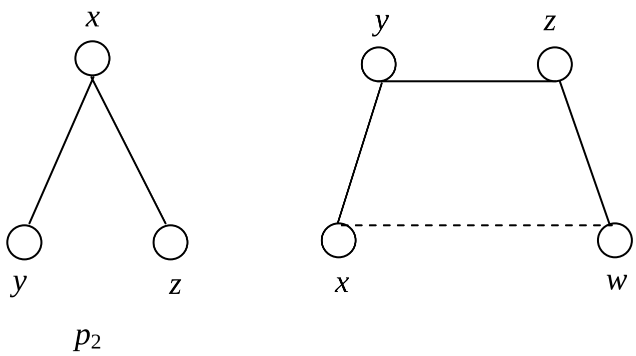
依以上的定義可知，<u>隨機扇圖是隨機幾何圖的一個很自然的擴充**(generalization)**</u>。也就是，隨機扇圖包含隨機幾何圖，而隨機幾何圖是隨機扇圖的一個特例(special case)(當角度θ=360 時，隨機扇圖將弱化成隨機幾何圖)。

<u>無線電網路上的基本問題，常可對應到某一個圖論問題</u>。例如，如果我們問當功率範圍(power range) r 需要調到多大以上，則隨機部署的無線網路是否完全連接？若用圖學的術語就是問：當 r 值多大之時，此隨機幾何圖是強連接的(strongly connected)的機率會極高。此問題稱為*隨機幾何圖的連接問題*[29]。此連接問題在無線網路(mobile ad hoc or sensor networks)上有相當多的應用，包含：省電機制設計(power saving)、網路佈置(deployment)、網路產值(throughput)之估算、及網路路由(routing)等問題[7, 10, 13, 14, 17, 24, 25, 26, 29]。

<u>隨機幾何圖及隨機扇圖上有一個共同的基本問題：計算子圖出現的機率</u>。我們注意到，若能準確地估算子圖出現的機率，無線電網路的許多基本問題，將會有一個統一的且有效的量化分析平台。例如，無線電網路 IEEE 802.11 CSMA/CA 通訊協定存在兩個有名的問題： 隱藏節點問題(the hidden terminal problem) [37-39]和暴露節點問題(the exposed terminal problem) [36]。這兩種問題都和子圖出現的次數有關。

隱藏節點問題的發生，是因為兩個節點不能感測對方的存在，而卻同時傳送給同一個接收器的問題。我們稱此兩節點為*隱藏節點配對*(a *hidden-terminal* *pair*)。隱藏節點配對的存在嚴重造成無線網路的資訊毀損(garbled messages)及通訊延遲(communication delay)，因而導致整個系統的效能(system performance)下降 [36-39]。暴露節點問題因為兩個節點可以相互感測對方，卻被不當禁止傳送給不同且不會相互干擾的接收節點[36]。暴露節點問題導致網路頻寬，受到不必要的限制。我們稱這些相關的節點為*暴露節點集合*(*the exposed-terminal set*)。

當我們利用一個圖 $G=(V, E)$代表一個無線網路時，<u>**隱藏節點配對和暴露節點集合都可以利用一個子圖(subgraph)來表示**</u>(圖四)。首先，一個隱藏節點配對可以利用一對 edges (x, y)和 (x, z)來表示。其中$(x, y)\in E$ 和$(x, z)\in E$，但是$(y, z)\notin E$。從圖論的名詞上可以說是此 induced subgraph 為一個長度為 2 的路徑(path)(圖四左圖)。相同地，一個暴露節點集合也可以用一個四個 vertices 的子圖來代表。其中$\{x, y, z, w\}\subseteq V$ 而$\{(x, y), (y, z), (z, w)\}\subseteq E$,但是$(x, z)\notin E$ 而且$(y, w)\notin E$(圖四右圖)。



圖四、隱藏節點配對 p_2 和暴露節點集合 H。

有少數學者發現：隱藏節點問題和暴露節點問題對無線網路效能的影響程度，和隱藏節點配對 p_2 和暴露節點集合 H 出現在網路上的次數有直接的關係[36, 37-39]。因此若我們可以準確地估算這些子圖出現的機率，將有助於正確評估無線網路效能及其它的基本性質。

可惜的是，大多前人對於估算隨機幾何圖上子圖出現次數的成果，都是非常粗略的估計值(asymptotic results)。如在[22]中第三章，Penrose 認為任意子圖 H其出現在隨機幾何圖上子圖出現次數滿足 Poisson limit theorem(當 $n^k r_n^{d(k-1)}$趨近一個常數時)和 normal limit theorem(當 $n^k r_n^{d(k-1)}$趨近無限大而 r_n 趨近 0 時，或當 r_n 是個常數時)。他們的粗略的估計值非常不精確，因此大大降低實際應用的時機及價值。較詳細的隨機幾何圖之相關研究，請參考[9-11, 29-32]。有關隨機扇圖上子圖出現次數的成果更是闕如，因此需要更多的研究及討論。

直到最近 Yu[41](其實此論文為我們最近的研究成果之一)第一個提出一個系統化的典範(方法)來精確計算隨機幾何圖上的子圖機率。以前學者所導出的公式或性質，總是需要假設網路的節點趨近無限大。相較之下，此篇論文不需要此假設，因此其所推導出的式子相當準確且實用性高。又因為此篇論文所提

的方法是一個系統化的法則(即非爲少數特定子圖設計)，故有相當廣泛的子圖，可利用此法精確地計算出其機率。再者，在此論文中，隨機幾何圖的子圖機率被證明是一個有效的工具，來計算縮減子圖(induced subgraph)的個數，進而被用於預測一個無線隨意網路上任意特定網路拓樸的出現機率，並可藉此進行無線隨意網路的量化分析。

可惜的是，Yu[41]所提的方法雖然可以計算出隨機幾何圖上的任意子圖機率。但是當該子圖的點集合(vertex set)變大(由其是遠大於 5 以上)時，他們的方法需要相當複雜且費時的計算，幾乎爲一般人力無法達成。而當一般的網路問題牽涉的規模較大時，其所需要考慮到子圖的點集合也會變大。另外，當運用隨機幾何圖上的任意子圖機率來計算隨機幾何圖上的任意子圖出現的次數時，目前並不存在一個系統性的方法。如何更有效率地精確計算(或估計)大型子圖的機率及次數將是一個有價值及挑戰的研究。

2. 研究目的

因本計劃只通過執行一年，故本計畫將專注於「計算或估計隨機幾何圖上任意大型子圖出現的機率及次數」。詳細目標爲：

1. 計算隨機幾何圖上任意大型子圖 $G=(V, E)$出現的機率，由其是當$|V|>5$時。
2. 當大型子圖出現的機率無法精準計算時，嘗試去逼近隨機幾何圖上任意大型子圖出現的機率。
3. 發展一個系統性的方法來利用子圖的機率來計算(或估計)隨機幾何圖上，任意大型(尤其是當$|V|>5$時)子圖 $G=(V, E)$出現的次數。
4. 應用隨機幾何圖上任意大型子圖 $G=(V, E)$出現的機率，來解決無線網路上量化分析問題。

總而言之，本計劃的價值爲：跨越圖論、機率、計算幾何、和演算法的範疇，來設計一個如何精確地估算隨機幾何圖的子圖出現的機率及次數的新方法。

3. 文獻探討

有關隨機幾何圖的相關研究成果羅列如下：

隨機幾何圖理論是一個正在起步中的學問。目前有一本 2003 年出版的專書，由 M.D. Penrose 所著作[22]。該書所討論的圖論問題包含：the longest nearest-neighbor link，the longest edge and total cost of the Euclidean Minimum Spanning Tree 等問題。其中 the longest edge of the Euclidean Minimum Spanning Tree 可用來解隨機幾何圖的連接問題，請參考該作者的相關著作[23]。

在 2003 年，Santi 和 Blough [29] 首先考慮一個在一維幾何上的隨機幾何圖(也就是 node 只分佈於一條直的線段上)何時會連結(connected)的問題。並討

論何時此隨機幾何圖，可以大部分地連結(例如 90%是連成一個 connected component)。他們的公式是當 $rn>=l \ln l$ 時，整個圖連接的機率極高。但當 $rn<=(1-\varepsilon)l \ln l$ 則此圖不易連接,此地的 ε 爲界於 1 到 0 的實數。他們也將此公式推廣於兩維和三維的問題上，只是這些公式都是假設 n 或 r 是無限大的(asymptoticlly)時推論而得；故當實際問題 n 或 r 是在一個普通大小的值時，他們的公式就值得檢驗是否仍然依舊正確可用。他們早期的研究也出現在此篇論文中[30]。

相當多文獻中，對隨機幾何圖的基本假設需要 node 分佈的狀況是 Poisson 分配，而不是先前定義的 Uniform 分配。因此分佈點的數目是一個隨機變數，只有其期望值可估計。並無法實際掌握正確的數目，有時並不符合實際的使用狀況。如在 2002 年，Bettstetter [1]利用 nearest neighbor method 考慮隨機幾何圖上的 minimum node degree，並將成果推廣到解 k-connectivity 的問題；因爲他利用 Penrose 在 1998 年發表的一個重要研究成果[23]：當隨機幾何圖成爲 k-connectivity 時此圖的 minimum node degree 也同時大於等於 k。注意此性質在隨機圖上也成立[2, 21]。在 2002 年，Dousse 等人 [7] 同樣在一維空間上分析連結問題，但也須假設 node 分佈是一種 Poisson 分配。在 1998 年，Gupta 和 Kumar 當傳輸半徑設定爲$((\log n+c(n))/n\pi^2)^{1/2}$ 時則整個網路連接的機率接近 1 若且爲若 $c(n)$趨近無限大[13]。在 1989 年，Philips 等人也討論 Poisson 分配下，當網路需連結時 node 需要的平均個數[24]。同樣的問題在一維空間上被 Piret 討論過[25]。

除了討論隨機幾何圖的連結問題外，其他相關的研究雖並未直接用隨機幾何圖來討論，但本質上卻息息相關，常藏身於無線電網路的相關論文中[14, 17, 18, 19, 33]。如網路容量(network capacity)[14]問題也吸引到一些目光。當每個收發器的功率半徑變大時，則每個收發器的鄰居變多，而到目的收發器的距離也變近了，導致訊息需較少的時間來傳輸。但是相對的，在 MAC 層上對相鄰點的干擾也增加了，因此也使得每個 hop 傳輸時間增長。如何取得一個平衡點，而得到整個系統的產值(throughput)爲最大是一個有趣的網路容量問題。在 1978 年, Kleinrock 等提出當 average degree 大約爲 6 時，整個網路的產值爲最大。因此他們稱 six 是一個神奇數字(a magic number) [17]。但 Philips[24]等認爲並無 magic number 的存在，他們也計算出 average degree 大約爲 2.195~10.525 之間時，整個網路的產值爲最大。Gupta 等也對此議題作深入的討論[14]。

4. 研究方法及成果

在了解前人對隨機幾何圖所作的研究成果之後，可有下列想法：

1. 隨機幾何圖基本性質的研究仍不足。隨機幾何圖並不是學術界早已熟知的*隨機圖*[2, 8, 9, 21] (*random graphs*)是眾所週知。但若干文獻所提到出的理由，有模糊不清之處[29]，不爲本計畫主持人所接受(請參考後文『Random graphs 及其不適用於無線網路的原因』該節所做的論述)。例如，隨機幾

何圖中的任兩個 edge 出現的事件是相同的(uniform distribution)嗎？是獨立(independent)出現的嗎？出現的機率有多大？文獻中的看法大多是否定的或闕如，但根據我們的實驗卻是指向另一個不同的答案。因此，我們認爲一些隨機幾何圖的基本性質並未被完整的討論過。
2. 隨機幾何圖雖不是隨機圖，但兩者之間的共通特性和不同處，値的深入探索。例如，兩圖都有門檻函數(threshold function)[21]的特質及兩圖都有 k-connectivity 和 minimum degree 爲 k 同時出現的特質[2, 23]。比較兩圖的差異及參考隨機圖現在已被發現的性質，有助於快速發現及證明隨機幾何圖的一些基本特性。
3. 先前的研究刻意忽視邊界效應的問題。一般學者在思考隨機幾何圖時，爲避免繁瑣的計算，都刻意不考慮邊界效應。但如此，將使得所有的估計不準確或落於不切實際的假設。
4. 如何運用隨機幾何圖於無線網路系統和應用上。無線電網路系統上的問題常常可視爲圖論問題，例如圖色問題(the coloring problem)[3]常可用於無線電網路資源的最佳分配上。是故如何將隨機幾何圖善加運用於無線網路上，値得學者深入研究。

在了解前人對隨機幾何圖及隨機扇圖所作的研究成果的缺失之後，我們可以有下列的研究方向：

1. 目前並無一套有效率簡單的方法，可用於精確估算隨機幾何圖上大型子圖出現機率或次數。
2. 隨機扇圖是隨機幾何圖的一個自然的擴充，可用來表示方向性天線的無線網路，但目前其基本性質的研究仍不足。
3. 隨機幾何圖及隨機扇圖雖不是隨機圖，但三者之間的共通特性和不同處，値得深入探索。
4. 先前隨機幾何圖及隨機扇圖的研究刻意忽視邊界效應的問題，因此並不符合實際的應用。
5. 如何運用隨機幾何圖及隨機扇圖子圖的機率及次數，於無線網路系統和應用上，目前人類所知有限。

若可對隨機幾何圖及隨機扇圖上一些特殊子圖出現的機率，作精準的估計。我們將有機會估計子圖出現的次數；進而有機會建立一個無線網路量化分析的理論。因爲此計劃只通過第一年且考慮篇幅的限制，本計劃一年的成果簡介如下:

1. 因爲同構的子圖(isomorphic subgraphs)會擁有相同的機率。我們的確可以利用 Polya’s counting technique 來處理有多少個子圖同構的問題。但是當圖的尺寸變大時，此技巧在 Yu [41]的整個計算過程中祇是其中的一個步驟。故要計算出或得到大子圖的逼近機率仍不容易。
2. 對於大型子圖最容易成功的方法，還是找到相近的 tree 或 Y-graphs [41]來逼近。雖然尋找增加或減少最少的 edge 使得改變後的圖爲 tree 或 Y-graphs 也不是容易的事，但是若是要找到一個尚可接受的(即改變增加或減少不多的 edge)圖爲 tree 或

Y-graphs 就容易多了。我們可利用 block-articulation graphs 的方式將一個輸入圖轉成一個樹(tree) (tree 中的點代表 bi-connected graphs)。因此我們的問題將注重估計一個 bi-connected graphs 的機率。方法一爲在此 bi-connected graphs 找一個代表性的 spanning tree 來估計此圖的機率。方法二爲在此 bi-connected graphs 找一個代表性的 cycle 來估計此圖的機率。方法三爲利用方法一及方法二的結果來選擇(如那一個需要最少改變)或推算此圖的機率。

3. 擴大 Yu[41]成功計算出或得到逼近機率的範例(如 C_4)，如利用相同的技巧計算大型子圖 C_k，當 k>4 時。但是當圖的尺寸變大時，此技巧要計算出或得到大子圖的逼近機率仍不容易。
4. 利用 algebra 的技巧協助快速地找到大型子圖上一個可計算(估計)的基底(basis)。

5. 討論

Ivan Stojmenovic 曾對此問題的建議，考慮不同的圖分解方法，也許有助於計算大型隨機幾何圖上，任意大型子圖 G=(V, E)出現的機率。也許 Ivan Stojmenovic 等人的論文可提供另一種思考方式。Furuzan Atay, Ivan Stojmenovic, Halim Yanikomeroglu, “Generating Random Graphs for the Simulation of Wireless Ad Hoc, Actuator, Sensor, and Internet Networks,” Pervasive and Mobile Computing (Elsevier), Volume 4, Issue 5, October 2008, Pages 597-615。但 Random Graphs 畢竟不是隨機幾何圖，故此法應不易成功。

此研究最有趣的後續，是隨機扇圖上一些特殊子圖出現的機率的估計並進而有機會建立一個無線網路量化分析的理論。

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行政院國家科學委員會補助國內專家學者出席國際學術會議報告

2010 年 12 月 31 日

附件三

報告人姓名	俞征武	服務機構及職稱	中華大學資工系 教授
會議 時間 地點	2010/12/20~22 杭州(大陸)	本會核定補助文號	NSC 99-2221-E-216-026
會議名稱	(中文)第六屆國際行動隨意感測網路會議 (英文) The Sixth International Conference on Mobile Ad-hoc and Sensor Networks (MSN'10)		
發表論文題目	CALE: A Context-aware Living Environment Based on Zigbee Sensor Network		

報告內容應包括下列各項：

一、參加會議經過

12/17 自桃園搭機直飛杭州，本系一行 10 人先前往蘇州訪問。於 12/20 回到 MSN 2010 大會會場。12/21 大會邀請 Sajal K. Das(Distinguished Scholar Professor of Computer Science and Engineering at the University of Texas at Arlington (UTA).)演講“Cyber-Physical and Networked Sensor Systems: Perspectives and Future Directions”。其中若干研究題目有其深度值得深思。中午與會學者一同用餐，值 Prof. Peng-Jun Wan (Illinois Institute of Technology, Xiangyang Li (Illinois Institute of Technology, Jie Li (University of Tsukuba), 及 Prof. Xing Wang (State university of New York, Stony Brook)及 Sajal K. Das。其中 Prof. Jie Li 我在相關會議見過約三次面(MASS 2009, MSN 2009), 十分活耀。Xiangyang Li 和我一同主辦過 WiNA 2009 及一個 IJAHUC 的 special issue。Prof. Peng-Jun Wan 我在 *IEEE Proceedings of International Conference on Wireless Algorithms, Systems and Applications* (WASA’07, 芝加哥)見過面, 當時他應為主辦單位,他同時也是交大易志瑋教授在 IIT 的指導老師。下午 PEWiN 會場進行順利,也邀請 Prof. Ouyang 擔任 session chair.值華北大學嚴新慶教授。我與他也是舊識, 曾在海南島一同出席會議,又在 MASS 2009 見一次面。他的 PEWiN 2010 論文同時也被推薦到 Special Issue on Recent Advance in Mobile Sensor Networks(Springer Telecommunication Systems)上發表。我們參加的是 MSN 的 workshop PEWiN 2010，故參與其中的兩個 session。PEWiN 2010 今年有 10 篇論文發表, 下一年將繼續與 MSN 合作, 移師到北京。大會晚宴於西湖畔舉行, MSN 也安排了印象西湖的表演,令人難忘。與 Sajal K. Das 作短暫交談, 也邀請他有機會到中華演講訪問。與 MSN 工作群杭州電子科技大學的教授戴國駿, 仇建, 馮云霞, 申興發, 劉鵬作一些交流後, 晚宴成功舉行。

12/22 下午前往機場，直飛桃園機場。此次杭州開會雖然短短三天，但是對台灣思念加深，真是人在他鄉念故鄉。

二、與會心得

有關 ad hoc and sensor networks 之研究目前得到全世界學者的重視, 中國的學者也慢慢迎頭趕上, 台灣的學者需要再加油了。

三、考察參觀活動(無是項活動者省略)

四、建議

應鼓勵國內學者團隊合作以在重要會議中主導一些議題.並從事頂尖的研究。

五、攜回資料名稱及內容

六、其他

2010 Sixth International Conference on Mobile Ad-hoc and Sensor Networks

CALE: A Context-aware Living Environment Based on Zigbee Sensor Network

Kun-Ming Yu[1], Jian-Yuan Liou[1], Bo-Han Yeh[2], Chang Wu Yu[1], Ching-Cheng Tien[3], Chih-Hu Wang[3], Ping-Yu Wang[3]

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***Abstract* — The paper employed some independently developed sensors based on the Octopus X platform to build a Zigbee-based Sensor Networks. Also, we implemented a Location-aware living environment by deploying the developed Zigee-based sensor. Besides, through the created window console interface, the sensed data can be transmitted and transformed to the database for further utilized. Moreover, by the devised Web interface, the update request data can be observed efficiently and responded effectively to any situations.**

Keywords-Context-Aware, Zigbee, Wireless Sensor Network

I. Introduction

The power of Information and Communication Technology (*ICT*) has been piercing through many things, breaking the limitation of space. In other words, nowadays, people exist a world of ICT around which has a hither and thither effective power abundantly. It is exact to say that, the relationship between human and technology is always been involved in living care and industrial development. By the high-speed development of wireless, embedded system, and multimedia technology, through various computer and sensor exist all over the environment. The application of ICT, the Context Aware ability[4], is evolving to ubiquitous. Actually, the generation of a Context-Aware living environment is gradually coming to life.

The major purpose of the paper is to materialize a Context-aware living environment, which is based on a Zigbee Sensor Networks to form a star network topology. The ZigBee devices can either be set up independently, or embedded in any 3C products. Moreover, every ZigBee devices can serve as a wireless router to relay packets don't need any other material cables [5]. In other words, if a facility has embedded ZigBee chip, it itself can be an exact sensor or perform a router function to form a Wireless Sensor Networks easily. Moreover, in a heterologous network, people can easily control and effectively manage any ZigBiee embedded devices by cell phone or notebook remotely as well.

∗This work is partially supported by the National Science Council NSC 98-2218-E-216 -003

Therefore, this paper practiced a Context-aware Living Environmental system (CALE), based on four different functions shown as below：

(i). a sensing function：Utilize the new created sensor to collect the environmental parameters, e.g., temperature, moisture, CO_2… etc.

(ii). a transmitting function：Utilize the Zigbee and wireless networks to transmit the sensed data back through router, coordinator to database.

(iii). a transforming function：Utilize a new created middle interface to transform the transmitted data packets to signals.

(iv). a monitoring function：Utilize the new created web interface to monitor the updated request data for further response.

This paper was organized as follows. Related work will describe in section 2. Section 3 illustrates the system architecture and modules of the proposed CALE. Experimental Results were given in section 4. Finally, the conclusion was given in section 5.

II. Related Work

Zigbee is a wireless technology of short distance, simple frame, low overheard and transmission rate, of which network frame has the Master/Slave attribute can bidirectional communicating to tens of meters as 10kbps to 250Kbps speed [1]. The best superiority of Zigbe is low cost and power consumption can apply to extensive ambits, based on Zigbee technology to perform Wireless Sensor Works supplying complete solution of power saving. For example, the perception and control system of the temperatures and moisture of a block, the lamp power saving system, the fuel gas auto record system and electric power saving relative applications. Nowadays, the Wireless Sensor Works technology of Zigbee is going over the world gradually, so the whole household living can be intelligent, for instance, digital appliance, lamplight, security and entrance guard, intelligent building are all the future platform of Zigbee. Beyond that, its main applications are the automatic controlling and sensor networks of family, business building and factory. In the future, it is convenient for consumers to control the entire operation of household automatic appliances, effectively to

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reach the control mechanism and saving the manpower, electric power of office block, promoting the reliability of the manufacture, the process control system and the control effectiveness of the factory. Moreover, owing to the low quantity transmission of ZigBee, by which can improve the elasticity of data transmissions and lower down the complicated of the product designs [2][3].

Helal et. al. [6] proposed a household's health care system, by the personal devices and the intelligent household communicational technology, the collected, analyzed, and computed data can effectively promote the observed efficiency, to help the patient. Beyond that, the referred feedback mechanism can timely report the patient behavior or device operation state. The mentioned framework by these scholars can be applied in remote healthy monitor environment. In next section, we will present our environmental feedback mechanism in CALE that are going to materialize the concept; the sensor transmitted back information will be employed by the users to adapt the environmental contexts for diverse comfortable condition.

III. Context-aware Living Environmental system

In this section, the framework of the Context-Aware Living Environmental system (CALE for short) are going to be addressed, of which a localization Zigbee wireless sensor network is set up to form the star topology. Because its low overhead ability a fairly long battery lifespan and a great deal of the facilities array can be maintained. In the real livelihood, from the block automation to the family medicine monitor, the applications of Zigbee are extensive. In the paper, a small Context-aware system is formed by the lab experimental wireless sensors.

The transmission scale of Zigbee can transmit through the multihop and more complex network to expend a more huge range; in the other hands, by the attribute of data transmission, owing to the application of IEEE802.15.4, Zigbee can offer many layer of diverse mechanism to ensure the reliabilities of data transmitting.

Even though each Zigbee topology has its own merit can be used in different topology, in this paper, the topology of Zigbee is star. In the star topology all others nodes can easily connect to the center nodes and the data collected and sent as well. This is quite a good compatibility to agree with any diverse intelligent environmental requirement. In this paper, two frameworks, hardware and software, are brought up. For the software, by its Web interface, people can observe the periodical update data easily. Beyond that, the every day, week or month average record can be produced for the judging criteria to the contingent use. Moreover, when the returned data are abnormal, the reactive mechanism will be started up. In the paper the Content-aware system is comprised of an independently developed hardware chip board and the Zigbee wireless sensor networks to practice the excellent concept of the environmental sensor function. The framework of CALE is shown as below.

(A) The hardware framework of CALE

The architecture of hardware framework in CALE is a Zigbee module ran on the Octopus X platform, shown in figure 1. There are two node members, Coordinator and Router, and installed in Octopus X-C board and Octopus X-A with sensors separately. When Zigbee network is operating, Router will keep update request to Sensor, by which the sensed data will be transmitted through Router to Coordinator and then transformed by the middle software in notebook or PC, through the wireless AP by internet back to the backend database.

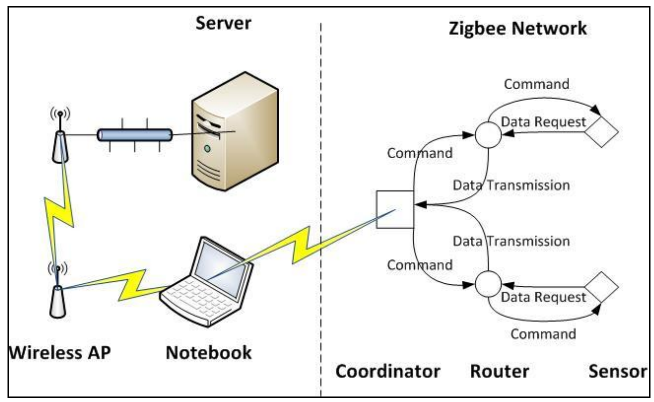

Figure 1. The hardware framework of CALE

(B) The software framework of CALE

Two sets of software are involved in the software framework, one is data interface for data analysis and transform written by Visual C#; the other is TI IAR Embedded Workbench works as compiler for the code to be executed in microprocessor. The software can be connected to hardware through USB debugger board, after burned into the 8051 microprocessor in Octopus X, the debug mode can be executed to set a break off point for checking the program mistake effectively. The structure of software framework is shown in Figure 2.

When the hardware started up, the software will command the 8051 microprocessor in Routers to initial and start to look for Coordinator; within the same wireless network. After then, the found Coordinator will join the wireless network as a member automatically, to complete the initialization procedure of the wireless network.

The delivery and reception mechanism between Coordinator and Routers is processed as follows. Coordinator command every Router within the wireless network has to request sensor to send back the sensed data to Router, and then packet as Zigbee format to send back Coordinator.

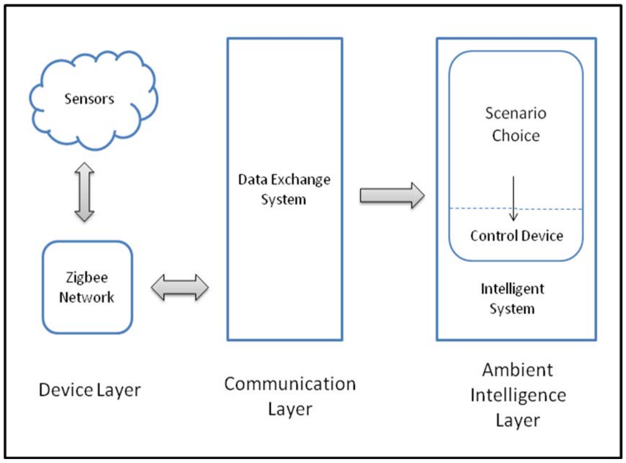

Figure 2. The software framework of CALE

There are three layers in the software framework. The first one is the devices layer, in which Zigbee network and sensors are binding to receive the sensed data from sensor. The second is the data transforming and transmitting layer, in which the middle interface for transforming the received data from Coordinator to Socket signals. The third is Ambient Intelligence layer. In the layer, the signals transmitting through Wi-Fi to the backend database and perform context-aware function. The functionality of the three layers will be described in detail as follows.

Device Layer：The layer is comprised of Zigbee network and sensors, by the command send form Router to the 8051 in Sensor board, the received data will be packed as Zigbee format, and then sent back to Coordinator.

Communication Layer：In the layer, data are transformed and transmitted, by the middle edited interface, which is written by C#. The transmitted data will be analyzed and transformed to Socket signals, and then transmitted back, through wireless, to the backend database.

Ambient Intelligence：This is an intelligent contexts layer, by which advanced contexts are going to be used. For now, the Web base interface is used to show all sensed data and three different modes: Theater mode, Conference mode, and Break_Time mode are implemented, and manifold models are going to be developed later. In the future, the appliances will be designed to have the Context-aware ability to match up the environment. For example, when the temperature of the entire room shown in the Web interface is too high, the system will turn on the air conditioner to lower the temperature. That is to say, all the sensed parameters will be used as the proactive decision references to conform to the contexts setting.

From the explanation above, we can see that CALE is practicable and implementable. Since, the data transmitting in the first Zigbee layer is simple and easy; the data transforming in the second Wireless layer is convenient; the data observing in third context layer is visualization and clarity. Therefore, the CALE is useful and proactive development for the human living.

IV. Experimental Results

In the hardware framework of CALE, a Zigbee module ran on the Octopus X platform, by which two hardware components and two assist devices are used. The Octopus X-A is set up in sensor to serve as Router; for Octopus X-C is set up as Coordinator to form the wireless center. The debugger board is tied in the compiled IAR hex files by the flash memory which is burnt into node. For USB Dongle, the Octopus nodes can be installed for testing the connection with Coordinator.

Each of the basic hardware components has a CC2430 chip, in which the 8051 microcontroller is installed, and its maximum program size is 128K Bytes, data size is 8K Bytes.

For the sensor, is independently developed two integrated Sensor Boards, one is LUX Sensor embedded with the thermometer and hygrometer, shown as Figure 3. The other is CO_2 Sensor embedded with the thermometer and hygrometer, shown as Figure 4. Both of them have a switch key can show the exact parameters of the real time temperature or moisture (Figure 5).

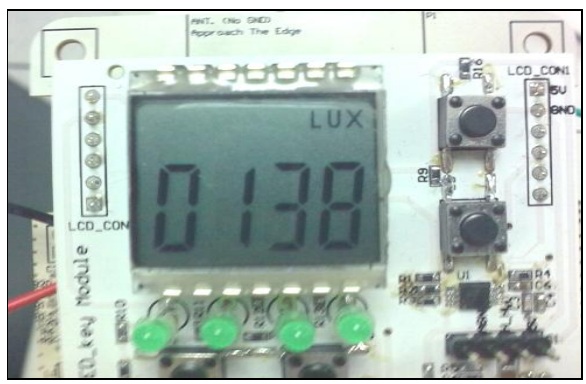

Figure 3. The LUX sensor

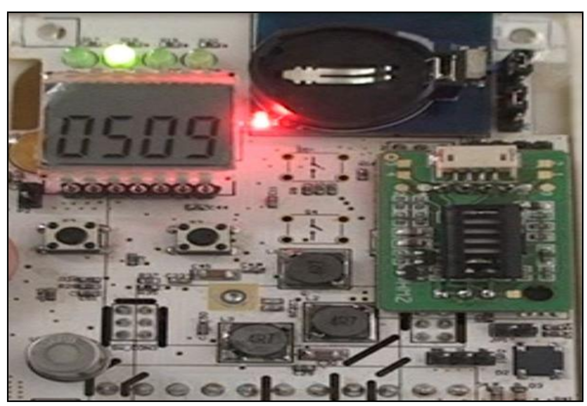

Figure 4. The CO_2 sensor

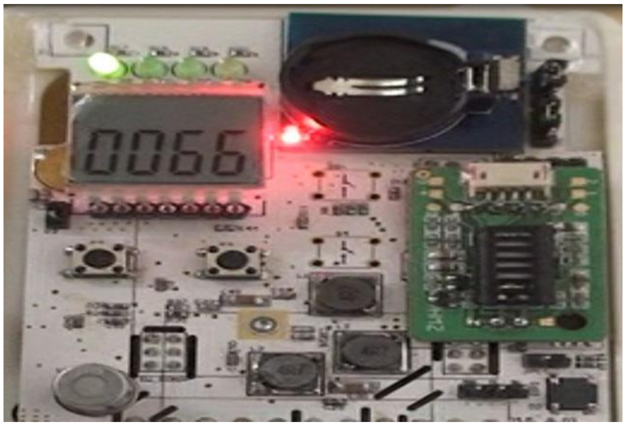

Figure 5. The moisture sensor

The experiment is conducted in indoor environment, a meeting room with sensors is implemented. The environmental Web interface is shown as Figure 6, in which 8 sensors are set up, different sensor parameters will be shown in one of them are updated in 5 seconds periodically.

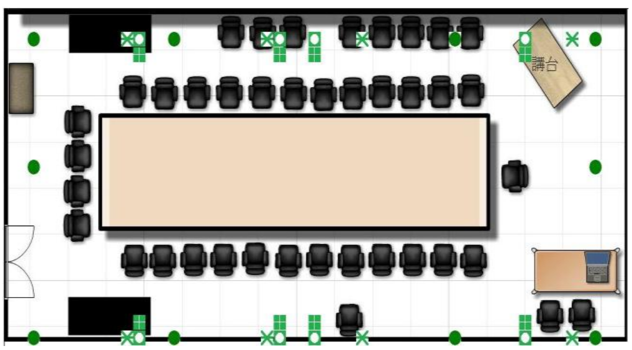

Figure 6. The web interface of the experimental environment

In the experiment, Visual C# was used to develop the middle interface software. First, before sensors powered on, the compiled IAR codes had to be burnt into nodes, after then, Router node would be installed to the sensor board and powered on. Second, the other node would be installed in notebook or PC to serve as the Zigbee wireless network center Coordinator. When the Zigbee network started, the software and hardware would co-work to sense the environmental conditions. After that the data would be transmitted and transformed, and all the update request data would be kept in the backend database finally. In the meantime, the Coordinator could be installed on a PC or notebook, or worked on an independent board, by which a port number would be chosen to perform receiving packets process. And the middle software would transform the received data to socket signals, sent them back to the database.

V. Conclusion

In this paper, a Context-Aware Living Environmental system (CALE) was designed and implemented, based on Zigbee technology companied with the independently developed hardware and software. The installed sensors could detect and transmit back the sensed data, through the Zigbee wireless network to the center node, by the middle transforming process. Moreover, all the timely parameters of those data could be exactly shown on the client interface in order to be reacted correctly and effectively. In this phase, we have materialized the basic function of CALE system, yet there are some problems needed to be resolved. For example, the collision would happen when Router sent back data to Coordinator. In the future, a better algorithm or data collection method will be involved to resolve the collision issue.

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國科會補助計畫衍生研發成果推廣資料表

日期:2011/11/06

國科會補助計畫	計畫名稱: 隨機幾何圖和隨機扇圖上子圖機率之研究	
	計畫主持人: 俞征武	
	計畫編號: 99-2221-E-216-026-	學門領域: 計算機理論與演算法

無研發成果推廣資料

99 年度專題研究計畫研究成果彙整表

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其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等,請以文字敘述填列。)	1. Editor, Ad Hoc & Sensor Wireless Networks, an International Journal (AHSWN) www.oldcitypublishing.com/AHSWN/AHSWN.html (2010~). (SCIE, 2009 IF=0.309) 2. Editor, ICTACT Journal of Communication Technology (2011~). 3. Editor, ISRN Sensor Networks (2011~). 4. Editor, International Journal on Cloud Computing: Services and Architecture (IJCCSA) (2011~). 5. Editor, Journal of Information Technology and Applications (JITA) (2010~). 本人為 WiNA,PEWiN, 的創始人: WiNA series: 1. The Third International Workshop on Wireless Network Algorithm and Theory (WiNA 2010) (Hong Kong, China, December 11~13 2010, Co-located with 8th IEEE/IFIP International Conference on Embedded and Ubiquitous Computing (IEEE/IFIP EUC 2010)). 2. The Second International Workshop on Wireless Network Algorithm and Theory (WiNA 2009) (Macau, China, 12 October 2009, co-located with The Sixth IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MASS 2009)). 3. The First International Workshop on Wireless Network Algorithms (WiNA 2008) (Yilan, Taiwan, 9 December 2008, co-located with IEEE Asia-Pacific Services Computing Conference (IEEE APSCC 2008)). PEWiN series: 1. The Third International Workshop on Performance Evaluation of Wireless Networks (PEWiN-2011)(Beijing, China, December 16-18, collocated with the 7th International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2011)). 2. The Second International Workshop on Performance Evaluation of Wireless Networks (PEWiN-2010)(Hangzhou, China, 20-22 December 2010, collocated with the Sixth International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2010)). 3. The First International Workshop on Performance Evaluation of Wireless Networks (PEWiN-2009)(WuYi Mountain, China, 14-16 December

	2009, collocated with the 5th International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2009)).

	成果項目	量化	名稱或內容性質簡述
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	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

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　　□其他原因

說明：

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