出國報告（出國類別：國際會議）

參加 2016 年 IEEE 第 84 屆車輛技術研討會(VTC2016-Fall)會議報告

服務機關：國防大學理工學院電機電子系

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摘　　要

2016 年 IEEE 第 84 屆車輛技術研討會(2016 IEEE 84th Vehicular Technology Conference: VTC2016-Fall)，於西元 2016 年 9 月 18 日至 21 日在加拿大蒙特婁的蒙特利爾酒店(the Hotel Montreal Bonaventure, in Montréal, Canada)舉行。本人於此研討會計有投稿會議論文乙篇，論文題目為「高效節能超密集小細胞之大數據自我組織網路」，因榮獲刊登，依大會議程，將於 9 月 19 日下午場次以口頭報告發表研究成果，故於 9 月 16 日搭機前往與會。

車輛技術研討會(Vehicular Technology Conference: VTC)是由電子電機工程協會(IEEE)的車輛技術協會(Vehicular Technology Society: VTS)所主辦的會議，此會議在全球無線通訊領域中是一個重要的會議。會議的目的在探討當今最新之無線通訊技術，促進全世界之學術交流並提供國際間合作的機會。該會議半年舉辦乙次，會議以專題演講(plenary)、專家講習(specialist tutorials)、關鍵演說(keynotes)、技術與應用論壇(technical and application sessions)方式舉行，同時邀請全球學界、政府、業界及相關單位針對無線通訊、行動通訊及車輛通訊來共同參與討論並交換意見與想法。

本人有幸能參加此研討會，除了藉由聽講與發表，可以讓自己的研究領域與世界接軌，同時又可以透過與各國學者的討論，彼此交換研究上的心得，了解自己研究上的優點與不足，相信這趟旅程一定能增加自己在學術方面的見聞以及拓展自己的國際視野。最後感謝科技部補助方得出席今年的 VTC2016-Fall 學術研討會。

目　　次

參加 2016 年 IEEE 第 84 屆車輛技術研討會(VTC2016-Fall)會議報告

一、目的：

2016 年 IEEE 第 84 屆車輛技術研討會(2016 IEEE 84th Vehicular Technology Conference: VTC2016-Fall)，於西元 2016 年 9 月 18 日至 21 日在加拿大蒙特婁的蒙特利爾酒店(the Hotel Montreal Bonaventure, in Montréal, Canada)舉行。車輛技術研討會(Vehicular Technology Conference: VTC)是由電子電機工程協會(IEEE)的車輛技術協會(Vehicular Technology Society: VTS)所主辦的會議，該會議半年舉辦乙次，會議以專題演講(plenary)、專家講習(specialist tutorials)、關鍵演說(keynotes)、技術與應用論壇(technical and application sessions)方式舉行，同時邀請全球學界、政府、業界及相關單位針對無線通訊、行動通訊及車輛通訊來共同參與討論並交換意見與想法。圖一為該會議的官方網頁。

本人於此研討會計有投稿會議論文乙篇，論文題目為「高效節能超密集小細胞之大數據自我組織網路」，因榮獲刊登，依大會議程，將於 9 月 19 日下午場次以口頭報告發表研究成果，故於 9 月 16 日搭機前往與會。本人有幸能參加此研討會，除了藉由聽講與發表，可以讓自己的研究領域與世界接軌，同時又可以透過與各國學者的討論，了解自己研究上的優點與不足，相信這趟旅程一定能增加自己在學術方面的見聞以及拓展自己的國際視野。

圖一：VTC2016-Fall 官方網站，網址：http://www.ieeevtc.org/vtc2016fall/index.php

二、過程：

第 84 屆 IEEE 車輛技術研討會(VTC2016-Fall)於 9 月 18 日至 21 日舉行，研討會的會場就辦在加拿大蒙特婁(Montréal, Canada)的蒙特利爾酒店(the Hotel Montreal Bonaventure)，如圖二。

圖二：VTC2016-Fall 研討會在加拿大蒙特婁(Montréal, Canada)的蒙特利爾酒店(the Hotel Montreal Bonaventure)內舉辦。

研討會的第 1 天主要都是專家講習(tutorials)及專題討論會(workshops)，相關議程如圖三。本人在報到後，參加了兩場專家講習(tutorials)，主題分別是早上場次的「T5: Enabling Technologies for Next Generation Mobile Communications」及下午場次的「T10: Vehicular Networks – The Story Today and Tomorrow」。

		LaSalle (A)	Loungueuil (B)	Fontaine C (C)	Fontaine D (D)	Fontaine E (E)	Fontaine F (F)	Fontaine G (G)	Fontaine H (H)	Fundy (I)	Fontaine A & B (P)	Salon Bonaventure et Terrace (Industry Track)
SUNDAY 18 September												
7:30-17:30		Registration (Inscription)										
8:30-17:00		Tutorials and Workshops (SEE SEPARATE PROGRAM)										
18:00-20:00		Welcome Reception (Salon Bonaventure)										
MONDAY 19 September												
7:30-17:30		Registration (Inscription)										
8:30-9:30		Welcome: Pierre Boucher and Fabrice Labeau, General Co-chairs, François Gagnon and Weihua Zhuang, TPC Chairs, Javier Gozalvez, VTS President (Ballroom Outremont-Westmount-Mount Royal-Hampstead-Cote St-Luc)										
9:30-10:30		Keynote: **5G Physical Layer: Technology Opportunities and Challenges**, Reinaldo. A. Valenzuela Director, Communications Theory Research Dept. Bell Labs, Alcatel-Lucent										
10:30-11:00		Refreshments (Fontaine B)										
11:00-12:30	(1)	5G I	D2D I	TV White Space	Multiuser Detection	Vehicular Communications	OFDM	Resource Allocation I	MIMO I	WWRF Workshop: the Internet of Everything (Verdun)	Signal Transmission and Reception Posters I	Customer, Service and Network Design in 5G
12:30-14:00		Lunch (Ballroom: Outremont-Westmount-Mount Royal-Hampstead-Cote St-Luc)										
14:00-15:30	(2)	Small Cells	Cognitive Radio Networks	RF Systems and Design	Vehicular Networks - MAC	Radio Access	Optical and Visible Light Communication	Massive MIMO I	**MathWorks Workshop: Wireless Design with MATLAB**	WWRF Workshop: the Internet of Everything (Verdun)	Signal Transmission and Reception Posters II	5G Architecture: to Implementation
15:30-16:00		Refreshments & Exhibits (Fontaine B)										
16:00-17:30	(3)	Cooperative Communication I	Energy Harvesting and Efficiency	Blind Sensing	Green Wireless Networking I	Vehicular Networks - Network Layer	Heterogeneous Networks I	Modulation	Full-Duplex Communication	WWRF Workshop: the Internet of Everything (Verdun)	Signal Transmission and Reception Posters III	LTE Advanced Pro
18:00-21:30		VTC2016-Fall Banquet, Windsor Hotel										
TUESDAY 20 September												
7:30-17:30		Registration (Inscription)										
9:00-9:45		Keynote: **Channels and systems for wireless communications in high-mobility environments**, Andy Molisch, USC (Ballroom Outremont-Westmount-Mount Royal-Hampstead-Cote St-Luc)										
9:45-10:30		Keynote: **Networked Society and 5G**, Jaco du Plooy, Ericsson (Ballroom Outremont-Westmount-Mount Royal-Hampstead-Cote St-Luc)										
10:30-11:00		Refreshments & Exhibits (Fontaine B)										
11:00-12:30	(4)	Millimeter Wave Communication	LTE I	Positioning and Tracking I	Spectrum Sensing I	Network Security	SDN	Network Performance Evaluation	Wireless Power Transfer	Coding	Vehicular Networks Posters	Future Connected Vehicles: 5G vs. DSRC V2X
12:30-14:00		Awards Luncheon (Ballroom: Outremont-Westmount-Mount Royal-Hampstead-Cote St-Luc)										
14:00-15:30	(5)	Channel characterization	5G II	Spectrum Management I	Cooperative communication II	Positioning and Tracking II	Beamforming I	Non-orthogonal Multiple Access	Resource Allocation II		Wireless Networks Posters I	5G Broadcast Convergence / 5G for Vehicle IoT
15:30-16:00		Refreshments & Exhibits (Fontaine B)										
16:00-17:30	(6)	Multiuser MIMO	D2D II	Transmission Performance Analysis	Green Wireless Networking II	Vehicular Networks - Positioning	Content Distribution	Diversity	Routing		Wireless Networks Posters II	Mission-Critical 5G for Vehicle IoT
17:30-19:30		Young Professionals Publication Seminar (Ballroom Outremont-Westmount-Mount Royal-Hampstead-Cote St-Luc). Registration required - see https://meetings.vtools.ieee.org/m/41031										
18:00-20:00		Exclusive Reception for VTS Members										
WEDNESDAY 21 September												
7:30-17:30		Registration (Inscription)										
9:00-9:45		Keynote: **Sustainable Spectrum Management for Vehicular Technology**, Jean-Luc Berube, CRC (Ballroom Outremont-Westmount-Mount Royal-Hampstead-Cote St-Luc)										
9:45-10:30		Panel: **Where is 5G Leading Us?** Moderator: Charles Despins; Panelists: Håkan Andersson, Ericsson; Peiying Zhu, Huawei										
10:30-11:00		Refreshments & Exhibits (Fontaine B)										
11:00-12:30	(7)	Full Duplex Systems	Channel modeling	Spectrum Sensing II	Energy Efficient Transmission	Cloud and Smart Grid	Vehicular Networks - Protocols	Vehicular Electronics and Machines	Cellular Networks	Positioning in Transportation	Multiple Antenna Systems & Cooperative Comms Posters	IoT/M2M integration & design in 5G: Service, Technology & Customers
12:30-14:00		Lunch (Ballroom: Outremont-Westmount-Mount Royal-Hampstead-Cote St-Luc)										
14:00-15:30	(8)	Massive MIMO II	Beamforming II	Spectrum Management II	Heterogeneous Networks II	M2M	LTE II	Vehicle Sensing and Perception	Resource Allocation III	Localization in Ad Hoc Networks	Radio Access Posters	Urban Mobility and Smart Cities
15:30-16:00		Refreshments (Fontaine B)										
16:00-17:30	(9)	5G III	Cooperative Communication III	Wideband Sensing	MIMO II	3D and Spatial Channel Modeling	Physical Layer Security	Vehicle Control for Traffic Safety	Vehicular Networks - Applications	Indoor Localization and Tracking		Unmanned Aerial Vehicles

圖三：VTC2016-Fall 研討會議程。

本人聆聽的第 1 場專家講習(tutorials)的講者是來自英國南安普敦大學(University of Southampton, UK)的 Lajos Hanzo 教授，題目為「Enabling Technologies for Next Generation Mobile Communications」。

Lajos Hanzo 教授提到，近幾年因應各種智慧終端的出現，例如智慧手機、平板電腦等等，使得行動數據流量大幅成長，需要發展新的技術來提升網路的系統容量，例如多載波通信(multicarrier communications)，合作式中繼(cooperative relaying)，全雙工無線電(full-duplex radios)和裝置間通訊網路(device-to-device communication networks)等等，使得行動用戶可以享有令人滿意的服務。因此，Lajos Hanzo 教授針對多載波收發機(multi-carrier transceivers)、空間調變(spatial modulation)、合作式中繼(cooperative relaying)、非同調解(non-coherent solutions)、全雙工通信(full-duplex communications)及非正交多重接取(non-orthogonal multiple access)等技術，提供基本概念以及應用發展。

本人聆聽的第 2 場專家講習(tutorials)的講者是來自英國華威大學(University of Warwick, UK)的 Harita Joshi 博士，題目為「Vehicular Networks – The Story Today and Tomorrow」。

Harita Joshi 博士認為現代汽車需要倚賴高速可靠的車聯網路(vehicular networks)來提供高性能的服務，例如先進駕駛輔助系統(Advanced Driver Assist Systems, ADAS)需要獨特的車輛通訊系統(automotive communication system)來提供品質良好的服務。Harita Joshi 博士還提到未來的車聯網路包含了無線通訊以及無線光通訊等技術之應用。

9 月 19 日至 21 日是會議的第 2 天到第 4 天，主要是以論壇(sessions)的方式進行學術發表及交流，相關議程如圖三。

會議的第 2 天，本人聆聽了下列三場論壇，分別是“D2D I”、“Small Cells”以及“Heterogeneous Networks I”。

關於“D2D I”的討論，包含了下列文章：

1. Energy-Efficient Power Control for Device-to-Device Communications with Max-Min Fairness
2. Exploiting Geographical Context in D2D Communications
3. Joint Resource Block Reuse and Power Control for Multi-Sharing Device-to-Device Communication
4. Auction based Energy-Efficient Resource Allocation and Power Control for Device-to-Device underlay communication
5. Bio-Inspired Resource Allocation for Relay-Aided Device-to-Device Communications

該場論壇主要是針對裝置間(device-to device, D2D)通訊網路的架構下，探討無線資源分配與管理對系統效能的效益。特別是第三篇文章，題目為“Joint Resource Block Reuse and Power Control for Multi-Sharing Device-to-Device Communication”，讓本人覺得很有創意。該篇文章認為下一代行動網路必須要能同時連線許多的裝置，且達到較高的系統頻譜效率及較低的功率消耗，因此提出多對裝置間通訊可以彼此共享無線資源，同時發展一套名為 MISS(maximum independent set based and Stackelberg game based)的演算法，可以同時考慮分享的資源塊與傳輸功率的控制。

關於“Small Cells”的討論，包含了下列文章：

1. Small Cells Deployment for Cost Reduction of Hybrid-Energy Cellular Networks
2. Initial Cell Search Method Based on Two-Step Frequency Offset Estimation for Small Cells in Heterogeneous Networks
3. Bi-SON: Big-Data Self Organizing Network for Energy Efficient Ultra-Dense Small Cells
4. Effects of Hyper-Dense Small-Cell Network Deployments on a Realistic Urban Environment
5. Partial Critical Path Based Greedy Offloading in Small Cell Cloud

該場論壇主要是在異質性小細胞(small cell)網路的架構下，探討無線資源分配與管理對系統效能的效益。本人投稿的文章因榮獲刊登，並以口頭方式發表，依大會議程，發表時間排在本場次論壇的第三次序。本人所發表的論文英文題目為“Bi-SON: Big-Data Self Organizing Network for Energy Efficient Ultra-Dense Small Cells”，論文中文題目為「高

效節能超密集小細胞之大數據自我組織網路」，在本論文中，我們提出了一個大數據的自組織網路（Bi-SON）架構，目標在優化超密集小細胞網路的能量效率。佈建小細胞雖然可以增強蜂巢式行動網路的整體容量，但是超密集的小細胞會造成嚴重的干擾以致系統的能量效率變差。小細胞密集部署使得鄰近小細胞之間距離過短，進而造成小細胞之間的嚴重干擾；另一方面，大量的小細胞同時運作時，將造成大量能量消耗，使得運營支出提高。在超密集小細胞所覆蓋的廣大面積中，由於使用者的移動性和非均勻分佈，使得部分小細胞可能出現僅服務少數使用者或者未服務任何使用者的現象，而造成資源浪費。由於在 3GPP 的規範中，現行的 SON 技術對於網路規劃，提供了自我配置、自我優化和自我修復的功能，以達減少人工干預目的，然而，目前的 SON 機制主要是針對室內毫微微小細胞(或稱家庭基站)做設計。本論文所提出的 Bi-SON 架構，是藉由數據的收集、分析，決策出優化參數，並執行網路參數重新配置，其中我們採用了統計分析的方法來決策出最佳的系統參數，以改善大量室外小細胞的能量效率。該 Bi-SON 架構將定期收集所有小細胞的管理數據，例如發射功率、基準信號接收功率及每個小細胞所服務的使用者數量等等。本論文對於所收集的大量資料進行簡單的排序和過濾分析，已有效地找出近最佳化的解決方案。在佈建 120 個小細胞的情境下，以未具任何節能機制做為比較基準，模擬結果顯示，本論文所提出的 Bi-SON 機制在整體系統的傳輸量及能量效率方面各別提升 70%和 160%。

關於“Heterogeneous Networks I”的討論，包含了下列文章：

1. Cluster-based Joint Cell Association and Interference Coordination Control in Heterogeneous Networks
2. Impact of Dynamic Planning on Uplink Service Quality in Heterogeneous Cellular Networks
3. Energy Efficient Resource Allocation in 5G Hybrid Heterogeneous Networks: A Game Theoretic Approach
4. Joint Queue-Aware and Channel-Aware for A Novel Operation of Hybrid FSO/RF Systems
5. On the Design of Irregular HetNets with Flow-Level Traffic Dynamics

該場論壇的主題是異質性網路(Heterogeneous Networks)，主要是在探討異質性的網路架構下，利用不同的技術來強化網路的效能。特別是第三篇文章，題目為“Energy Efficient Resource Allocation in 5G Hybrid Heterogeneous Networks: A Game Theoretic Approach”，作者提到毫米波(mmWave)技術在異質性網路已經成為一個新的可用波段，可以提高數據傳輸率和增加可用的頻譜，因此該篇文章考慮在有毫微微細胞(femtocell)與巨細胞(macrocell)的異質性網路架構下，制定一個兩階層式的賽局理論架構使網路資源最佳化，進而改善能量效率，讓本人覺得很有創意。

會議的第 3 天，本人聆聽了下列三場論壇，分別是“SDN”、“Resource Allocation II”以及“Green Wireless Networking II”。

關於“SDN”的討論，包含了下列文章：

1. SDN Enabled High Performance Multicast in Vehicular Networks

2. SDN Enabled Dual Cluster Head Selection and Adaptive Clustering in 5G-VANET
3. Bandwidth Provisioning in Cache-enabled Software-defined Mobile Networks: A Robust Optimization Approach
4. Network Virtualization Optimization in Software Defined Vehicular Ad-Hoc Networks
5. A Proposal For Hybrid SDN C-RAN Architectures for Enhancing Control Signaling Under Mobility

該場論壇的主題是軟體定義網路(Software Defined Networking, SDN)，主要是在探討如何利用軟體定義網路的技術來改善網路系統的效能。例如第三篇文章，題目為“Bandwidth Provisioning in Cache-enabled Software-defined Mobile Networks: A Robust Optimization Approach”，該篇文章結合軟體定義行動網路，提出了一個流量控制問題來支持頻帶配置，同時提供最佳的轉發策略和資源分配，讓本人覺得相當有趣。

關於“Resource Allocation II”的討論，包含了下列文章：
1. Dynamic Inter-Channel Resource Allocation for Massive M2M Control Signaling Storm Mitigation
2. Resource Allocation and Massive Access Control using Relay Assisted Machine-Type Communication in LTE Networks
3. User Selection and Power Allocation Schemes for Downlink NOMA Systems with Imperfect CSI
4. Utility Based Resource Management in D2DNetworks using Mesh Adaptive Direct Search Method
5. Opportunistic forwarding using rate-less codes in OFDMA multi-hop networks

該場論壇的主題在探討如何利用無線資源管理技術來改善無線網路的效能，包含系統涵蓋率、數據傳輸率、頻譜效率及能量效益等等。特別是在基於 LTE 蜂巢式網路的機器型態通信(Machine-Type Communication , MTC)架構下，資源管理成為一個非常具有挑戰性的問題，因為所有 MTC 裝置與 LTE 用戶必須競爭相同的無線資源，當大量的 MTC 裝置與 LTE 用戶同時傳送連線要求時，會產生許多的上行鏈路(uplink)流量請求及訊號，導致上行鏈路傳輸發生擁塞。例如第二篇文章，題目為“Resource Allocation and Massive Access Control using Relay Assisted Machine-Type Communication in LTE Networks”，作者考量 LTE 用戶、MTC 裝置及中繼節點(relay node)共存的 LTE 網路的資源分配管理，提出一個分析模型，透過檢測基地台的過載情況來評估 MTC 裝置的可用資源，並設計一個中繼節點輔助的資源管理方案，來改善系統容量。該篇文章的創意及想法，讓本人覺得相當有趣。

關於“Green Wireless Networking II”的討論，包含了下列文章：
1. Green Cellular Demand Control with User-in-the-loop Enabled by Smart Data Pricing using an Effective Quantum (eBit) Tariff
2. BaLAnce: Battery Lifetime-Aware LTE Switching-Off Strategy in Green Network

Infrastructures
3. Energy-efficient Access Scheme with Joint Consideration on Backhauling in UDN
4. An Energy-Saving Algorithm Based on Base Station Sleeping in Multi-hop D2D Communication
5. Regular and Static Sector-Based Cell Switch-Off Patterns

該場論壇的主題是綠能無線網路(Green Wireless Networking)，主要是針對無線網路，探討各種技術如何改善網路的能量效益。例如第三篇文章，題目為“Energy-efficient Access Scheme with Joint Consideration on Backhauling in UDN”，作者針對超密集網路(ultra-dense network, UDN)，考量回載(backhaul)容量的能量效率，提出一個接取(access)評估模式，來彈性地調整各種裝置用戶進入接取點(access point, AP)，減少鏈結的延遲及功率消耗，以改善能量效率。

會議的第 4 天，本人聆聽了下列三場論壇，分別是“Full Duplex Systems”、“Resource Allocation III”以及“5G III”。

關於“Full Duplex Systems”的討論，包含了下列文章：
1. Scheduling and transmission point selection methods for space division full duplex systems
2. Full Duplex Medium Access Control Protocol for Asymmetric Traffic
3. Asynchronous Full-Duplex Cognitive Radio
4. Sum-Power Minimization Under Rate Constraints in Full-Duplex MIMO Systems
5. Dynamic Resource Allocation for Full-Duplex OFDMA Wireless Cellular Networks

該場論壇的主題是全雙工系統(Full Duplex Systems)，主要是探討全雙工技術如何改善網路的各種效益。例如第五篇文章，題目為“Dynamic Resource Allocation for Full-Duplex OFDMA Wireless Cellular Networks”，作者在全雙工正交分頻多工接取(OFDMA)無線蜂巢式網路的架構下，探討動態資源分配如何改善系統的數據傳輸率。這篇文章提出一個迭代的演算法，可同時分配所有用戶的子載波以及功率，使系統的數據傳輸率最佳。

關於“Resource Allocation III”的討論，包含了下列文章：
1. A SMDP Based Virtual Resource Allocation Model for Multimedia Services in 5G Network
2. Load-based Resource Allocation and Interference Coordination for Multi-carrier Dense Networks
3. Cost-Efficient Codebook Assignment and Power Allocation for Energy Efficiency Maximization in SCMA Networks
4. Online Power Allocation for Opportunistic Radio Access in Dynamic OFDM Networks
5. Scheduling Energy Harvesting Roadside Units in Vehicular Ad hoc Networks

在該場論壇中，本人注意到第四篇文章，題目為“Online Power Allocation for Opportunistic Radio Access in Dynamic OFDM Networks”，作者認為用戶移動性已成為未來

無線網路中資源分配最佳化策略設計的關鍵屬性，特別是在感知無線電(cognitive radio)系統，網路必須透過資源管理來避免主要用戶(primary users, PUs)受到有害的干擾以保證主要用戶的服務品質，因此需要某種安全管理機制，來管理次要用戶(secondary users, SUs)移動性，並減少對主要用戶的干擾。因此作者在感知無線電系統架構下，提出一種分散式學習演算法(distributed learning algorithm)，讓次要用戶根據無線通道狀況快速地調整發射功率，以減少對主要用戶的干擾，改善整體系統的數據傳輸率。

關於"5G III"的討論，包含了下列文章：

1. Asynchronous Scrambled Coded Multiple Access (A-SCMA) ? A New High Efficiency Random Access Method
2. Enabling RAN Moderation and Dynamic Traffic Steering in 5G
3. Fog RAN over General Purpose Processor Platform
4. Wireless Backhaul Capacity of 5G Ultra-Dense Cellular Networks
5. Towards a Low-Delay Edge Cloud Computing Through a Combined Communication and Computation Approach

該場論壇的主題是第五代行動通訊系統，簡稱 5G，主要是探討未來可能的行動通訊技術。例如第四篇文章，題目為"Wireless Backhaul Capacity of 5G Ultra-Dense Cellular Networks"，作者為了改善未來 5G 超高密度蜂巢式網路的回載網路容量(backhaul network capacity)，從多跳中繼(multi-hop relay)技術的觀點，探討分析具多閘道之 5G 超密集蜂巢式網路，同時設計一種最小平均跳數(minimum average hop number, MAN)演算法來改善 5G 超密集蜂巢式網路的回載網路容量及其能量效率。該篇文章的想法相當有趣。

三、心得及建議：

車輛技術研討會(Vehicular Technology Conference: VTC)是由電子電機工程協會(IEEE)的車輛技術協會(Vehicular Technology Society: VTS)所主辦的會議，此會議在全球無線通訊領域中是一個重要的會議。會議的目的在探討當今最新之無線通訊技術，促進全世界之學術交流並提供國際間合作的機會。該會議每半年舉辦乙次，分別在春季與秋季舉行，今年秋天剛好是第 84 屆，該協會選擇於西元 2016 年 9 月 18 日至 21 日在加拿大蒙特婁的蒙特利爾酒店(the Hotel Montreal Bonaventure, in Montréal, Canada)舉行 2016 年 IEEE 第 84 屆車輛技術研討會(2016 IEEE 84th Vehicular Technology Conference: VTC2016-Fall)，會議以專題演講(plenary)、專家講習(specialist tutorials)、關鍵演說(keynotes)、技術與應用論壇(technical and application sessions)方式舉行，同時邀請全球學界、政府、業界及相關單位針對無線通訊、行動通訊及車輛通訊來共同參與討論並交換意見與想法。

相關聆聽論壇的心得均已撰寫在上述過程中，另外本人發現，面對未來第 5 代行動通訊的挑戰，我們應著重在下列幾項應用：

1) 巨量機器型態通訊(Massive Machine Type Communications, mMTC)、
2) 強化式行動寬頻(enhanced Mobile BroadBand, eMBB)、
3) 超可靠低延遲通信(Ultra-Reliable Low Latency Communications, uRLLC)、
4) 超密集網路(Ultra-dense network)、
5) 整體系統最佳化(Overall system optimization)、
6) 新的介面效能及其相關價值鏈(New air interface performance and its associated value chain)、
7) 第 5 代行動通訊和工業物聯網的結合應用(5G & industrial IoT)。

本人這次出國參加國際研討會，見識到許多來自不同國家的學者，不論在學術上或文化上，都讓本人的視野更加寬廣，實在獲益良多。另外，在這次研討會中午用餐的時候，本人也遇到了一些來自台灣的教授以及學生，還有來自英國南安普敦大學(University of Southampton, UK)的 Lajos Hanzo 教授，也互相交流一些意見，實在受惠良多。但我也發現，從台灣來的學者，為數不多，而參加會議的台灣學生，更是寥寥無幾。我認為，國際研討會是國際學術交流一個很好的平台，應該多多鼓勵台灣的學者與學生參加，提供多一點機會與補助，以提升台灣學者及學生個人的專業素養以及國際視野。

圖四：本人與來自台灣的教授、學生以及來自英國南安普敦大學(University of Southampton, UK)的 Lajos Hanzo 教授，在中午用餐時互相交流意見，實在受惠良多。

四、攜回資料名稱及內容：

- 大會議程手冊
- 大會論文資料隨身碟

五、感謝：

承蒙「科技部」的國外差旅費補助得以順利參加本次 2016 IEEE 第 84 屆車輛技術研討會(VTC2016-Fall)，讓我有機會參與國際性的研討會，增進國際視野及專業領域的成長，內心深表感謝之意。

附　　錄

附錄一、發表論文中英文摘要

Bi-SON: Big-Data Self Organizing Network for Energy Efficient Ultra-Dense Small Cells

高效節能超密集小細胞之大數據自我組織網路

Li-Chun Wang, *Fellow*, *IEEE*, Shao-Hung Cheng, and Ang-Hsun Tsai, *Member*, *IEEE*

Abstract

In this paper, we present a big-data self organizing network (Bi-SON) framework aiming to optimize energy efficiency of ultra-dense small cells. Although small cell can enhance the capacity of cellular mobile networks, ultra-dense small cells suffer from severe interference and poor energy efficiency. Dense deployment of small cells cause severe interference to the neighboring small cells with a very short distance. On the other hand, energy consumption of huge number of small cells yields high operation expense (OPEX). In a wide area covered by ultra-dense small cells due to user mobility and non-uniformly distributed users, the void cell issue may occur, a phenomenon that a small cell is serving very few users, or even without any users.

In the third generation partnership project (3GPP), current self organizing networking (SON) techniques provide the new functions of self-configuration, self-optimization, and self-healing for network planning with reduced manual intervention. However, current SON-enable mechanisms mostly focus on indoor femtocells or called home evolved Node B (HeNB). Our proposed Bi-SON suggests a data flow framework from data collection, analysis, optimization to reconfiguration. We adopt the statistics analysis approach to determine the optimal system parameters to improve the energy efficiency of a huge number of outdoor small cells. The Bi-SON mechanism periodically collects the management data of small cells, e.g. transmission power, reference signal receiving power, and the number of users per cell. We find that simple sorting and filtering data analysis from huge number of small cells can already effectively find the almost the optimal solution. In the considered case with 120 small cells, our simulation results show that Bi-SON can improve throughput and energy efficiency by 70% and 160% respectively, compared to the scheme without energy saving approach.

Index Terms—Big-data; energy efficiency; self organizing network; ultra-dense small cell.

中文摘要

在本研究中，我們提出了一個大數據的自組織網路（Bi-SON）架構，目標在優化超密集小細胞網路的能量效率。佈建小細胞雖然可以增強蜂巢式行動網路的整體容量，但是超密集的小細胞會造成嚴重的干擾以致系統的能量效率變差。小細胞密集部署使得鄰近小細胞之間距離過短，進而造成小細胞之間的嚴重干擾；另一方面，大量的小細胞同時運作時，將造成大量能量消耗，使得運營支出（OPEX）提高。在超密集小細胞所覆蓋的廣大面積中，由於使用者的移動性和非均勻分佈，使得部分小細胞可能出現僅服務少數使用者或者未服務任何使用者的現象，而造成資源浪費。

在 3GPP 的規範中，現行的 SON 技術對於網路規劃，提供了自我配置、自我優化和自我修復的功能，以達減少人工干預目的，然而，目前的 SON 機制主要是針對室內毫微微小細胞(或稱家庭基站)做設計。我們提出的 Bi-SON 架構，是藉由數據的收集、分析，決策出優化參數，並執行網路參數重新配置，其中我們採用了統計分析的方法來決策出最佳的系統參數，以改善大量室外小細胞的能量效率。該 Bi-SON 架構將定期收集所有小細胞的管理數據，例如發射功率、基準信號接收功率及每個小細胞所服務的使用者數量等等。我們對於所收集的大量資料進行簡單的排序和過濾分析，已有效地找出近最佳化的解決方案。在佈建 120 個小細胞的情境下，以未具任何節能機制做為比較基準，模擬結果顯示，我們提出的 Bi-SON 機制在整體系統的傳輸量及能量效率方面各別提升 70％和 160％。

關鍵詞：大數據；能量效率；自組織網路；超密集小細胞。

附錄二、發表論文全文

Bi-SON: Big-Data Self Organizing Network for Energy Efficient Ultra-Dense Small Cells

Li-Chun Wang, *Fellow, IEEE*, Shao-Hung Cheng, *Student Member, IEEE* and Ang-Hsun Tsai, *Member, IEEE*

***Abstract*—In this paper, we present a big-data self organizing network (Bi-SON) framework aiming to optimize energy efficiency of ultra-dense small cells. Although small cell can enhance the capacity of cellular mobile networks, ultra-dense small cells suffer from severe interference and poor energy efficiency. The self organizing network (SON) can automatically manage and optimize the system performance. However, current SON-enable mechanisms mostly focus on indoor femtocells. Our proposed Bi-SON suggests a data flow framework from data collection, analysis and optimization to reconfiguration. We adopt the statistics analysis approach to determine the optimal system parameters to improve the energy efficiency of a huge number of outdoor small cells. The Bi-SON mechanism periodically collects the management data of small cells, e.g. transmission power, reference signal receiving power and the number of users per cell. We find that simple sorting and filtering data analysis from huge number of small cells can already effectively find the almost optimal solution. Our simulation results show that Bi-SON can improve throughput and energy efficiency by 50% and 135% respectively, compared to the scheme without energy saving approach.**

***Index Terms*—Big-data; energy efficiency; self organizing network; ultra-dense small cell.**

I. Introduction

To meet massive mobile data traffic demand in the next decade, the ultra-dense small cell network is an explicit trend in the future network deployment. The network operators deploy small cell densely with almost 100% coverage for serving the huge access demands.

Generally, when ultra-dense small cells deployment is considered, energy consumed and serious co-channel interference in the small cell layer becomes more significant. If there is no intelligent and automated small cells management strategy, users will suffer serious interference and the operators will have high operational expense (OPEX).

Operators can utilize the self organizing network (SON) to automatically manage and optimize the system performance for lower OPEX [1]. In the current SON framework [2], the static analysis model can not dynamically update the decision function according to the variations of active user densities to optimize the system at any time moment. Therefore, the SON framework may need the optimization algorithm with a dynamic analysis model to improve the co-channel cell interference and the energy efficiency.

In the literature, most papers [3], [4] studied SON-enable mechanisms for indoor femtocells. In [3], the authors proposed a novel self-optimization mechanism for femtocells, which can improve indoor coverage and promote energy efficiency of networks. The paper [4] proposed a reinforcement-learning based SON framework for interference management in femtocells networks. However, these papers [3], [4] did not consider outdoor small cells to improve the energy efficiency in the SON framework. In addition, most papers [5], [6] investigated the energy saving schemes with the power switched mechanism. In [5], the authors designed a novel database-aided mechanism to help macro cells control the sleeping mode of small cells for energy saving in the heterogeneous network. The paper [6] proposed a small cell on/off scheme to improve the throughput and energy efficiency of an ultra-dense centralized/cloud radio access network with various densities of small cells. However, these papers [5], [6] did not consider the power adjustment scheme to improve the energy efficiency in the SON framework.

In this paper, we develop a big-data self organizing network (Bi-SON) framework with data-driven dynamic power control scheme to improve energy efficiency of the outdoor ultra-dense small cell network system. The Bi-SON combines a data-driven dynamic analysis (D3A) model and an interference-aware (IA) energy saving algorithm into the data-driven dynamic power control scheme to optimize the energy efficiency and total cell throughput for the ultra-dense small cell network. Simulation results show that the proposed Bi-SON with data-driven dynamic power control scheme can improve 50% higher cell throughput and 135% higher energy efficiency respectively, compared to the approach without any power control in the 5G ultra-dense small cell network.

The remainder of the paper is organized as follows. Section II introduces the system architecture, channel model and performance metrics. The Bi-SON framework and the data-driven dynamic power control scheme are detailed in Section III and IV, respectively. We show the simulation results in Section V. Finally, our concluding remarks are given in Section VI.

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II. System Model

A. System Architecture

We consider a downlink ultra-dense small cell network with a power adjustment mechanism. The cell layout is set according to small cell deployment scenario in 3GPP LTE Release 12 standardization [7], as shown in Fig. 1. We assume that the macro cell and the small cell use different frequency for transmission so that there is no cross-tier interference, and the co-channel interference exists only in the small cell layer. Each small cell and each user is equipped with only one isotropic antenna. As small cells are deployed densely in some typical hot pots in ultra-dense network scenario, small cell clusters are formed in hot spots. We assume three sectors in a macro cell, four clusters in a sector and ten small cells in a cluster. Total 120 small cells are deployed in the macro cell coverage. The radius of each cluster is 50 m and the small cell density in a cluster is 1300 cells/km^2, which is considered for an ultra-dense deployment. On the other hand, users are randomly deployed around the area with the radius of 70 m from cluster center in each cluster. We consider the variations of active user densities over time.

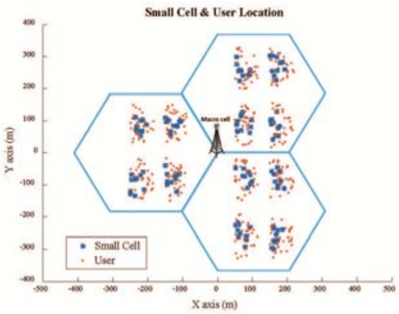

Fig. 1. The downlink heterogeneous network system.

B. Channel Model

We consider the radio propagation effects, including path loss and shadowing, to evaluate the co-channel interference in the ultra-dense small cell network. The receive power of the user n from the small cell q, denoted by $P_{R,q,n} = P_{T,q}\xi d_{q,n}^{-\alpha}$, where$P_{T,q}$ represents the transmission power from a small cell q. α is the path loss exponent and $d_{q,n}$ is the distance between the user n and the small cell q. Shadowing is modelled by a normal distribution $10log_{10}\xi$ with zero mean and standard deviation σ_{ξ}, where ξ is a random variable with log-normal distribution.

C. Performance Metrics

We assume that there are N users and Q small cells in the ultra-dense small cell network. The downlink signal to interference plus noise power ratio (SINR) from the small cell q to the user n can be expressed as

$$SINR_{q,n} = \frac{P_{R,q,n}}{\sigma^2 + \sum_{l \neq q} P_{R,l,n}} , \quad (1)$$

where $P_{R,q,n}$ is the receive power from the small cell q to the user n. $P_{R,l,n}$ is the interference power from the small cell l to the user n in the small cell q. σ^2 is the background noise.

To maximize the sum utility of data rate, we assume that the system uses a full-buffer traffic model [8]. The served users share the total bandwidth of the attached cell. The overall cell throughput R of the system and the data rate r of the user n can be defined as

$$R = \sum_{q}^{Q} \sum_{n} r_{q,n} = \sum_{q}^{Q} \sum_{n} \frac{B}{M_q} log_2(1 + SINR_{q,n}) , \quad (2)$$

where M_q represents the number of served users in the small cell q. B is the bandwidth of each small cell. The spectral efficiency of the user n which served by the small cell q can be expressed as $log_2(1 + SINR_{q,n})$.

When no user is connected to a small cell, the small cell can be switched to the sleeping mode for saving power and reducing the interference to adjacent cells. We assume that a small cell q consumes $P_{sleep,q}$ watt under the sleeping mode or $P_{active,q} = P_0 + \frac{1}{\eta}P_{T,q}$ watt under the active mode. P_0 is the basic consumption of circuit depending on the small cell type, and η is the power amplifier (PA) efficiency. The transmission power of the active and the sleeping mode is P_T watt and 0 watt, respectively. In addition, in the dense small cell region, the small cell caused the strongest interference to neighboring cells should give the priority to be reduced transmission power for decreasing interference and energy consumption. The power control decision is made by central controller like a macro cell. Consequently, the total energy consumption of the system can be represented as

$$\begin{aligned} P_{total} &= \sum_{q} P_q = \sum_{q} [\alpha_q P_{active,q} + (1 - \alpha_q) P_{sleep,q}] \\ &= \sum_{q} [\alpha_q (P_0 + \frac{1}{\eta} P_{T,q}) + (1 - \alpha_q) P_{sleep,q}] , \quad (3) \end{aligned}$$

where $\alpha_q \in \{0, 1\}$. If the small cell q is in the sleeping mode, $\alpha_q = 0$, and the small cell q is in the active mode as $\alpha_q = 1$.

We define that the energy efficiency $E(Mbits/J)$ is the ratio of the total cell throughput R to the total power consumption P_{total}, which can be represented as

$$E = \frac{Overall\ cell\ throughput}{Total\ power\ consumption} = \frac{R}{P_{total}} . \quad (4)$$

III. The Framework of Big-Data Self Organizing Network (Bi-SON)

Figure 2 shows the block graph of our proposed Bi-SON framework. In the following, we illustrate the block of the framework step by step:

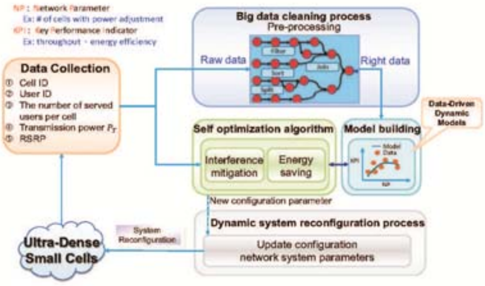

Fig. 2. The framework of energy efficient Bi-SON.

1) Data collection: This step is set to gather massive management data from the ultra-dense small cell network. The data include the number of users per cell, transmission power, reference signal receiving power (RSRP), and so on.
2) Big data cleaning process: Unprocessed massive management data are called big raw data. This block performs data pre-processing via underlying data analytics (e.g., sort, filter) to extract useful right data from big raw data. The right data contain key performance indicator (KPI) (e.g., throughput, energy efficiency) with the corresponding network parameter (NP) (e.g., the number of cells with power adjustment).
3) Model building: The right data are used by this block which employs statistics analysis approach to derive the functional relationship, known as model, between the KPI and the NP. The statistics analysis approach used in this work is polynomial regression (PR). The model can dynamic update the polynomial coefficients to fit data distribution at the moment. Due to periodically collecting management data, the model is called a data-driven dynamic analysis (D3A) model.
4) Self optimizing algorithm: Massive management data are injected into this block to calculate the energy efficiency of the ultra-dense small cell network. When the energy efficiency is less than a preset threshold, our proposed interference-aware (IA) energy saving algorithm is triggered and this block extracts the most appropriate NP from the D3A model to make the optimal decision. Consequently, this block determines new configuration parameters for system reconfiguration to achieve improving network performance.
5) Dynamic system reconfiguration process: The new configuration parameters are injected into the source cellular network to update configuration parameters and improve the system performance.

We propose a promising framework for empowering SON with big data to implement intelligent procedure and to satisfy the performance requirements of 5G. In the next section, we illustrate data-driven dynamic power control scheme which is considered for the core technique of the Bi-SON framework.

IV. Data-Driven Dynamic Power Control Scheme

A. *Interference-Aware (IA) Algorithm*

The data-driven dynamic power control scheme includes both data-driven dynamic analysis (D3A) model and interference-aware (IA) energy saving algorithm. In the IA estimation method, we calculate the total interference power caused by each active small cell in each dense district. The total interference power I_q caused by the small cell q can be expressed as

$$IA_q = I_q = \sum_{n \notin U_q} P_{R,q,n} \ , \tag{5}$$

where $P_{R,q,n}$ is the received power of user n from the small cell q. Denote U_q as the served user set of the small cell q and $n \notin U_q$ as the non-served user set of the small cell q. The small cells which cause stronger interference (i.e., larger IA value) should be turned down the transmission power to decrease the co-channel interference and to improve the energy efficiency.

Under the described above, we calculate the IA value of each small cell and then sort the values in the descent order. For the given sorted small cells, we filter the first k cells which be turned down the transmission power to reduce severe interference and effectively improve energy efficiency. We define k as the number of cells with power adjustment. The proper k value is provided by D3A model. The detail D3A model is described in the next subsection.

B. *The Joint IA Algorithm and Data-Driven Dynamic Analysis (D3A) Model*

We propose the D3A model which can dynamically update the polynomial coefficients based on continuously collecting the management data form the ultra-dense small cell network. We assume that each small cell can be controlled by the central controller like the macro cell. The central controller can periodically collect the management data for data pre-processing to be transformed into the useful right data. The data pre-processing includes sorting the IA value and calculating the cell throughput, and so on. The right data can form the data sets of the cell throughput and the corresponding k value. The D3A model is built for the reliable functional relationship between the cell throughput and the corresponding k value by the statistics analysis approach, such as polynomial regression (PR) [9]. We fit the right data by using a PR function of the form

$$y(x, W) = w_0 + w_1 x + w_1 x^2 + ... + w_M x^M = \sum_{j=0}^{M} w_j x^j \ , \tag{6}$$

where M is the order of the polynomial, x^j denotes x raised to the power of j, x is independent variable which represents

k value, and y is corresponding variable (i.e., predictive value) which represents cell throughput. The polynomial coefficients $w_0, ..., w_M$ are collectively denoted by the vector W. The values of the coefficients will be determined by fitting the polynomial to the right data. After verification, the third order ($M = 3$) polynomial gives the best fit to the right data.

The D3A model is used to choose the most appropriate k value that meets the expected cell throughput. After choosing appropriate k value, we put it in algorithm to have an optimal decision making. Figure 3 is the flow chart of our proposed data-driven dynamic power control scheme with the joint IA algorithm and D3A model. In the following, we illustrate more detail of the scheme step by step:

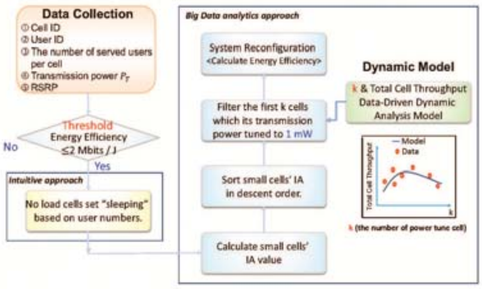

Fig. 3. The data-driven dynamic power control scheme flow chart.

1) The ultra-dense small cells generating massive management data are injected into the computing platform for data processing and analysis.
2) Calculate the energy efficiency of overall network. If the energy efficiency is less than a presetting threshold (i.e., 2 Mbits/J), the power control scheme is triggered to improve network performance.
3) Users choose serving cells based on the RSRP. When the small cell without any active user attached, it will be switched to the sleeping mode in order to decrease power consumption of the overall network. This small cell switching strategy is known as the intuitive approach.
4) For each small cell, we can sum the total interference (i.e., IA value) to the users outside the served region.
5) Sort the small cells based on IA value in descent order.
6) Filter the first k cells which tune down the transmission power to 1 mW (milliwatt). The proper k value is provided by D3A model.
7) New power configuration parameters for system reconfiguration achieves network performance improvement.

V. Simulation Results

In this section, we show performance improvements of the Bi-SON with data-driven dynamic power control scheme for the ultra-dense small cell network. The simulation environment is shown in Fig 1. Assume that the maximum transmission power $P_T = 1$ W, the basic circuit power consumption $P_0 = 6.8$ W, the sleeping mode power consumption $P_{sleep} = 4.3$ W, and the power amplifier (PA) efficiency $\eta = 0.25$ [10]. The downlink ultra-dense small cell system parameters are list in Table I [8]. We compare our proposed data-driven dynamic power control scheme (i.e., ISA algorithm with D3A model) with no energy saving approach, the intuitive scheme (i.e., the small cell would be switched to sleeping mode if no user is connected), and IA with static analysis model. The static analysis model can not update the polynomial coefficients with the density variations of active users, while the D3A model can periodically update the polynomial coefficients every three hour.

TABLE I
THE DOWNLINK ULTRA-DENSE SMALL CELL SYSTEM PARAMETERS

Parameters	Value/Mode
System bandwidth	10 MHz
Density of cell	1300 $cells/km^2$
Transmission power, P_T	1 W
P_0	6.8 W
P_{sleep}	4.3 W
The power amplifier (PA) efficiency, η	0.25
Path loss coefficient, α	3.67
Shadowing standard deviation, σ_ξ	4 dB
Service type	Full buffer

TABLE II
THE VARIATIONS OF ACTIVE USER DENSITIES OVER TIME.

Time (Hour)	0	3	6	9	12	15	18	21	24
User Density (users/km^2)	1500	700	500	900	1100	1300	1700	1900	1500

Table II shows the typical daily variation of active user density against the time [11]. From the table, the minimal user density and the maximal user density are 500 users/km^2 and 1900 users/km^2, and occur at 6 o'clock and 21 o'clock, respectively. The largest difference of user density can reach 1400 users/km^2. For the sharp variation of active user density, our proposed D3A model is more suitable than the static analysis model to optimize the system performance, because the D3A model can dynamically update the polynomial coefficients according to the density variation. For simplification, we assume that the static analysis model can generate the polynomial coefficients based on 1200 users/km^2 only.

Figure 4 shows that the total cell throughput against the time. From the figure, we have the following observations:

1) For the IA algorithm, the static analysis model has the same total cell throughput as the D3A model with a high active user density. However, the static analysis model has lower total cell throughput than the D3A

model in a low user density because the static analysis model can not dynamically update the decision function to optimize the system.

2) In this case, the IA method with the D3A model can improve 50% higher total cell throughput than the no energy saving approach.

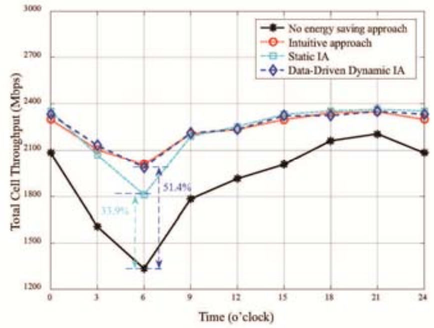

Fig. 4. The total cell throughput in varied time. There are three schemes for comparison with our proposed ISA algorithm with D3A model, including the no energy saving approach, the intuitive scheme, and the IA with static analysis model.

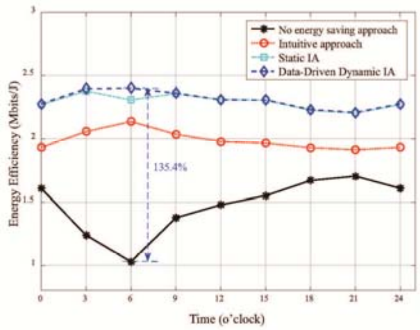

Fig. 5. The energy efficiency in varied time.

Figure 5 shows that the energy efficiency against the time. From the figures, we have the following observations:

1) The IA algorithm has better energy efficiency than the intuitive approach. This is because the IA algorithm can significantly reduce co-channel interference and power consumption in the high density region of active small cells to improve the energy efficiency.
2) Compared with no energy saving approach, the IA method with D3A model can provide the 135% energy efficiency.

VI. Conclusion

In this paper, we proposed the Bi-SON framework with the data-driven dynamic power control scheme to improve the total cell throughput and energy efficiency of the ultra-dense small cell network. The power control scheme includes both data-driven dynamic analysis (D3A) model and interference-aware (IA) energy saving algorithm. With collecting the management data from the small cells, our proposed IA algorithm can estimate and sort the cells with large interference to neighboring users, and decrease the transmission power of the cells for reducing interference and power consumption. The fitting amount of these cells with the transmission power adjustment can be provided by our proposed D3A model, according to the statistics analysis approach. With the effective cooperation between the D3A model and the IA algorithm, the Bi-SON can produce the new configuration parameter for the network reconfiguration, thus improving the total cell throughput and energy efficiency for the ultra-dense small cell network system. We showed that our proposed Bi-SON can achieve the highest total cell throughput and the energy efficiency for the ultra-dense small cell network. Compared with no energy saving approach, our proposed Bi-SON can improve the total cell throughput and the energy efficiency by 50% and 135% respectively.

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