行政院國家科學委員會專題研究計畫 成果報告

適用於無線視訊娛樂之多系統融合及節能技術--子計畫二：適用於無線多媒體通訊之跨層多系統接取控制層軟硬體協同設計(3/3)

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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

適用於無線視訊娛樂之多系統融合及節能技術-子計畫二：

適用於無線多媒體通訊之跨層多系統接取控制層軟硬體協同設計(3/3)

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中　華　民　國　99 年　7　月　31　日

行政院國家科學委員會專題研究計畫成果報告

適用於無線視訊娛樂之多系統融合及節能技術-子計畫二：
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中文摘要

本份報告分成四個部分，每個部份介紹本實驗室團隊研究的不同的主題與成果。第一部分，我們將介紹 MAC 層的垂直換手機制。第二部分的內容將闡述我們所提出的媒體控制連階層(MAC)嶄新驗證方法與其實現。而第三部分將著重在 3GPP LTE 規格下的媒體接取控制層(MAC)的無線資源管理研究。第四部分，我們將介紹一種計算媒體接取控制層封包長度的計算法，來避免過度的重傳。以下就各細項做說明。

在系統設計上，垂直換手機制(VHO)對於異質網路的影響很大。傳統上是利用 SINR 以及頻道的可利用性來做為決策的條件。但是傳統的決策機制仍有可能造成錯誤的決策。因為好的 SINR 並不代表好的產量效能(Throughput)，為了避免此種問題的發生，本篇報告提出以有效 SINR (effective SINR)來計算可完成的資料率。另外， MAC 層的系統驗證通常是通過預設儲存的資料做分解重組，並未考慮到真實交通流量的情形。而軟體層模擬的缺點是只能看到數據，而無法看見多媒體的實際運作效果。因此，為了驗證與模擬通訊 MAC 系統並增加分析的精準度，本報告透過引入新的系統驗證方法(MAC 擬真系統的設計)來達到降低設計複雜度與開發周期的目的。 而在本報告第三部分所要探討的主題裡，主要是針對解決超微細胞(或者是說家用基地台)中訊號干擾的問題做探討。並建構一個以軟體實現的實驗性模擬系統，藉此可以協助標準活動的參與、相關的智慧財產權佈局與使用該實驗性模擬系統做系統設計之先期驗證，以利產品研發。而我們的研究工作主要是針對 3GPP LTE 的標準，設計干擾管理的技術。由於超微細胞基地台為新興技術，如何與大型基地台及其他極微細胞基地台做有效的資源分配及管理並降低干擾為重要的議題。

最後，我們將探討與封包傳輸有關的重要問題。在傳輸系統中，封包切割大小的適當與否，將會決定傳輸的品質。如果封包切割的不恰當，便會經常造成封包錯誤的產生。因此如何將封包切割成適當大小來維持好的服務品質是相當重要的。

關鍵詞：垂直換手機制、服務品質、異質網路、負載、驗證、抗干擾、最佳化

Abstract — **This report contains four parts with different topics. In the first part, we introduce the vertical handover mechanism in the MAC layer. The second part is mainly about a new verification method of the MAC layer and its realization. The third part is about the resource management in 3GPP LTE system. And finally, in the fourth part, we will discuss a method to calculate the payload length of the MAC layer packet, which will improve the system performance. Details of each part are discussed as follows.**

The vertical handover mechanism (VHO) affects the heterogeneous networking environments a lot. Previous research often takes SINR and the availability as its decision condition. But it may still pick inappropriate decision, because good SINR will not necessarily brings good throughput. To avoid this, effective SINR is raised. It is used to calculate the data rate that could be completed. Besides,

verification of MAC is usually done in "artificial situation". Data and video streaming are store in the system, and then fragmented and combined. It does not actually take the real traffic into consideration. If the simulation is done in "software tools", we can see nothing but only numbers. In order to verify and emulates the MAC system to a raise the function accuracy to some degree, a new verification scenario is proposed to lower the design complexity and development time. In the third part of this report, we mainly discuss the problem of signal interference in femtocell , or the home node. We also construct a simulation software for experiment to help the design of spec and the design of systems in the early stage. And it also helps the development of intellectual property. A technique to avoid interference is developed in 3GPP LTE system. Because the technology about femtocell is just starting-up, how to make it co-operates well with other femtocells and with the base station to make good utilization of resources and to lower the interference is an important issue.

In the final part, we discuss an important problem about transmission. Inappropriately fragments may cause bad Quality of service (Qos) because of error in packets. So it is important to fragments the packets into appropriate size to maintain good service quality.

Index Terms— Vertical Handover, Quality of Services (QoS), Heterogeneous Networking, Loading, Verification, Interference Mitigation, Optimization

I. INTRODUCTION

A. The heterogeneous network and the VHO algorithm

HETEROGENEOUS networks provides efficient wireless accessibility in different environments. The idea is to incorporate the current existing networks, usually of mutual complement, into an integrated network, and allow users to choose the most preferable access. An example scenario is illustrated in Figure 1.

Figure 1. Example Heterogeneous Network

In such heterogeneous networking environment, the process of switching among different type of systems, called vertical handover (VHO), is a critical technique to provide ubiquitous coverage while maintaining the connectivity and quality of services (QoS).

B. The MAC Emulation system

Resource management is an important issue in communication systems. When an algorithm is proposed, it is also important to consider its validity. Because some algorithm may be perfect mathematical model but be unrealistic when designed in real systems because of its complexity. So it is very important to verify if the algorithm works well with the real traffic. In previous work, verification in MAC system is often done by artificial case, which means we usually set all conditions that we want in the program, and then run it to get the results. However, this may be not close to the real situation. The better way to verify the system is by emulation instead of simulation. We will not know exactly what will happen unless we run the system in the real environment. That is why the MAC emulator architecture is proposed to solve the problem.

C. The Femtocell technology and resource management

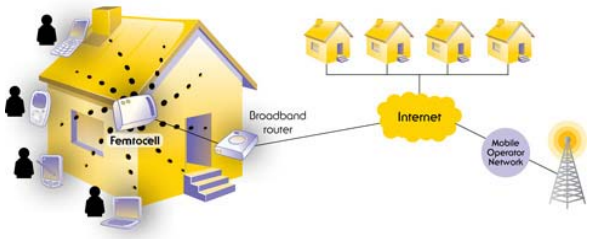

Figure 2 Femtocells

The use of femtocell to increase the coverage is an important technology in 3GPP-LTE systems. While in-door transmission occupies most applications, but it suffers many difficulties to

transmits in the in-door environment. The challenge is that the femtocell shares the frequency originally used by the base station. This may save the frequency, but it may also cause interference between the cells and the base station. Besides, the femtocell is a plug-and-play device that should have the ability to do self-organization. Figure 3 shows how cells interference with each other, and table 1 shows the types of interference.

Figure 3. The interference between devices

Table 1: Interference Types

Number	Aggressor	Victim
1	UE (User) attached to Home Node B	Macro Node B Uplink
2	Home Node B	Macro Node B Downlink
3	UE attached to Macro Node B	Home Node B Uplink
4	Macro Node B	Home Node B Downlink
5	UE attached to Home Node B	Home Node B Uplink
6	Home Node B	Home Node B Downlink
7	UE attached to Home Node B and/or Home Node B	Other System
8	Other System	UE attached to Home Node B and/or Home Node B

D. The packet payload length calculation

H.264/AVC is a high-coding-efficiency video coding technique and can compress the size of high-definition (HD) video frame into a smaller frame size for band-limited wireless environments. This application requires high transmission rates and low frame error rates. In the WiMedia system, the Distributed Reservation Protocol (DRP) mechanism could meet the requirement. The minimum number of reserved medium access slots to meet the strict error constraint and delay budget as well as the associated optimal payload length to maximize the throughput will be investigated in this paragraph.

II. THE MAC EMULATION SYSTEM

An MAC Emulation system is an verification architecture that can test the performance of the MAC layer of an communication system. It is designed under the Object-based concept shows in figure 2. Instead of the numerical data, it shows the performance that how a system works under a specific algorithm by real data flow.

Figure 4. The object-based MAC Emulation System

The whole emulation system contains a BS system and could also contains many MS systems (or end user). They can both be set in real equipments, and communicates via computer network by TCP/IP protocols. The benefit of this architecture is that we can see the performance of the system under real applications. The block diagram of the separate BS and MS architecture is shows in the figure 5 and figure 6.

Figure 5. The BS Architecture

Figure 6. The MS Architecture

III. THE VHO ALGORITHM

Considering loading-based QoS prediction, the handover procedure is described by a finite state machine (FSM) depicted in Figure 5. And the operation of each state is listed in table 1.

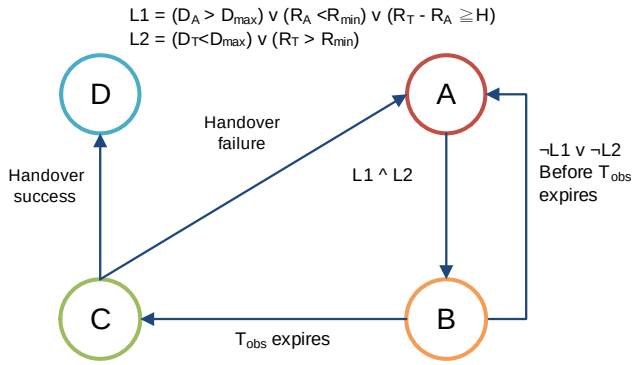

Figure 7. FSM for Handover Procedure

Table 2: Operation within States

State	Operations
A (Normal Operation)	1. Normal data transmission 2. Collecting neighbor information
B (Observation)	1 maintain the candidate set; do comparison and find the handover target 2 Observe the target; make handover decision
C (Network Re-entry)	1 Perform network re-entry to target network 2 Terminate service from anchor network
D (success)	1. Normal operation in target network

The handover will be triggered when current delay and transmission rate are below requirements, or when the target network is expected to provide higher performance. A positive handover decision will be made if such condition holds within an observation period (to avoid ping-pong effect), and the target network QoS meets the requirements.

IV. INTERFERENCE MITIGATION ON OFDMA FEMTOCELL

Here we demonstrate the construction of the software platform. The simulation environment is shows in figure 8, and figure 9.

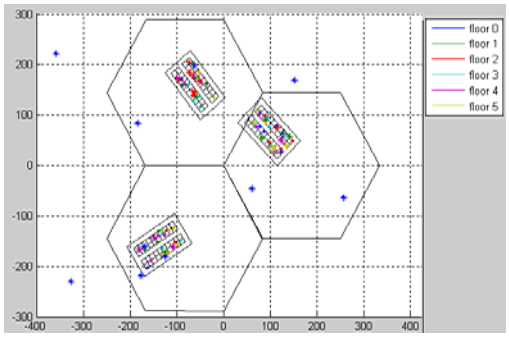

Figure 8. femtocell blocks

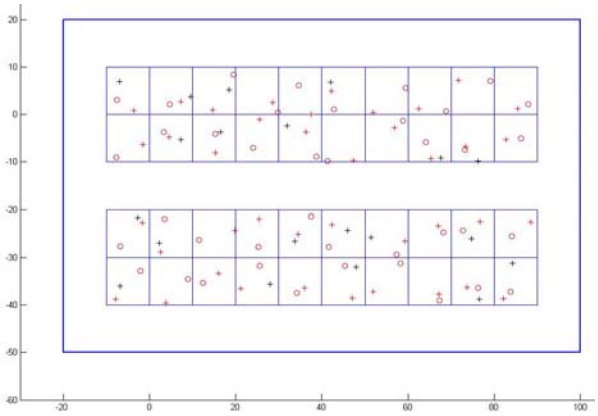

Figure 9. femtocells and users

We construct the simulation platform and then set the parameters of environment. And here we propose a method to reduce femto-to-femto interference by grouping the femtocells. We make those who interfere most severely into one group and then dispatch different frequency to each.

Here we consider two possible grouping cases, as shows in table 3.

Table 3. grouping cases comparison

UE based	HNB based
Downlink received power	Uplink/Downlink Received Interference Power
Advantage: precise	Advantage: easy deployment
Drawback: waste of resources between UE and femtocell	Drawback: not optimize for every users.
Measurement periodically and update resources of femtocell periodically.	Update only when femtocell deployment changes.

The Hierarchical Clustering grouping algorithm is used here. And the City-block distance(1) and Single-link clustering(2) is defined as follows

$$d_{cb}(\mathbf{x}^r, \mathbf{x}^s) = \sum_{j=1}^{d} \left| x_j^r - x_j^s \right| \quad (1)$$

$$d(G_i, G_j) = \min_{\mathbf{x}^r \in G_i, \mathbf{x}^s \in G_j} d(\mathbf{x}^r, \mathbf{x}^s) \quad (2)$$

We continuously group the cells that are nearest to each other until all femtocells are in the same group. We can group them by different thresholds. The result is shows in figure 10. And the simulation results are shows in figure 11 and figure 12.

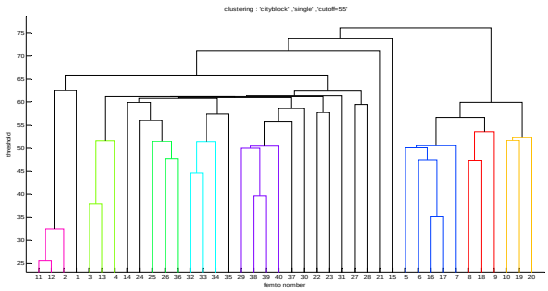

Figure 10. The femto tree

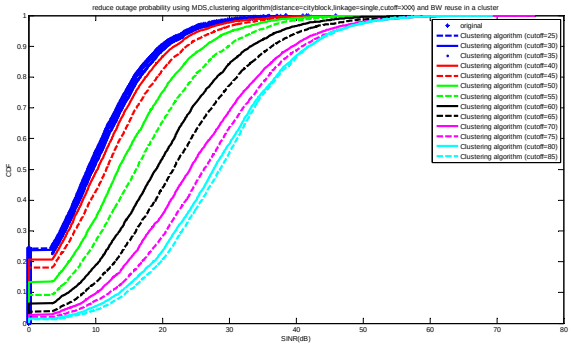

Figure 11. different cutoff threadholds

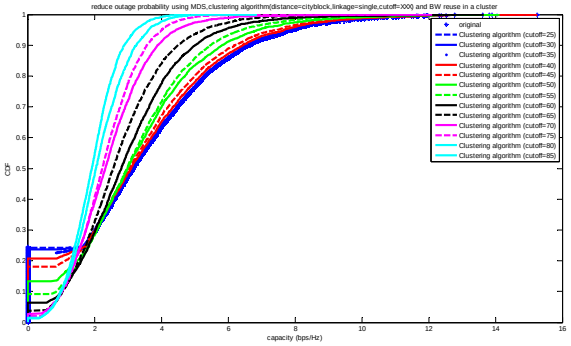

Figure 12 capacity with different cutoff threadholds

V. Optimal Performance of H.264 HD Video

A. *Minimal Reservation Slots*

Here we would like to calculate the minimum reservation slots. For HD video transmission in WiMedia system the locations of the transmitter and receiver are mostly fixed, so the transmission channel can be approximated as AWGN channel. In this case, the number of correct received packets X could be considered as a random variable with the binomial distribution. The probability mass function of X, $B(X, N_R, P)$ is:

$$B(X, N_R, P) = \binom{N_R}{X} * P^X * (1-P)^{N_R - X} \quad (3)$$

where N_R is the reserved packet number, and P is the packet success rate (*PSR*).

If the frame error rate is P_e and suppose that a video frame is fragmented into N_F packets, then the packet error rate must be less than $1 - \sqrt[N_F]{1-P_e}$ to satisfy the error constraint. And the probability of the frame error rate is:

$$P_e = \sum_{i=0}^{N_F - 1} \binom{N_R}{i} P^i * (1-P)^{N_R - i} \quad (4)$$

where P is the packet success rate.

In general, there will be multiple video frames, N_{MB}, buffered and fragmented into N_F packets in the MAC before the transmssion. To meet the frame error rate, the resulting frame error rate from transmitting N_{MB} video frames has to be less than $1 - (1-P_e)^{N_{MB}}$.

The reserved packets N_R will depend on total fragmented

packets N_F (from N_{MB} video frames), the target frame error rate P_e, and over-the-air success rate P. To calculate the minimal required reservation packet number N_{min} for transmitting total fragmented N_F packets and to meet the frame error constraint P_e, the optimization problem can be formulated as:

$$N_{min} = Min \quad N_R$$

subject to

$$\sum_{i=0}^{N_F-1} \binom{N_R}{i} P^i * (1-P)^{N_R-i} \leq 1-(1-P_e)^{N_{MB}}, N_{MB} \in N \qquad (5)$$

If N_F is large enough, N_{min} will converge to reciprocal of the packet success rate times the N_F, N_{min}= N_F/P. By central limit theorem, if $N_F \rightarrow \infty$, then $N_{min} \rightarrow \infty$

$$\frac{X - N_{min} * P}{\sqrt{N_{min} * P * (1-P)}} \sim N(0,1) \qquad (1)$$

where X is the number of packets received correctly.

The constraint of (5) can be rewritten:

$$F\left(\frac{X - N_{min} * P}{\sqrt{N_{min} * P * (1-P)}} \leq s\right) \cong \Phi(s) \qquad (2)$$

$$\Phi(s) \leq 1-(1-P_e)^{N_{MB}} \qquad (3)$$

where $\Phi()$ is cdf of standard normal distribution, and $F()$ is cdf of the random variable $\frac{X-N_{min}*P}{\sqrt{N_{min}*P*(1-P)}}$.

$$Let\ \Phi(s) = 1-(1-P_e)^{N_{MB}} \qquad (4)$$

$$s = \frac{(N_F - 1) - N_{min} * P}{\sqrt{N_{min} * P * (1-P)}} \qquad (5)$$

$$N_F = s * \sqrt{N_{min} * P * (1-P)} + N_{min} * P + 1 \qquad (6)$$

$$\lim_{N_F \to \infty} \frac{N_{min}}{N_F}$$

$$= \lim_{N_{min} \to \infty} \frac{N_{min}}{s * \sqrt{N_{min} * P * (1-P)} + N_{min} * P + 1} \qquad (7)$$

$$= \frac{1}{P}$$

And the simulation results are showed in figure 13.

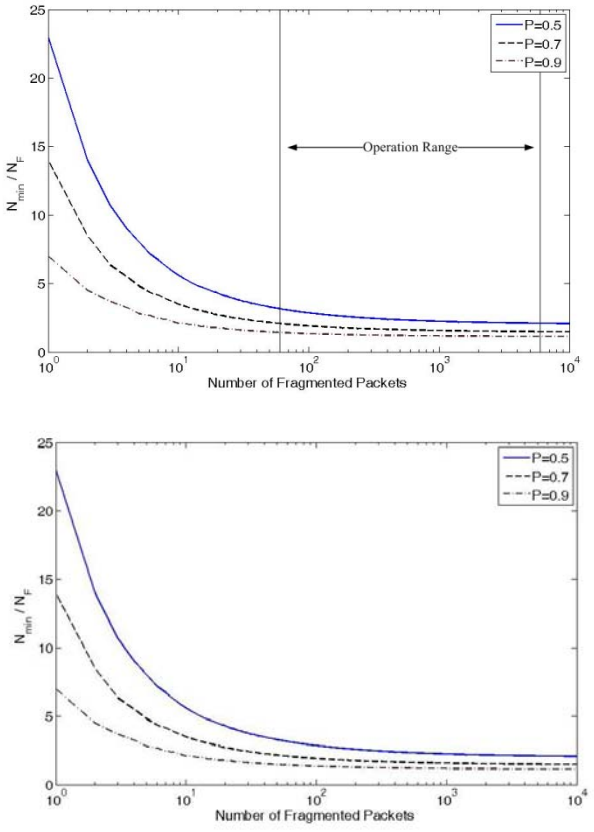

Fig. 11 Variation of minimal reservation packet number to the number of fragmented packets with different packet error rate

B. *Minimal Transmission Time*

The optimization problem can be constructed as:

$$\min_{L} \quad N_{min}(L) * T_{tran}(L) \qquad (8)$$

where $N_{min}(L)$ is minimal reservation number of packets fragmented by payload length L in bytes, and $T_{tran}(L)$ is the packet transmission time plus ACK response time using the payload length of L. And the calculation procedure is show in figure 15.

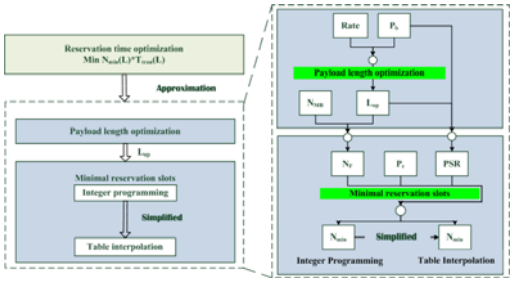

Figure 15. the calculation of minimal transmission time

VI. CONCLUSIONS

A. *Conclusions of the VHO algorithm*

In our research, we have shown that the proposed algorithm is important for the VHO control mechanism. It does improve the performance not only for VoIP service but the FTP service. Especially when the loading imbalance between WLAN and WiMAX networks increases, the performance in terms of VoIP packet drop rate or FTP throughput is improved significantly by such prediction method. As showed in figure 16 and figure 17.

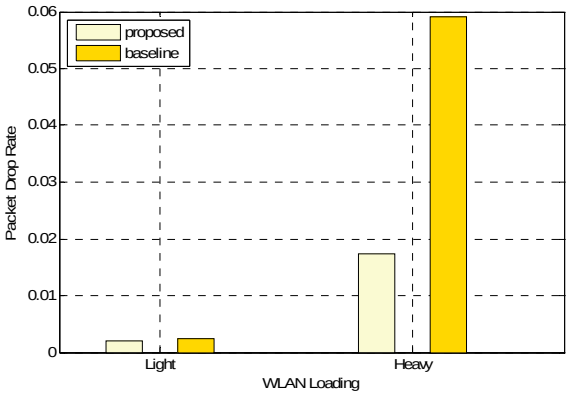

Figure 16. Packet Drop Rate for VoIP traffic

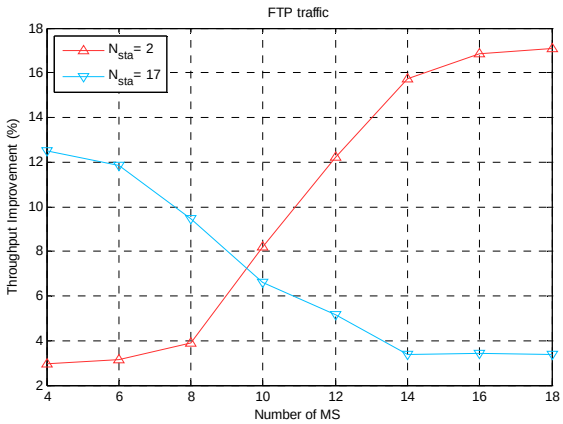

Figure 17. Throughput for FTP traffic

B. *Conclusions of the Emulator*

The previous system verification is usually done by simulate on a single computer. We can see nothing more than numeric results. Maybe we have no idea what these numbers tell. But in our work, we propose a new approach. It is able to visualize the whole picture about the procedure. We can see clearly if the system works well under a specific algorithm by the quality of the video stream. We thought that this approach is more suitable for the coming application of multi-media service.

C. *Conclusions of the femtocell system*

The Hybrid mode is an effective way to decrease the effect of interference, even the users are few. The available resource is decided by the company of telecommunication. But the point here is that we can improve the performance by our method even under limited resource. We can improve the situation of interference and further the performance of the overall system. Maybe this could be a new approach that worth the cost of time and resource.

D. *Conclusions of the femtocell system*

In this part of research, we propose a new approach to solve the optimization problem of the system. An analytical model is established to calculate the minimal transmission time to satisfy the error constraint of real-time HD video. Instead of using the integer program method, we separate the calculation of optimal payload length and the look-up table for the number of required reservation slots. From our approach, only 1% error is created, much improvement is made.

相關論文發表與 3GPP 標準貢獻

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國科會補助計畫衍生研發成果推廣資料表

日期:2010/12/15

國科會補助計畫	計畫名稱: 子計畫二：適用於無線多媒體通訊之跨層多系統接取控制層軟硬體協同設計(3/3)		
	計畫主持人: 黃經堯		
	計畫編號: 98-2220-E-009-003- 學門領域: 晶片科技計畫--整合型學術研究計畫		
研發成果名稱	(中文) WiMAX 仿眞模擬器		
	(英文) WiMAX Emulator		
成果歸屬機構	國立交通大學	發明人(創作人)	黃經堯,曾理銓
技術說明	(中文) 針對WiMAX標準，完成功能性之協定設計。承接者能快速練習WIMAX之協定設計。 MAC層的系統驗證通常是通過預設儲存的資料做分解重組，並未考慮到眞實交通流量的情形。而軟體層模擬的缺點是只能看到數據，而無法看見多媒體的實際運作效果。因此，爲了驗證與模擬通訊MAC系統並增加分析的精準度，本報告透過引入新的系統驗證方法(MAC擬眞系統的設計)來達到降低設計複雜度與開發周期的目的。 WiMAX 仿眞模擬器架構爲模組化設計，使用者可以置換3GPP LTE 相關之設計。		
	(英文) Based on WiMAX standard the emulator has accomplished the functional designs. The users can quickly test the protocol designs.		
產業別	電信業		
技術/產品應用範圍	WiMAX 協定設計		
技術移轉可行性及預期效益	The emulator can be used in more operators to valid new radio resource management control algorithms.		

註：本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。

98 年度專題研究計畫研究成果彙整表

計畫主持人：黃經堯	計畫編號：98-2220-E-009-003-
計畫名稱：適用於無線視訊娛樂之多系統融合及節能技術--子計畫二：適用於無線多媒體通訊之跨層多系統接取控制層軟硬體協同設計(3/3)	

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	2	0	100%	人次	
		博士生	1	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	1	0	100%	篇	
		研究報告/技術報告	2	0	100%		
		研討會論文	1	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

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。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	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

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 ■申請中 □無

技轉：□已技轉 ■洽談中 □無

其他：(以 100 字為限)

Published in ACM Wireless Networks

Two 3GPP standard contributions

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）(以 500 字為限)

The WIMAX based emulator can be used by system designer for introducing new control algorithms for functional test.

A control is currently under negotiation at the budget of 400K for using the emulator.