**Arab Academy for Science, Technology and Maritime Transport**
**Cairo, Egypt**

***College of Engineering and Technology***
Electronics and Communications Engineering Department

# Priority-Based Scheduling for Cognitive Radio Systems

*A Thesis by*

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# DECLARATION

I certify that all the material in this thesis that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this thesis reflect my own personal views, and are not necessarily endorsed by the university.

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# ABSTRACT

A problem in modern wireless communications is the scarcity of electromagnetic radio spectrum. The traditional fixed spectrum assignment strategy results in spectrum crowding on most frequency bands. Due to limited availability of radio spectrum and high inefficiency in its usage, cognitive radio networks have been seen as a promising solution to reducing current spectrum under-utilization while accommodating for the increasing amount of services demands and applications in wireless networks. Compared with the traditional networks, cognitive radio networks exhibit some distinct features, which result in necessity of further research in the resource allocation and scheduling that have been solved for the traditional networks.

In this thesis, we focus on the packet scheduling in a single cell cognitive radio system, an adaptive downlink scheduling for real time and non-real time applications with the consideration of the primary user activity is proposed. The proposed algorithm satisfies different traffic models based on the QoS level of each traffic type and the spectrum availability. The performance of the proposed algorithm has been evaluated in terms of throughput and delay. This algorithm provides better QoS guarantee for real time traffic and more efficient spectrum utilization for cognitive radio systems.

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| | |
|---|---|
| **1xEV-DO** | 1x Evolution-Data Only |
| **2G** | Second Generation |
| **3G** | Third Generation |
| **ADC** | Analog-to-Digital Converter |
| **AMC** | Adaptive Modulation and Coding |
| **BBS** | Base station subsystem |
| **BER** | Bit Error Rate |
| **BS** | Base Station |
| **BTS** | Base Transceiver Station |
| **BSC** | Base Station Controller |
| **BSS** | Base Station Subsystem |
| **CDMA** | Code Division Multiple Access |
| **CR** | Cognitive Radio |
| **CRNS** | Cognitive Radio Networks |
| **CRUS** | Cognitive Radio Users |
| **CRS** | Cognitive Radio System |
| **DAB** | Digital Audio Broadcasting |
| **DAC** | Digital-to-Analog Converters |
| **DSL** | Digital Subscriber Line |
| **DDC** | Digital Down-Conversion |
| **DFT** | Discrete Fourier Transform |
| **DUC** | Digital Up-Converter |
| **DMR** | Digital Modulator Radio |
| **DSP** | Digital Signal Processor |
| **ECMA** | European Computer Manufacturers Association |
| **EDGE** | Enhanced Data rates for GSM Evolution |
| **ETSI** | European Telecommunications Standards Institute |
| **FCC** | Federal Communications Commission |
| **FDMA** | Frequency Division Multiple Access |
| **FFT** | Fast Fourier Transform |
| **FTP** | File Transfer Protocol. |
| **GPRS** | General packet radio service |
| **HSDPA** | High-Speed Downlink Packet Access |
| **HTTP** | Hypertext Transfer Protocol |
| **IEEE** | Institute of Electrical and Electronics Engineers |
| **IF** | Intermediate Frequency |
| **IP** | Internet Protocol |
| **IPP** | Interrupted Poisson Process |
| **ISI** | Inter-Symbol Interference |
| **ITU** | International Telecommunication Union |
| **LAN** | Local Area Networks |
| **LOS** | Line Of Sight |

| | |
|---|---|
| **MAC** | Medium Access Control |
| **MAN** | Metropolitan Area Network |
| **MIMO** | Multiple Input Multiple Output |
| **MPEG** | Moving Pictures Expert Group |
| **MSPS** | Million samples per second |
| **NLOS** | Non Line of Sight |
| **OFDM** | Orthogonal Frequency Division Multiplexing |
| **OFDMA** | Orthogonal Frequency Division Multiple Access |
| **PHY** | Physical Layer |
| **PUs** | Primary Users |
| **USRP** | Universal Software Radio Peripheral |
| **QAM** | Quadrature Amplitude Modulation |
| **QoS** | Quality of Service |
| **RF** | Radio Frequency |
| **RRS** | Reconfigurable Radio Systems |
| **RSSI** | Received Signal Strength Indicator |
| **RX** | Receiver |
| **SCC** | Standards Coordination Committee |
| **SDR** | Software-Defined Radio |
| **SNR** | Signal to Noise Ratio |
| **SUs** | Secondary Users |
| **TC** | Technical Committee |
| **TCP** | Transmission Control Protocol |
| **TRAU** | Transcoder and Rate Adaptation Unit |
| **TDMA** | Time Division Multiple Access |
| **TX** | Transmitter |
| **VOIP** | Voice over Internet Protocol |
| **WAN** | Wide Area Network |
| **WI-FI** | Wireless Fidelity |
| **WIMAX** | Worldwide Interoperability Microwave Access |
| **WMAN** | Wireless Metropolitan Area Network |
| **WLL** | Wireless Local Loop |
| **WRC** | World Radio Conference |
| **WP** | Working Party |

# LIST OF SYMBOLS

| | |
|---|---|
| $b_{in}^{(j)}$ | Number of bits for each user $i$ with traffic class $j$ using sub-channel $n$ |
| $b_n$ | Number of bits allocated over the $n$th subcarrier |
| $\alpha_j, \beta_j$ | Weights for balancing the impact of delay and throughput priority terms |
| $C$ | Channel capacity |
| $c_j$ | Adaptive service coefficient |
| $H(n)$ | Channel frequency response over the $n$th subcarrier |
| $L$ | Time slot length |
| $M$ | Number of sub-channels during one scheduling period |
| $N$ | Total number of the available sub-channels |
| $\bar{n}$ | Number of non-real time traffic classes |
| $P_n$ | Power allocated over the $n$th subcarrier |
| $P_n^{(f)}$ | Probability that channel $n$ is free |
| $p(i,j)$ | Priority function of user$i$ of traffic queue $j$ |
| $p_{e,n}$ | BER over $n$th subcarrier and $\mathcal{N}$ the set of modulated subcarriers |
| $q(i,j)$ | Traffic queue of user $i$ and class $j$ |
| $R_j$ | Target bit rate |
| $R(n)$ | Output from the receive DFT |
| $r_j$ | Maximum expected packet throughput of traffic class$j$ |
| $r(n)$ | Remaining free slots of sub-channel $n$ |
| $S(n)$ | Corresponding input symbol |
| $T_j$ | Maximum packet delay bound of traffic class$j$ |
| $W(n)$ | White Gaussian noise |
| $w_{i,j}$ | Waiting time of the user $i$ of traffic queue $j$ |

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الفصل الاول من الاطروحة يتم فيه تناول مقدمة عن الدافع ومخطط للاطروحة. الفصل التاني يتم فيه مناقشة مفهوم شبكة الراديو الإدراكي. في الفصل الثالث تعرض دراسة لتخصيص الموارد وخطط الجدولة أما في الفصل الرابع فيتم تقديم نموذج نظام الراديو الإدراكي بما في ذلك هندسة الشبكات و نموذج حركة المرور ونموذج القناة علاوة على تقديم مقترح ديناميكي لمخطط الجدولة و عرض نتائج محاكاة لتقييم أداء نظام الجدولة المقترح. وأخيرا، يستعرض الفصل الخامس أهم الاستنتاجات و يناقش نقاط العمل المستقبلية.

# ملخص الرسالة


توجد هناك مشكلة في الاتصالات اللاسلكية الحديثة ألا وهي ندرة الطيف الراديوي الكهرومغناطيسي. إن الإستراتيجية التقليدية الثابتة لتوزيع الطيف تسفر عن تكدس الطيف علي معظم نطاقات الطيف. ونظراً لمحدودية توفر الطيف الترددي وعدم الكفاءة في استخدامه، فإن شبكات الراديو الادراكي تعتبر حلاً جيداً ومبشراً يمكن من خلاله تقليل دونية الإستخدام الحالي للطيف الترددي وفي نفس الوقت استيعاب الكم المتزايد من الطلب علي الخدمات و التطبيقات في الشبكات اللاسلكية.

تتسم الشبكات الراديوية الإدراكية ببعض السمات المتميزة مقارنة بالشبكات التقليدية، مما يؤكد انه من الضروري إجراء المزيد من البحوث بشأن موضوعي تخصيص الموارد و التوزيع الزمني للطيف، وهما الموضوعان اللذان تم حلهما في الشبكات التقليدية.

نركز الاهتمام في هذه الرسالة علي الجدولة الزمنية الحزمية في نظام الراديو الادراكي الوحيد الخلية و الجدولة الزمنية في الوصلة الهابطة المتهأية لتطبيقات الزمن الحقيقي و غير الحقيقي مع الأخذ في الأعتبار نشاط المستخدم الرئيسي.

إن الخوازم المقترح يرضي النماذج المختلفة المرور استناداً الي مستوي جودة خدمات كل نوع من أنواع المرور، ومدي توافر الطيف. ولقد تم تقييم أداء الخوارزم المقترح من حيث العبورية و التأخير. ان هذا الخوارزم يقدم ضماناً أفضل لتحقيق جودة مرور في الزمن الحقيقي وكفاءة أعلي لأستخدام الطيف لأنظمة الراديو الإدراكي.

الفصل الاول من الاطروحة تناول مقدمة عن الدافع ومخطط للاطروحة. يتم في الفصل التاني مناقشة مفهوم شبكة الراديو الإدراكي. يعرض الفصل الثالث دراسة لتخصيص للموارد وخطط الجدولة أما في الفصل الرابع فيتم تقديم نموذج نظام الراديو الإدراكي بما في ذلك هندسة الشبكات و نموذج حركة المرور ونموذج القناة علاوة على تقديم مقترح ديناميكي لمخطط الجدولة و عرض نتائج محاكاة لتقييم أداء نظام الجدولة المقترح. وأخيرا، يستعرض الفصل الخامس أهم الاستنتاجات و يناقش نقاط العمل المستقبلية.

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القاهرة
كـلـية الهـنـدسة و الـتكـنولـوجـيا
قـسـم هندسة الالـكـترونـيات و الإتـصـالات

# جدولة الأولويات القائمة على الأنظمة الراديوية الإدراكية

إعداد

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