The Center for Wireless Studies (CWS)
Part One: A Long Engagement
• **CWS** was established in 2008 as a culmination of research efforts within Cairo University.

• **CWS** is heavily involved with the local regulatory body **NTRA** to give technical consultations to the regulator decision making process.

• **CWS** is involved in a variety of research lines that orbit around the communication system physical layer standard designs
  
  (LTE, WiMAX, Bluetooth, Zigbee, WiFi, DVB, …..)
The center for Wireless Studies CWS currently has 3 funded research projects:

- “System Design and Standard Contribution to WiMAX Standard Committee,” funded by the NTRA.

- “Micro-Coded Programmable Solution for OFDMA Wireless Applications,” funded by STDF.

- “Tool for Extensive Management and Performance Optimization (TEMPO) for 3G”, to be funded by NTRA.
Team Members

- Associate Professor Dr. Mohamed Khairy, PI
- Associate Professor Dr. Ahmed Shalash
- Assistant Professor Dr. Yasmine Fahmy  
  (since February 2009)
- Assistant Professor Dr. Omar Nasr  
  (since February 2010)
- Assistant Professor Dr. Rabie Ramadan  
  (since September 2010)
- Assistant Professor Dr. Karim Abbas  
  (since January 2011)
• **CWS** participated by submitting 17 contributions while attending 11 IEEE 802 standard meetings.

• **CWS** shared results with the standards group email reflector.

• **CWS** Attended the ITU-R WP5D (Working Party 5D) meeting to follow the submission of the WiMAX and LTE standards to the ITU.

• **CWS** active participation garnered wide praise and earned the right to host the IEEE 802 meeting.
Standard Contribution

- **CWS** invited IEEE 802.16's Session #61 to Cairo, Egypt.
  - (co-hosted by **NTRA** and **CWS**).

- **CWS** organized an orientation session to the participants from Egypt to acquaint them with the standardization process.

Dr. Roger Marks (Chair, IEEE 802.16) and Dr. Brian Kiernan (Chair, Task Group-m, IEEE 802.16) with CWS members during the meeting in Cairo, May 2009.
CWS output

• **CWS** published over 36 papers in reputable journals and conferences.

• **CWS** 25 students finished their M.Sc. Theses under the supervision of CWS members, 11 of which are doing their Ph.D. in the US and Canada.

• **CWS** is currently supervising 8 Masters theses.

• **CWS** supervised over 30 graduation projects, many of which earned visibility and recognition.
Publications (1)

- Mohamed A. El-Gendi, Omar A. Nasr and Mohamed M. Khairy, “Cooperative Multicasting Based on Superposition and Layered Coding,” IEEE GLOBECOM, 5-9 December 2011, Houston, TX, USA.


Publications (2)


Publications (3)


Publications (4)


Publications (5)


Publications (6)


Publications (7)


- Ahmed Gomaa, Mohammed Nafie, and Mohamed Abdallah “Novel Reliability-Based Hybrid ARQ Technique” IEEE GLOBAL COMMUNICATIONS CONFERENCE (IEEE GLOBECOM 2009), 30 November-4 December 2009, Hawaii, USA.


Publications (10)


Hoda Hafez, *Channel estimation and pilot design for MIMO systems*, successfully defended in November 2010.

Mai Hassan *Coordinated Multiple Points Transmission Precoder Design in Finite Capacity Backhaul*, to be defended in December 2011.

Mohamed Abobakr, *Cooperative Multicasting Based on Superposition and Layered Coding*, to be defended in 2012.

Alaa Awad *Cross-Layer Optimization for Delay-Sensitive Applications Multihop networks*, to be defended in December 2011.

Hanan Moharam Hassan, *ASIP engine for FFT/DCT/FIR functions*, to be defended in December 2011.

Mahmoud Abdelall, *ASIP engine for communications synchronization functions*, to be defended in December 2011.
Eid Abdelhamid, *Configurable Turbo Engine for multi-standard applications*, to be defended in December 2011.

Medhat Hamdy *Channel Estimation and Equalization by using micro-coded engines*, to be defended in December 2011.


Ahmed Hareedy, *Design and Implementation of Low Density Parity Check Codes*, to be defended in October 2011.

Assem Abdelhakim, *Channel Estimation Techniques in OFDM Systems*, successfully defended in April 2011.


The research conducted in CWS focuses on the next generation communications systems, both from communications theory point of view and system implementation point of view, such as:

- Advanced MIMO Techniques
- Cooperative transmission systems
- Cross layer design
- Design for Implementation of LTE and WiMAX Systems
- Design of reconfigurable engines for multi-standard implementation
Part Two: WiMAX and LTE
IEEE 802.16 is:

- A Working Group (WG):
  - The IEEE 802.16 Working Group on Broadband Wireless Access (since 1999)
  - Develops and maintain a set of standards
  - Evolves by amendments and revision
- The Working Group’s core standard
  - IEEE Std 802.16: Air Interface for Broadband Wireless Access Systems
  - The WirelessMAN® standard for Wireless Metropolitan Area Networks
IEEE 802.16 Evolution

- IEEE Std 802.16-2001 (fixed access)
- + 802.16a OFDM/OFDMA 2003
- IEEE Std 802.16-2004
- + 802.16j Multihop Relay 2009
- IEEE Std 802.16-2009
- + 802.16e Mobility 2005
- + 802.16h License-Exempt 2010
- + 802.16m “IMT-Advanced” 2011
Worldwide Participation

• Open process; everyone may participate
• Current 802.16 WG Membership: 226 people
• Actively seeks worldwide applicability
  • Seeks worldwide participation.
  • Attendees from Australia, Belgium, Brazil, Canada, China, Egypt, Finland, France, Germany, Greece, Hong Kong, India, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Pakistan, Romania, Russia, Singapore, Spain, Sweden, Taiwan, Thailand, USA, UK, etc.
• Major coordination with ITU-R
IEEE 802.16m Project

• Amendment project, initiated December 2006
• Scope:
  – amend the IEEE 802.16 WirelessMAN-OFDMA specification to provide an advanced air interface for operation in licensed bands
  – meet the cellular layer requirements of IMT-Advanced next generation mobile networks
  – continuing support for legacy WirelessMAN-OFDMA equipment (i.e., backward compatibility)
  – Provide performance improvements to support future advanced services and applications
• “WirelessMAN-Advanced” air interface
Participation in IEEE 802.16m

• Since 802.16m project began, 802.16 WG participation includes:
  – Over 1200 professionals
  – From about 240 organizations
  – From 23 countries

• Contributed documents to 802.16m Task Group
  – 2007: >300 documents
  – 2008: >1500 documents
  – 2009: > 2700 documents
  – 2010: > 1400 documents
IMT is:

- ITU Coordinated development of a global broadband multimedia International Mobile Telecommunication (IMT) system.
- IMT-2000 (3G)– implementation of first family of standards derived from IMT.
- Today 3G is widely deployed and being rapidly enhanced.
- “IMT-Advanced” - a global platform to build next generations of mobile services.
IMT-Advanced is:

• Radiocommunication Assembly (RA-07) (Geneva, Switzerland, 15 October-19 October 2007)
  • Consensus was reached to expand the IMT-2000 3G Radio Interface Family with OFDMA technology and to establish IMT-Advanced as the name for systems beyond IMT-2000.
  
• Developed around the year 2010, capable of supporting high data rates with high mobility.
  
• Deployment planned the year 2015 in some countries.
“IMT” Spectrum

• IMT-2000 Identifications
  – 800/900 MHz bands
  – 1700/2100 MHz bands
  – 2500-2690 MHz

• World Radiocommunication Conference 2007
  (Geneva, Switzerland, 22 October-16 November 2007)
  – Identified additional spectrum
    • 450-470 MHz globally
    • 2300-2400 MHz globally
    • 790-862 MHz in much of world
    • 3400-3600 MHz in much of world
  – changed spectrum identification to “IMT”
  – includes “IMT-2000” and “IMT-Advanced”
IMT-Advanced Submission

- Submissions received by October 2009:
  - 3GPP submitted LTE-Advanced air interface
    - Two other entities submitted proposals of the same technology: Administration of Japan and China (People’s Republic of)
  - IEEE submitted WirelessMAN-Advanced air interface
    - Two other entities submitted proposals of the same technology: Administration of Japan and TTA (Korean SDO)
IMT-Advanced Schedule

- 2010-10: approved two technologies for IMT-Advanced
- 2011-04: Review of detailed specifications of two technologies
- 2011-09: Transpositions due
- 2011-10: Final WP 5D agreement on IMT-Advanced standard
- 2011-11: Final Study Group 5 agreement
- 2012-02: ITU-R approval at Radiocommunication Assembly
Is IMT-Advanced = 4G?

• No.

• The development of IMT-Advanced was authorized by resolutions of the Radio communication Assembly

  – The term “4G” is not used.
Is IMT-Advanced = 4G?

• On 21 Oct 2010, ITU announced that WirelessMAN-Advanced and LTE-Advanced were “accorded the official designation of IMT-Advanced,” suggesting also that “IMT-Advanced” is the “true 4G.”

• On 6 Dec 2010, ITU revised its position on 4G:
  – 4G is “undefined”.
  – “4G may also be applied to” forerunner technologies, such as WiMAX
Following a detailed evaluation against stringent technical and operational criteria, ITU has determined that “LTE-Advanced” and “WirelessMAN-Advanced” should be accorded the official designation of IMT-Advanced. As the most advanced technologies currently defined for global wireless mobile broadband communications, IMT-Advanced is considered as “4G”, although it is recognized that this term, while undefined, may also be applied to the forerunners of these technologies, LTE and WiMAX, and to other evolved 3G technologies providing a substantial level of improvement in performance and capabilities with respect to the initial third generation systems now deployed. The detailed specifications of the IMT-Advanced technologies will be provided in a new ITU-R Recommendation expected in early 2012.
802.16m
Technical Review
IEEE 802.16m – Key Features

- New Subframe-based Frame Structure
- New Subchannelization Schemes and More Efficient
- Pilot Structures
- New and Improved Control
- Channel Structures
- Extended and Improved MIMO Modes
- Increased VoIP Capacity
- Multi-Hop Relay
- Femto BS
- Self-organization
- Multi-carrier Operation
- Interference Mitigation
- Multi-BS MIMO
- Improved Intra-RAT and Inter-RAT Handover
- Multi-Radio Coexistence
- Location Based Services
- Enhanced Multicast and Broadcast Service
<table>
<thead>
<tr>
<th>Requirements</th>
<th>IMT-Advanced</th>
<th>802.16m SRD</th>
</tr>
</thead>
</table>
| Peak spectral efficiency (b/s/Hz/sector)         | DL: 15 (4x4)  
UL: 6.75 (2x4)                                 | DL: 8.0/15.0 (2x2/4x4)  
UL: 2.8/6.75 (1x2/2x4)                          |
| Cell spectral efficiency (b/s/Hz/sector)         | DL (4x2) = 2.2  
UL (2x4) = 1.4  
(Base coverage urban)                           | DL (2x2) = 2.6  
UL (1x2) = 1.3  
(Mixed Mobility)                                 |
| Cell edge user spectral efficiency (b/s/Hz)      | DL (4x2) = 0.06  
UL (2x4) = 0.03  
(Base coverage urban)                           | DL (2x2) = 0.09  
UL (1x2) = 0.05  
(Mixed Mobility)                                 |
| Latency                                          | C-plane: 100 ms (idle to active)  
U-plane: 10 ms                                   | C-plane: 100 ms (idle to active)  
U-plane: 10 ms                                   |
| Mobility b/s/Hz at km/h                          | 0.55 at 120 km/h  
0.25 at 350 km/h                                 | Optimal performance up to 10 km/h  
“Graceful degradation” up to 120 km/h  
“Connectivity” up to 350 km/h  
Up to 500 km/h depending on operating frequency |
| Handover interruption time (ms)                  | Intra frequency: 27.5  
Inter frequency: 40 (in a band)  
60 (between bands)                               | Intra frequency: 27.5  
Inter frequency: 40 (in a band)  
60 (between bands)                               |
| VoIP capacity (Active users/sector/MHz)          | 40 (4x2 and 2x4)  
(Base coverage urban)                           | 60 (DL 2x2 and UL 1x2)                          |
## Significant Improvement in Peak Rates

<table>
<thead>
<tr>
<th></th>
<th>802.16e (From [1])</th>
<th>802.16m (From [2])</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bandwidth, CP</strong></td>
<td>10MHz, 1/8</td>
<td>20MHz, 1/16</td>
</tr>
<tr>
<td><strong>Streams</strong></td>
<td>DL:2, UL:2</td>
<td>DL:4, UL:2</td>
</tr>
<tr>
<td><strong>Overhead</strong></td>
<td>3 symbols + pilot</td>
<td>1 symbol + pilot</td>
</tr>
<tr>
<td><strong>TDD DL : UL</strong></td>
<td>2 : 1</td>
<td>2 : 1</td>
</tr>
<tr>
<td><strong>DL MCS</strong></td>
<td>64QAM, 5/6</td>
<td>64QAM, 1</td>
</tr>
<tr>
<td><strong>UL MCS</strong></td>
<td>16QAM, 3/4</td>
<td>64QAM, 1</td>
</tr>
<tr>
<td><strong>DL Peak [Mbps]</strong></td>
<td>40.32</td>
<td>226.1</td>
</tr>
<tr>
<td><strong>UL Peak [Mbps]</strong></td>
<td>10.08</td>
<td>61.5</td>
</tr>
</tbody>
</table>
India:
- June 2010, ISP Infotel, now owned by Indian industrial conglomerate Reliance Industries and the lone winner of a nationwide license, announced its intentions to deploy TD-LTE in the 2.3 GHz band.
- Qualcomm (NASDAQ:QCOM) won four service areas and had already announced its intention to deploy TD-LTE.

China:
- China Mobile “is keen on becoming the first in the world to deploy TD-LTE and will begin market trials in several cities.”

Russia:
- WiMAX Russian operator Yota announced plans to deploy LTE instead of WiMAX in the rest of its markets.
Part Three : Moving Forward
Cooperative Multicasting

- Multimedia broadcast and multicast have been attracting great attention in the last few years.
- Efficient transmission algorithms that utilize the system resources to serve the subscribers are needed.
- The dynamically changing characteristics of the wireless channels along with the multipath fading and path loss make each multicast groups’ subscribers experience different channel conditions.
- The diverse channel conditions of multiple subscribers in the multicast group makes it a challenge to adapt the transmission rate to satisfy all group members and improve the total group throughput, simultaneously.
Cooperative Multicasting Based on Superposition and Layered Coding

- In the first phase, the Base Station (BS) broadcasts a composite message.
- Most of the subscribers in the multicast group will decode the base message and the subscribers who experience better channel conditions will decode the enhancement message as well.
- In the second phase, a fraction of the subscribers who decoded the first enhancement message, cooperatively transmit the first enhancement message to the subscribers who failed to decode it.
- The remaining subscribers who successfully received the first enhancement message will not participate in the cooperative transmission and will receive a second enhancement message transmitted by the BS.
Cooperative Multicasting

**Phase 1**
- Base station transmit $B_1$ superimposed with $E_1$
- $N$ subscribers decode $B_1$ and $E_1$
- $M-N$ subscribers decode $B_1$

**Phase 2**
- Base station transmit $E_1$ superimposed with $E_2$
- $N_L$ relays forward $E_1$
- $M-N$ subscribers Decode $E_1$
- $N_H$ subscribers Decode $E_2$
Throughput

\[ TH \times (T_1 + T_2) = T_1 R_{B1} p(SNR_b > 2^{R_{B1}} - 1) \]

\[ + \ T_1 R_{E1} p(SNR_e > 2^{R_{E1}} - 1 / SNR_b > 2^{R_{B1}} - 1) \]

\[ + \ T_2 R_{E1} \sum_{N=1}^{M-1} \begin{pmatrix} M \\ N \end{pmatrix} (p(SNR_e < 2^{R_{E1}} - 1))^{M-N-1} \]

\[ \times \ \sum_{N_L=1}^{N} \begin{pmatrix} M \\ N \end{pmatrix} \frac{M-N}{M} (p(SNR_e > 2^{R_{E2}} - 1))^{N-N_L} \]

\[ \times \ p(\zeta > 2^{R_{E1}} - 1) \prod_{j \in S_{NL}} p(2^{R_{E1}} - 1 < SNR_e < 2^{R_{E2}} - 1) \]

\[ + \ T_2 R_{E2} p(SNR_e > 2^{R_{E2}} - 1 / SNR_b > 2^{R_{B1}} - 1) \]
Multi-User Cross-Layer Optimization over Multihop Mesh Networks

**Aim**
Minimizing the total transmission energy in the network

**Challenges**
Delay constrain. Interference.

**Apply in**
Wireless Multihop Mesh Network

**Using**
Cross-Layer Optimization

Diagram: Network topology with sources, destinations, intermediate nodes, and hops.
Cross-layer architecture

Transmitters

- Application layer
- Network layer
- Link layer
- Physical layer

Cross-Layer Server

- Delay constraints
- Routing
- Scheduling
- Maximum possible Tx power
- Modulation & Transmitted power

Receivers

- Physical layer

Channel Condition
Optimization Problem

- Delay constraint
  \[ \sum_{j=1}^{K} \sum_{i=1}^{N} t_{ij} \leq D_l \]

- The problem of minimizing the total transmission energy can be written as
  \[
  \min \left( \sum_{j=1}^{K} \sum_{i=1}^{N} \frac{l_j}{r_{ij} x_{ij}} \left(2^{r_{ij}/w} - 1\right) \right)
  \]
  such that
  \[ \sum_{j=1}^{K} \sum_{i=1}^{N} \frac{l_j}{r_{ij}} \leq D_l \]
Proposed algorithm

- Cross layer optimization framework is proposed.
- Considers explicit delay deadline as one of its parameters.
- A mixed TDMA-simultaneous transmission scheduling scheme, that minimizes the total transmission energy is proposed.
- Optimal (high complexity) and sub-optimal (lower complexity) schemes are proposed.
Coordinated Multi-Point (CoMP)

- CoMP can dramatically improve the system performance by allowing user data to be jointly processed by several interfering base stations to mitigate their inter cell interference.
- The achievement of these gains largely depends on the amount of channel state information available at the cooperative base stations.
- For this purpose, limited feedback techniques, that employ codebook-based quantization, are used in CoMP transmission to convey the Channel State Information (CSI) between base stations.
CoMP types

- **Coordinated BeamForming (CB):** the perfect channel knowledge at the BSs is required to be shared among all cooperative points in transmission.

- **Joint Processing (JP) transmission:** the data stream of the MS in addition to the channel state information (CSI) are required to be shared.

- Such feedback requires infinite backhaul capacity to carry the shared CSI among BSs and between MSs and BSs.

- Such infinite capacity is not practical and therefore, different quantization techniques are considered.
Random Vector Quantization is used with the codebooks to choose a channel representation.

The use of RVQ results in a phase ambiguity problem that severely degrades the performance of the system.

We proposed a novel techniques to avoid the phase ambiguity problem and significantly improve the performance.
CB CoMP

BS1 Interference signals

Limited Backhaul Link

BS1 Useful signals

BS2

MS4

MS3

MS2

MS1

d_{12}

d_{13}

BS1

d_{11}
Each base station is assumed to have perfect knowledge of its own users’ channels.

A user in the second cell estimates the channel between himself and cell 1 base station.

The estimates are transferred to the base station of the second cell, and then these channel estimates are conveyed through the backhaul to cell 1 base station to do coordinated beamforming.
CB CoMP

- However, due to the limited backhaul bandwidth, only quantized versions of the channels may be exchanged between the coordinating basestations.
- Even with coordinated ZF beamforming, the users whose channels were quantized will suffer from interference due to quantization.
- This quantization interference is what is left from the multi-cell interference and is still the major limit for the system performance.
Limited Backhaul Optimization

- Proposed considering Fairness as a criterion to allocate backhaul bits allocation among users.
- Introduced two novel, low complexity, backhaul bandwidth distribution schemes that can achieve a very close to maximum sum rate, and at the same time, offer throughput fairness among users.
Vision

- To work on application oriented advanced research in the wireless communications arena
- To provide forum for Cairo University graduate students to earn degrees with world class research contributions
- To energize the local industry connection with the state-of-the-art in the wireless technology
Acknowledgment

The NTRA support was a real catalyst in making CWS a reality, and allowing CWS to make the impact it did both in the standardization groups and the research contribution highlighted by the papers published from CWS.