MIMO – OFDM WIMAX for Commercial Networks in Urban Environment

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Abstract: The demand for global connectivity and seamless data and voice services on-the-go has increased the requirements for all data-centric applications and accessibilities irrespective of geographical location. New systems and standards are in a phase of continuous evolution. They will finally bring the information services provided by the Internet and the World Wide Web to mobile users, together with a variety of new multimedia entertainment services. Mobile Communication Technology 1st Generation (AMPS), 2nd Generation (GSM), even 2.5 Generation (GPRS & EDGE) could not fulfill the rising need for greater data rates to support real-time applications. Even 3rd Generation (UMTS) which is currently being roll-out in most of the world does not provide data rates high enough to support real-time applications. Need for 4th Generation Mobile Communication (LTE & WiMAX) is growing resulting into new standards being set for Mobile Communication Evolution for complete IP-Based network support. In this paper we explore the possible suitability of implementing and applying MIMO-OFDM in an urban environment.

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Introduction:

Performance of "MIMO" system depends on several factors such as Nature of environment [Morphology], Location of users [LoS, NLoS], Type of users [Static, Pedestrian, Mobile], and CPE Capabilities [Support for "MIMO" features, measurement and switching criteria]

For our case study we choose Kuala Lumpur City Center for the following reasons:

- Dense Urban environment of Kuala Lumpur City Center was selected as morphology to exploit diversity gain of Radio Frequency Signals.
- Sub-Urban environment of Kuala Lumpur surrounding area was selected as morphology to fine-tune MIM-A & "MIMO-B" switching criteria.
- 3 x 10 MHz channel in WiMAX band (2.3 GHz)
- TDD [2:1] with "MIMO-OFDM" deployed
- 2 x 2 "MIMO" Antennas were deployed
- DBF was also experimented to establish technology comparison for dense-urban, urban and sub-urban morphologies.
- Field Measurement was performed using Couei X-Cal (Field Measurement) & X-Cap (Post-Processing) tools.
- Statistics monitoring and analysis was based on Alcatel-Lucent NPO tool.

2. MORPHOLOGY ANALYSIS

Kuala Lumpur City Center provides ideal morphology for "MIMO-OFDM" air-interface features as it provides rich scattering environment [1,2].

It provided following Mobile Subscriber Station (MSS) case studies:

- Micro Cell Deployment where multi-path effect is guaranteed
- Outdoor sites serving indoor users
- Macro Deployment: Dense urban environment with NLOS conditions

SWITCHING ALGORITHM BETWEEN MIMO-A & MIMO-B

- Mode selection was completely CPE decision based on radio-conditions
- Weights were assigned to following radio parameters for switching:
  - Signal Correlation Level
  - Fading Conditions
  - Downlink CINR
- Base Station may modify MSS choice by computing best combination of:

  - Mode selection
  - Modulation & Coding Scheme (MCS)
- In Low DL CINR (Cell Edge, bad RF conditions) "MIMO-A" is always chosen by CPE for its robustness
- After network entry, CPE is directed first to "MIMO-A" for connection stability.
- CPE measures DL channel based on common pilots and determines preferred "MIMO" mode, and reports to WBS.
- WBS directs CPE to requested mode
- Pilots are boosted with respect to data subcarriers

3. TRIAL RESULTS

Implementation of "MIMO-OFDM" for commercial WiMAX network provided significant improvement in air-interface and data rate performance e[2].

RSSI & CINR Improvement:

"MIMO-A" is major contributor towards improvement in signal strength and TX-Diversity resulting in interference cancellation. Significant improvement was observed thus insuring better coverage for dense urban indoor users and week-coverage users at cell coverage boundaries [2,3].

PER Improvement:

"MIMO-A" significance in terms of robustness of system is evident from following chart. "MIMO-OFDM" integration resulted in constructive combination of signal arriving from scattered diffracted paths resulted in reduction in Packet Error Rate [2,3].

Uplink Transmit Power Reduction:

Although significance of "MIMO" technique is for Downlink channel improvements, but reduction in Uplink Power transmitted by CPE was observed, pointing to that fact that Uplink Radio Conditions had also improved [3,4].

Throughput Enhancement:

Both "MIMO-A" & "MIMO-B" contributed in improvements in total traffic generated by WiMAX commercial users. "MIMO-A" resulted in improvement in cell-edge coverage and network entry, thus resulting in increase in number of users connected, whereas, "MIMO-B" resulted in better usage of MCS and data-slots, thus generating increased throughput per user.

Throughput based on MCS Distribution was calculated based on following method:

Link Capacity =	**Frames per second* Slots per frame* bytes*8**

MCS	Useful Bytes per Slot	No. of Frames per Second	DL No. of slots per frame	UL No. of slots per frame	DL Capacity (kbps)	UL Capacity (kbps)
QPSK1/2	6	200	390	140	3744	1344
QPSK3/4	9	200	390	140	5616	2016
16QAM1/2	12	200	390	140	7488	2688
16QAM3/4	18	200		140		4032
64QAM1/2	18	200	390		11232	
64QAM2/3	24	200	390		14976	
64QAM3/4	27	200				
64QAM5/6	30	200	390		18720	

UL Max Capacity:	(QPSK1/2% * 1344) + (QPSK3/4% * 2016) + (16QAM1/2% * 2688) + (16QAM3/4% * 4032)
DL Max Capacity:	(QPSK1/2% * 3744) + (QPSK3/4% * 5616) + (16QAM1/2% *7488) + (64QAM1/2% * 11232) + (64QAM2/3% * 14976) + (64QAM5/6% * 18720)

4. FIELD MEASUREMENT RESULTS:

Drive-test was performed using Couei WiMAX Air Interface Measurement Tools for Sub-Urban areas of Kuala Lumpur to get a better understanding of switching between "MIMO-A" & "MIMO-B". Due to tough road-conditions, Drive-test couldn't be

performed for Kuala Lumpur City Center Dense Urban Areas [5, 6].
Field measurement results show that for selected suburban environment 25% of drive test route was "MIMO-A" selective and 75% of drive test route was "MIMO-B" selective.
This distribution can vary from case to case based on the morphology and drive test speeds.

Drive test results show that:

- ~52% less slots used with "MIMO-B" vs. "MIMO-A"
- 25% overall better spectral efficiency in "MIMO-B" vs. "MIMO-A"
- Optimization of Burst-Profile thresholds leads to 38% spectral efficienc

MIMO comparison with DBF

Dynamic Beam-forming [4x4]	Adaptive "MIMO" switching [2x2]
Better suitable for suburban and rural environment	Improvement in coverage in dense urban / microcellular / indoor / hot-spot environment (rich scattering)
Coverage improvement for both Uplink and Downlink	Link reliability and robustness in downlink.
Capacity improvement for both DL & UL	Capacity improvement in DL only
No degradation with high user mobility	Preferred low to medium mobility users
Capacity improvement = ~16%	Capacity improvement = ~ 50%

5. Scope of MIMO-OFDM in Future Wireless Networks

Classification of growth markets

Market growth and subscriber trends are soul motivation forces for technological evolutions. Mobile commerce is expanding and evolving more rapidly than internet commerce. It relates directly to user preference to carry out preferred data-centric activities irrespective of time and place.
Following are the potential classes demanding higher data rates from wireless networks [3,7].

Home Environment:
The massive use of high quality multimedia applications (streaming audio and video, with data rates in excess of several tens of Mbps) for numerous users is one reason for the anticipated need of very high bit rates. Other key requirements in this area are self configuration and zero maintenance features as well as low transmit powers, to minimize exposure of humans to electromagnetic radiation.

Office and Enterprise Environment:
WLAN solutions available to date already enabled office staff to work detached from its desk. However, with high number of users accessing a single access point and 100 Mbps Ethernet being state of the art, peak data rates can be expected to be in the order of 1 Gbps. Moreover, core business applications such as Voice over IP and video conferencing demand very high Quality of Service [3].

Hot Spot / Public Access Environment:
Large scale coverage in a future heterogeneous wireless access network will be provided by next generation cellular networks whereas high data rate access in urban and hot spot environments will be provided by short range wireless systems. Expected high variations in user data rates and differing service requirements call for a highly flexible MAC. In order to enable user mobility, the system will have to interoperate with other Beyond-3G standards [4,7].

MIMO-OFDM: Enabling New Wireless LAN Applications and Markets

First major success for wireless LANs was due to vertical industrial applications but after it being shared by broadband access for small businesses & homes and embraced by PC Networking, its market exploded.

Currently, hundreds of millions of wireless LAN nodes are shipped annually. Home entertainment applications present the opportunity to sell even greater number per year.
Cordless VoIP and video conferencing is estimated to be the greatest consumer market of the future driving technology trends [7]. These could enable strategic

alliances and mergers between mobile phone and cable network operators.
Similarly, Machine-to-Machine [M2M] applications are also discovering new markets like asset monitoring, mobile commerce, health-care, homeland security and real-time enterprise communication.

"MIMO-OFDM" could prove to be a key enabler in all of these markets. Some applications require high data rates; others demand real-time low-latency streaming which are key strengths of "MIMO-OFDM" based networks [5]. This technology is not just major technology upgrade for WLANs, rather a technology upgrade which would facilitate improvements in existing applications and address new huge market potential.

MIMO-OFDM: Evolution path for Broadband Wireless Networks

"OFDM" System's ability to handle common radio frequency distortions without involving complicated algorithms and equipment has made it a preferred modulation scheme for wireless networks. During recent years, it has successfully been deployed to Wireless LANs, WiMAX broadband internet and Broadcasting [DVB].
"MIMO" has already been standardized for HSDPA and WCDMA. WiMAX broadband and 3G [UMTS] mobile networks have already opted for "MIMO" as an optional mode to enhance performance and capacity of their networks. "MIMO-OFDM" is being proposed and implemented as part of feasibility study for 3GPP LTE [Long Term Evolution – regarded as 4th Generation of Broadband wireless networks] standard.
Majority of telecom companies round the world prefer "OFDM" based downlink for 3GPP LTE. Telecom Giants like Nortel, Ericsson, Motorola, Siemens and Alcatel-Lucent are developing system and architecture to support "MIMO-OFDM". Some have performed Lab-Tests with promising results. Some like Alcatel-Lucent have even started Trial-Implementations on large scale commercial networks as well. This confirms a bright future for "MIMO-OFDM".

5.1 FUTURE RESEARCH AREAS

Following are few areas where "MIMO-OFDM" needs further research and evaluation:

- Co-optimization of "MIMO" and "OFDM" modules
- "MIMO-OFDM" decoding and decompression
- Optimal methods for lowering algorithmic and architectural complexity
- Reduction of power consumption for "MIMO-OFDM" systems
- Uplink improvements for robustness and spectral efficiency of "MIMO-OFDM"
- Exploitation of "MIMO-OFDM" for 4G Wireless Networks – LTE

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