Proposal for Link Adaptation via Network Coding in IEEE 802.16m

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*<http://standards.ieee.org/faqs/affiliationFAQ.html>

Re: IEEE 802.16m-08/024 – Call for Contributions on Project 802.16m System Description Document (SDD), on the topic of "Link Adaptation Schemes"

Purpose: Adopt the proposal into the IEEE 802.16m System Description Document

Scope

- This contribution presents a MIMO-based network coding scheme for bi-directional communication in IEEE 802.16m

IEEE 802.16m System Requirements

- The TGm SRD (IEEE 802.16m-07/002r4) specifies the following requirements:
  - Section 7.1 User Throughout
    - The downlink/uplink average user throughput and cell-edge user throughput need to be doubled.
  - Section 6.2 Latency
    - Latency should be further reduced as compared to the WirelessMAN-OFDMA Reference System for all aspects of the system including the air link, state transition delay, access delay, and handover.
- The proposed design targets the above requirement.

Introduction (1/2)

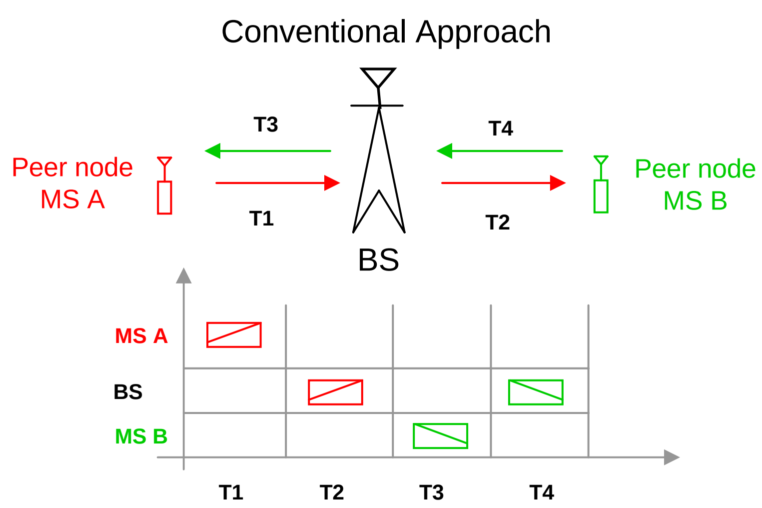
- What is network coding (NC)?
  - Definition: Mix incoming information
  - Network coding increases multicast throughput in wireline network
- What is wireless network coding?
  - The marriage of network coding and wireless multicast transmission increases unicast throughput of bidirectional traffic.

Introduction (2/2)

- Why network coding for 16m link adaptation?
  - Bi-directional communication (e.g., VoIP and gaming) has great potential in future wireless networks. In many cases, bi-directional communication is within the same cell.
  - Air link transmissions, including coding schemes, should be adaptive and optimized to support bi-directional communication.
  - Wireless network coding technique enhances throughput and reduces delay for bi-directional communication.

Conventional Approach of Bi-directional Communication between Users

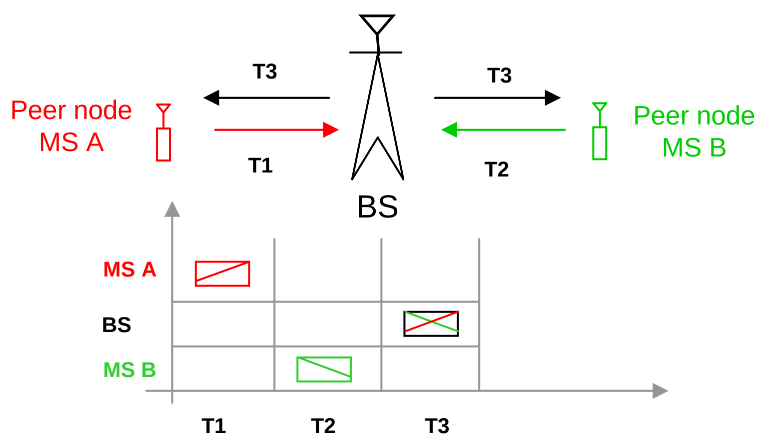
- Conventional Approach
  - Take 4 resource units (e.g. time slots) to finish the information exchange between mobile station (MS) A and mobile station (MS) B.



Proposed Approach for Bi-directional Communication (1/2)

- Network Coding
  - At time 1, MS A sends information a
  - At time 2, MS B sends information b
  - At time 3, base station (BS) decodes, mixes x = (a+b) mod 2, and multicasts information.
  - MS A receives x, and decodes b = (x+a) mod 2
  - MS B receives x, and decodes a = (x+b) mod 2
  - It takes three resource units (e.g., time slots) to finish the information exchange.

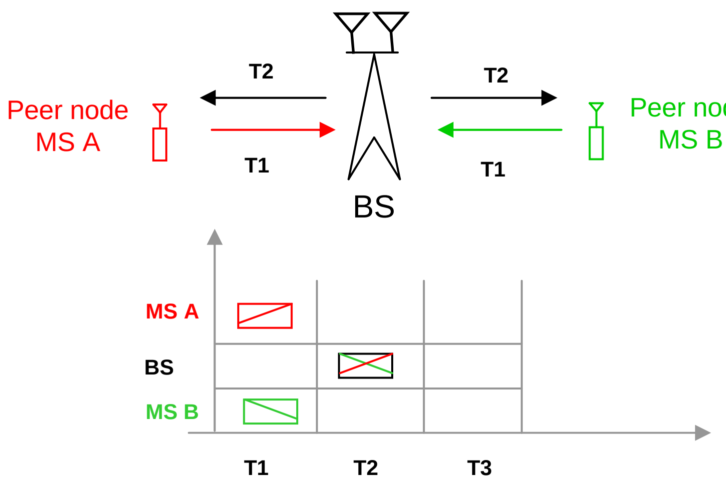
SISO Network Coding



Proposed Approach for Bi-directional Communication (2/2)

- MIMO Network Coding
  - When multiple antennas are equipped at a base station (BS), BS receives multiple streams from different mobiles via uplink link adaptation.
  - BS decodes and mixes the information via network coding.
  - BS multicasts information in downlink.
  - It could take as small as 2 resource units (e.g., time slots) to finish the bi-directional information exchange.

MIMO Network Coding



Control Signaling

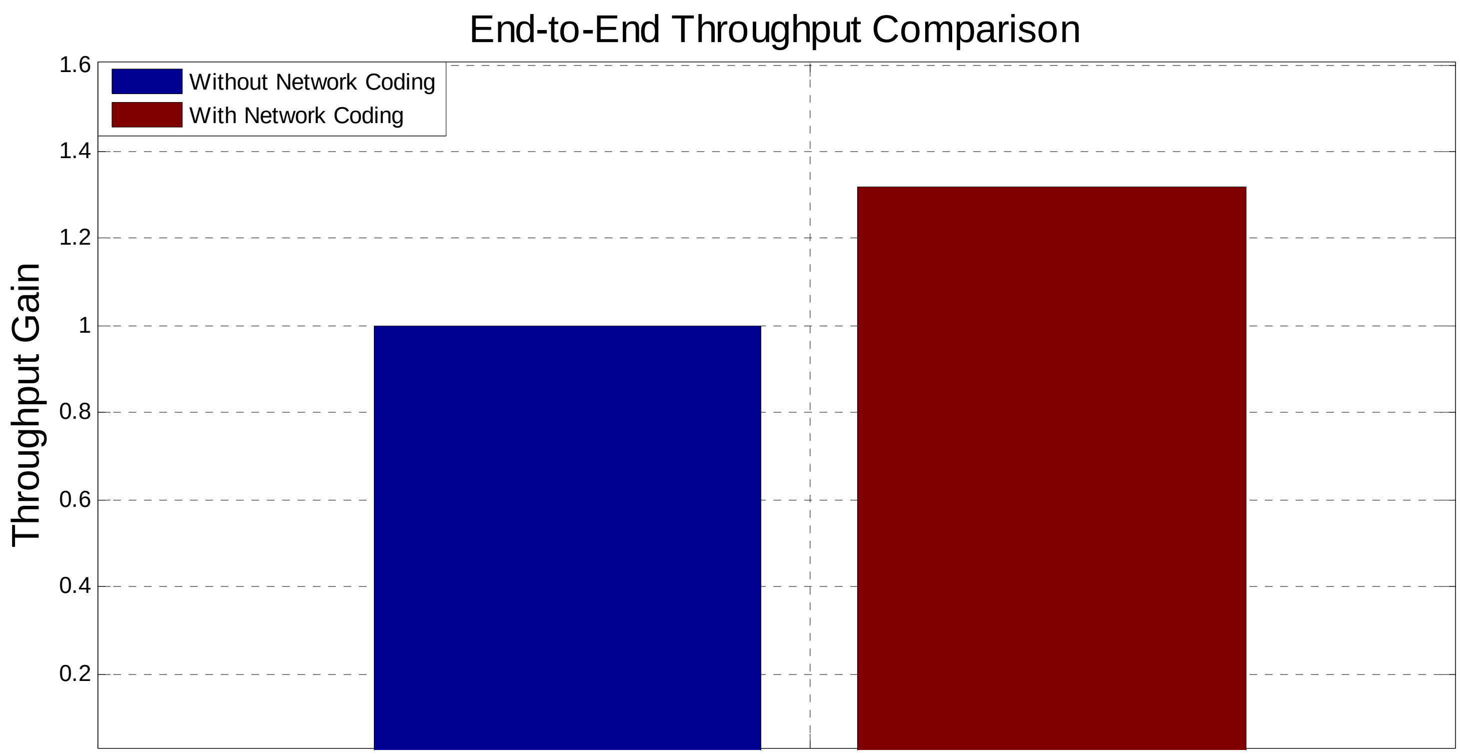
- Uplink transmission is same as usual
- Downlink transmission is multicast to two users with common data information.
  - User pair ID is assigned to the two users
  - Control information is multicast to both users. It contains
    - Number of layers
    - MCS per layer
    - Indication of whether network coding transmission is enabled
    - Encoder packet ID used for network decoding by each user
- Both diversity and localized channelizations are supported.
- Both open-loop and close-loop are supported.

System-Level Performance Evaluation (1/2)

- Simulation Assumptions*
  - 57 sectors, each sector has 24 users.
  - Randomly group two users into one bi-directional communication pair, therefore 12 pairs per sector.
  - Scheduler is pair-based round robin. In order to maximize the opportunity to perform network coding on user pairs, the BS ensures that the receiver buffer at BS contains sufficient data for the user pair.
  - Adaptive collaborative MIMO for uplink, and STTD for downlink.
  - Performance metric is the end-to-end throughput for each pair.

* Detailed simulation assumptions are listed in appendix.

System-Level Performance Evaluation (2/2)



Summary

- Network coding technique enhances the throughput of bi-directional communication.
- Network coding technique reduces the delay of bi-directional communication.

Proposed Text for SDD

- Section 11.x: Link Adaptation
  - Section 11.x.1 Network Coding
    - For bi-directional communication within a cell, base station encodes multiple incoming streams from multiple users in uplink, and multicasts the encoded information to those users in downlink.

Appendix
Simulation Assumptions & Parameters (1/4)

Parameters	Value
Number of cells	19
Number of sectors per cell	3
Total number of sectors	57
BS-BS distance	1.5 km
Center frequency	2.5 GHz
Channel bandwidth	10 MHz
Frequency reuse	Reuse-1
BS transmission power/sector	46 dBm
BS height	32 m
BS antenna pattern	70º (-3dB) with 20 dB front-to-back ratio
BS antenna gain	17 dBi
MS transmission power/sector	23 dBm
MS height	1.5 m
MS antenna pattern	Omni directional
MS antenna gain	0 dBi
MS Noise Figure	7 dB
Penetration loss	10 dB
Hardware losses (Cable, implementation, etc.)	2 dB

Simulation Assumptions & Parameters (2/4)

Slow fading	
Path loss model	Loss (dB) = 130.62 + 37.6log10(R) (R in km)
Lognormal shadowing	μ=0 dB, σ_{SF} =8 dB
Shadowing correlation	100% inter-sector, 50% inter-BS
Fast fading	
Channel model	ITU PB3
Time correlation	Jakes spectrum
Spatial model (MIMO)	
Spatial correlation	specified as in 16m EMD (none correlation) with 4 wavelength antenna spacing

Simulation Assumptions & Parameters (3/4)

Parameters	Value
Frame duration	5 ms
DL/UL OFDM symbols	24 DL symbols and 24 UL symbols
Control overhead per DL/UL sub-frame	9 DL control symbols and 3 UL control symbols
Channelization	Localized
BS antenna number	2
MS antenna number	1 for transmission, 2 for receiver
DL transmission scheme	STTD
UL transmission scheme	Virtual MIMO
Number of strong interferers	57
Initial PER	10%
HARQ type	Chase combining
Maximum number of HARQ retransmissions	4
PHY abstraction	Shannon

Simulation Assumptions & Parameters (4/4)

Parameters	**Value**
Number of active users per sector	24 users (12 pairs)
Traffic type	Full buffer
Scheduling algorithm	Pair-based Round Robin, within each pair UL: Shortest Queue Highest Priority
Uplink power control	Fractional power control
CQI feedback delay	2 frames
CQI feedback error	0.0
CQI feedback period	1 frame
Channel Estimation	Ideal