

# Giga-bit WLAN:

## Areas with Potential for Breakthrough

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# Outline

- Spectrum Sharing & More Spectrum Sharing!
  - 1 Gbits/sec in 4 Key Network Configurations:



Uplink=Multiple  
Access Channel



Down-link=  
Broadcast Channel



Parallel Links=  
Interference Channel



Channel with feedback=  
Two-way Channel

- Is Coding & Modulation Dead? Never!

# Main Message

- MIMO with better Frequency Reuse:  
***Interference Management*** (instead of ***Interference Avoidance***)
  - TDM/FDM is NOT the right choice
- Closer Attention to Fundamentals
  - Cross Layer Design
  - Network Information Theory

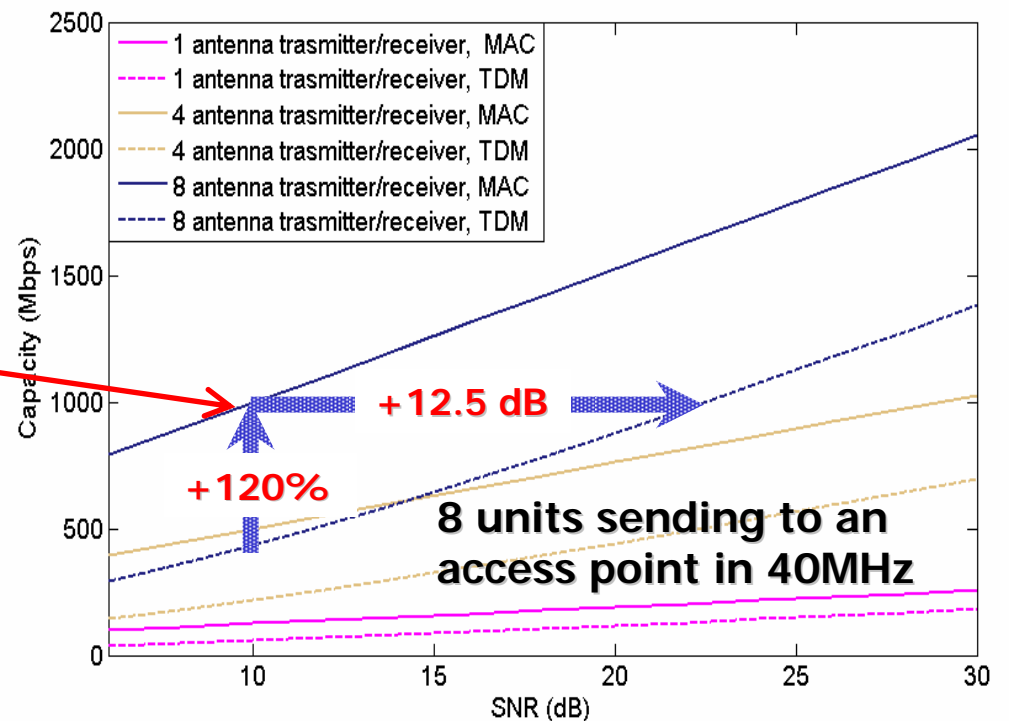
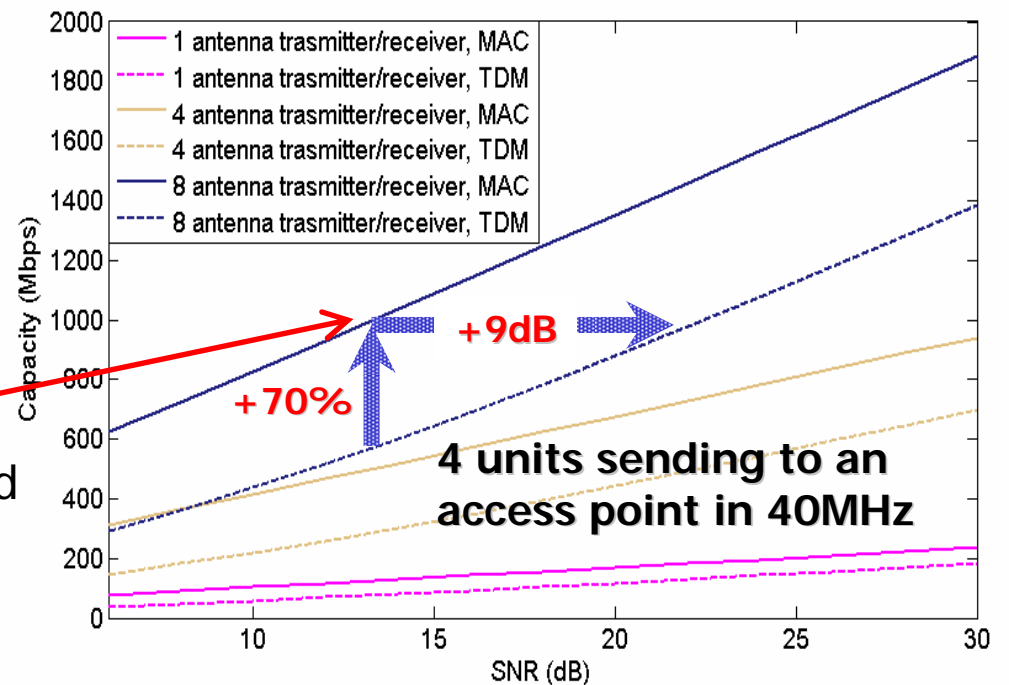
## Multiple Access Channel: Interference Cancellation, Joint Detection



1Gb/sec @  
**13.5dB** vs.  
**22.5dB** obtained  
with 8x8 MIMO  
and TDM/FDM



1Gb/sec @  
**10.0dB** vs.  
**22.5dB** obtained  
with 8x8 MIMO  
and TDM/FDM



# Advantages of MIMO

- Multiplexing Gain (MG):  $Rate \sim MG \times W \times \log(SNR)$ 
  - $MG$  shows an effective increase in bandwidth
- Diversity Gain (DG):  $P(error) \sim SNR^{-DG}$ 
  - $DG$  determines reliability when CSI is not available at the transmitter
- MIMO breakthrough:  
 $K \times K$  MIMO offers  $MG = K$  or  $DG = K^2$   
and a variety of **tradeoffs** in between

## Forgotten Link: Bandwidth

- People got so excited about MIMO that forgot the effect of bandwidth ( $MG \times W$ ) in the effective rate:

$$Rate \sim \underline{MG \times W} \times \log(SNR)$$

- Traditional view in a point-to-point system:
  - There is a tradeoff between  $MG$  and  $DG$  for a fixed  $W$
- Correct view in a network of links:
  - In addition to the tradeoff between  $MG$ ,  $DG$ , there is a tradeoff between  $W$  and  $SNR$
  - Bandwidth allocation should be taken into account

# MIMO Broadcast Channel:

## Space Division Multiple Access (SDMA)

- **Main result:** A system with  $K$  transmit antennas support  $MG = K$  if the total number of receive antennas is at least  $K$ 
  - Same  $MG$  as a point-to-point MIMO
- Disadvantage vs. point-point MIMO:
  - Transmitter needs to know the channel to all receivers
- Advantages vs. point-point MIMO:
  - Rich scattering as each receiver is at a different location
  - Low complexity receivers
    - Each receiver receives a fraction of the total rate

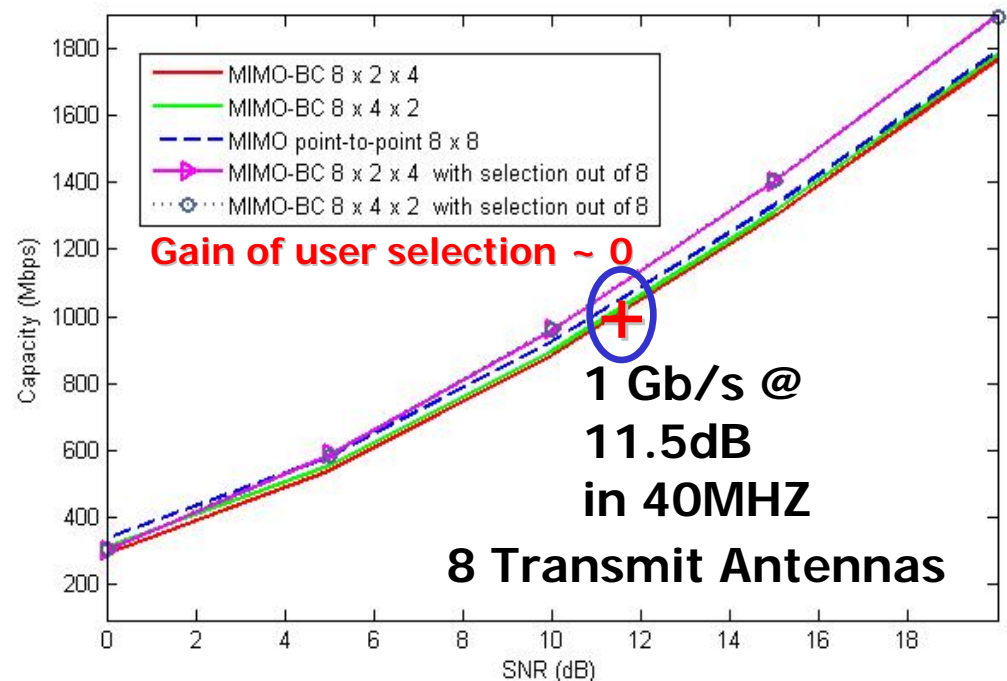
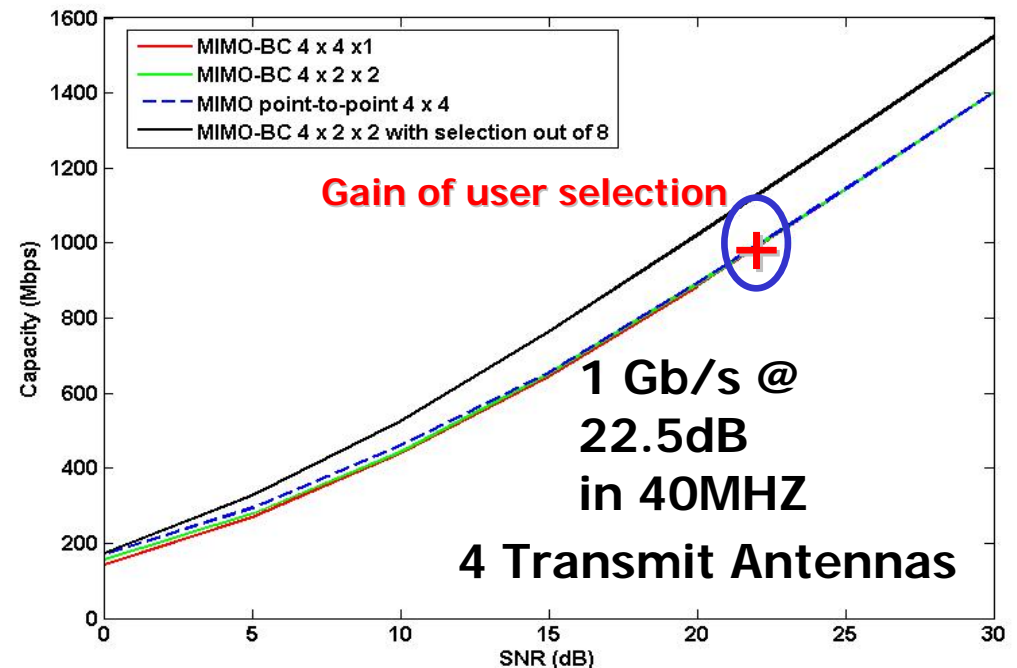


# MIMO-BC=SDMA



## Observations:

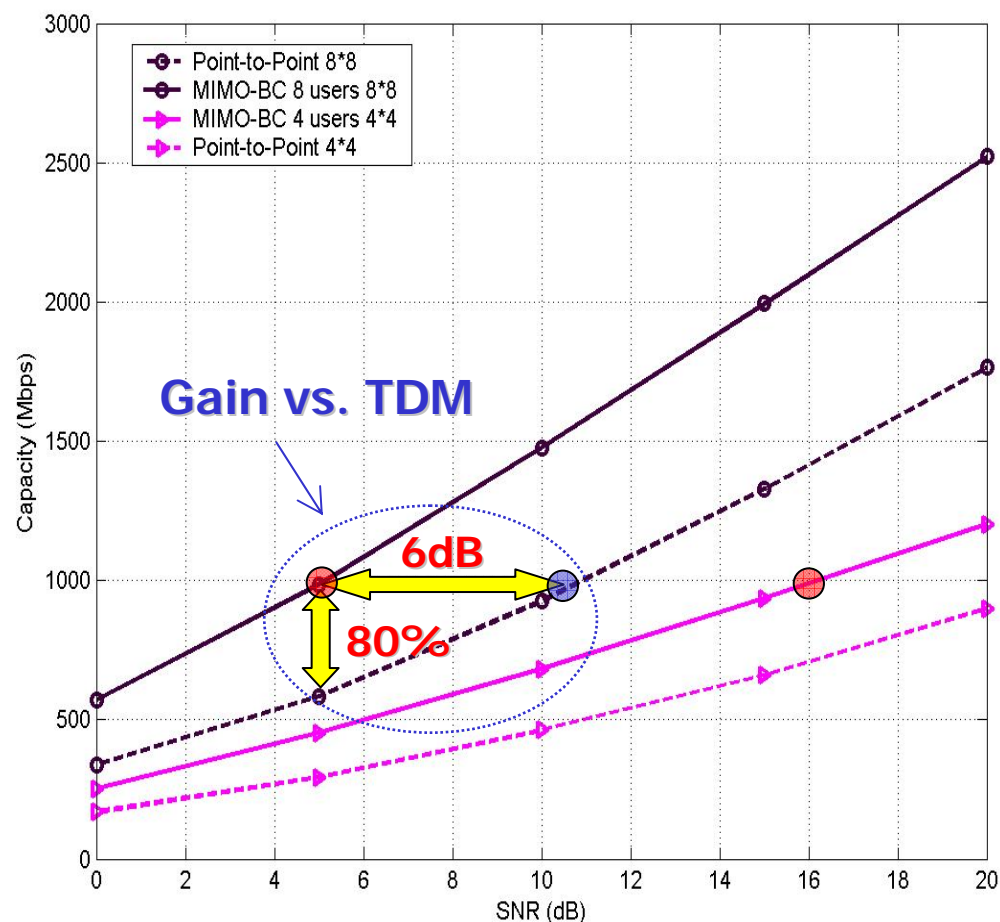
- Perform almost the same as point-to-point MIMO
- Various configurations provide almost the same gain as log as the total number of receive and transmit antennas are the same
- User selection (multi-user diversity) does not help much





# A More Promising Case in MIMO-BC: Transmitters/Receiver units have Equal Number of Antennas

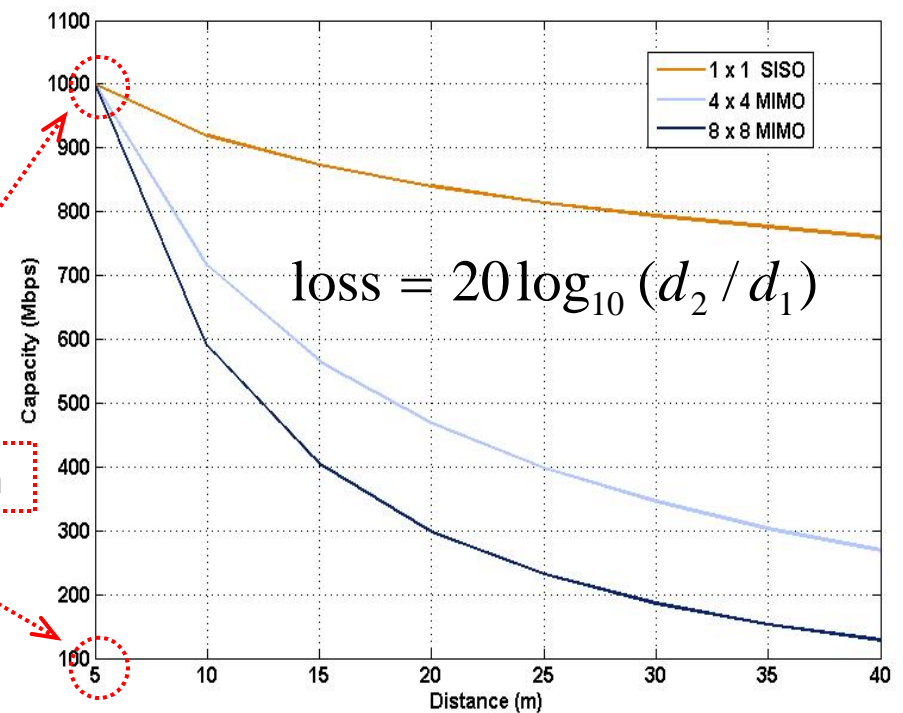
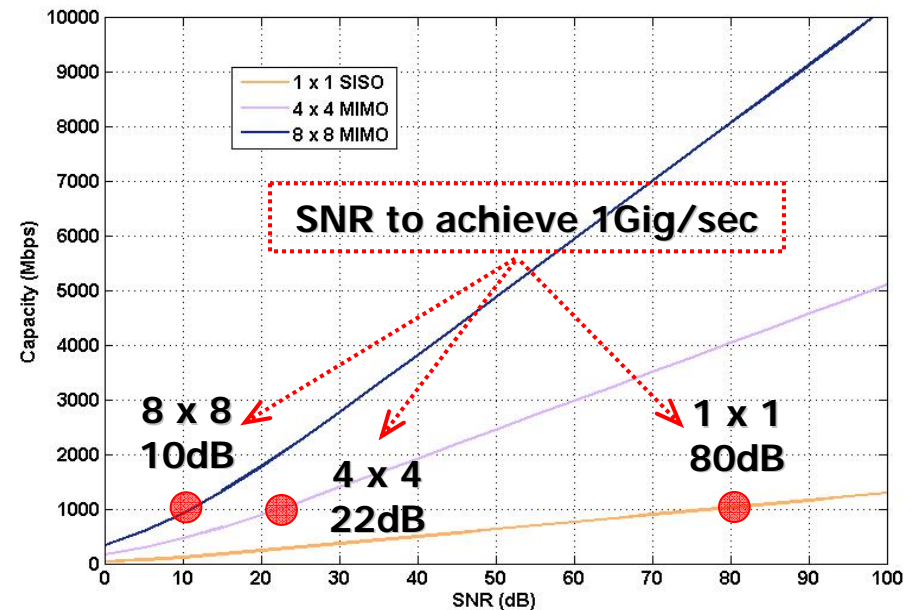
- 1 Gb/sec @  $W=40\text{MHz}$ :
  - ~5dB with 8 antenna units
  - ~16dB with 4 antenna units
- Significant gain vs. TDM/TDM
  - ~6dB gain in SNR
  - 80% increase in rate
- Reduced Complexity
  - Low rate receivers
- Good for environments with low scattering



# Bad News: Effect of Distance

Possible solution:

## Relays



Curves normalized to deliver 1Gig/sec at 5m

# Interference Channel: Spectrum Sharing

- Receiver's Strategies:

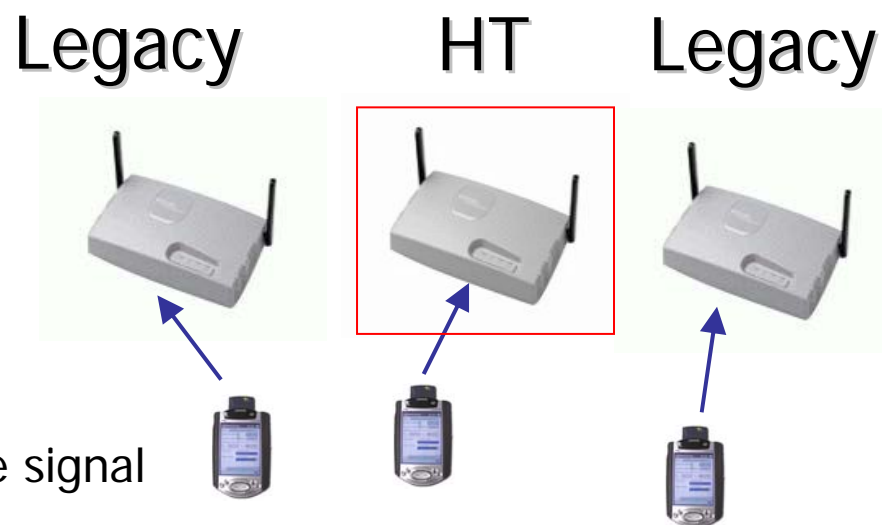
- 1) Treat interference as noise
- 2) Decode interference jointly with the signal
- 3) Decode and cancel interference

- Key Point:

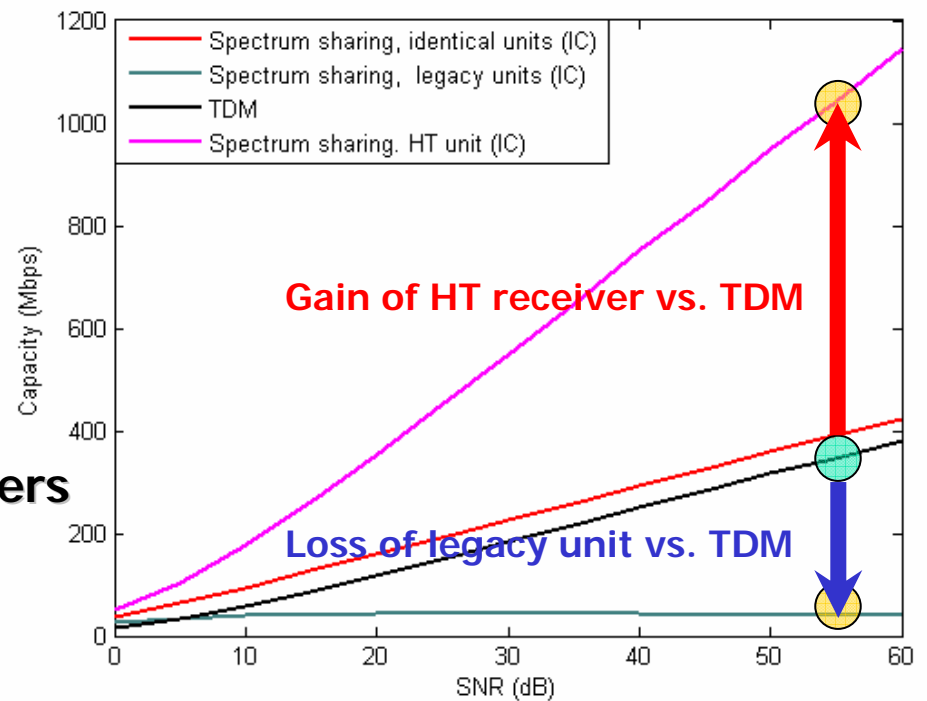
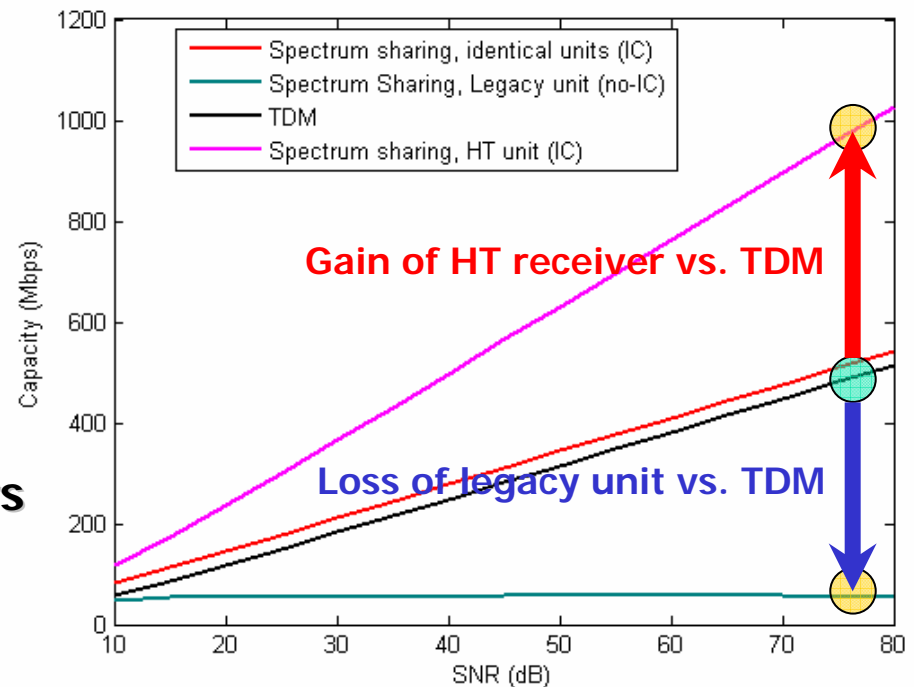
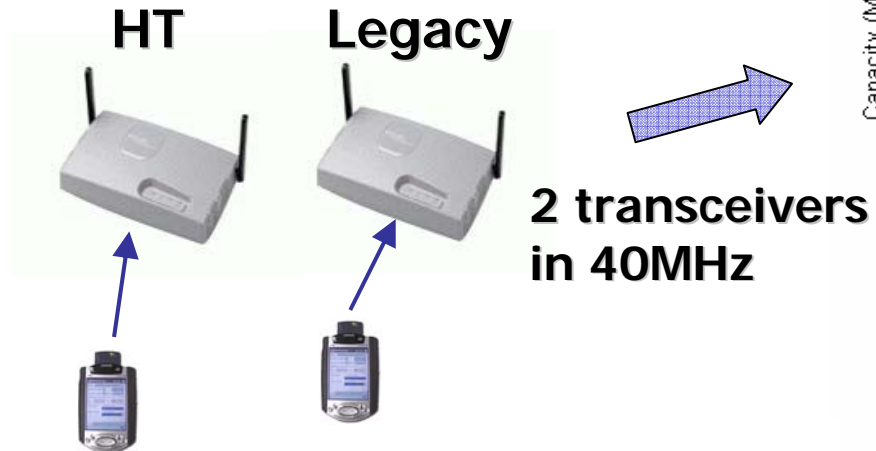
- Strong interference is good for strategy 3**

- Assume two types of receivers:

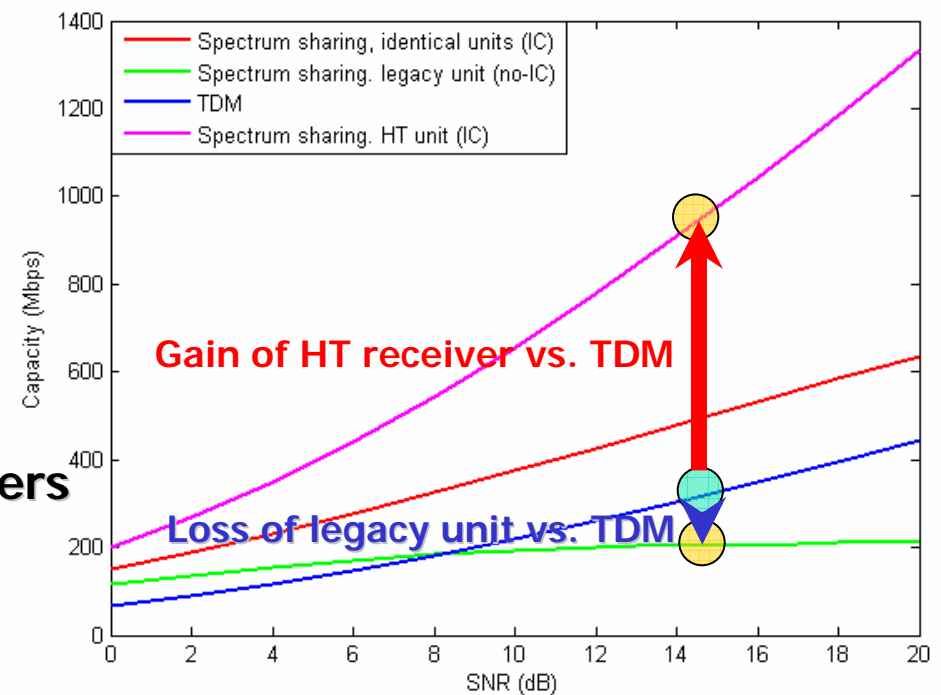
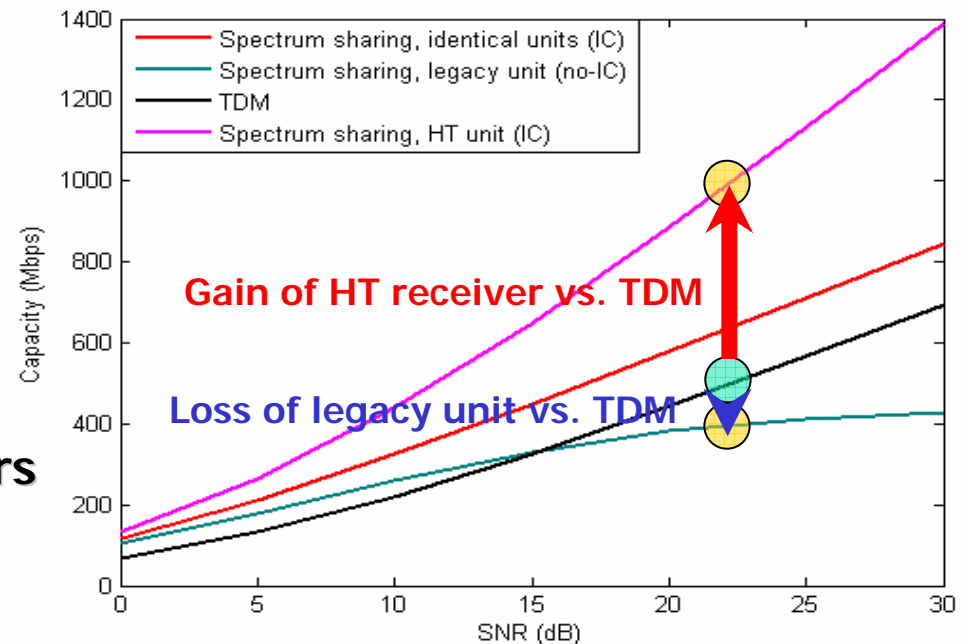
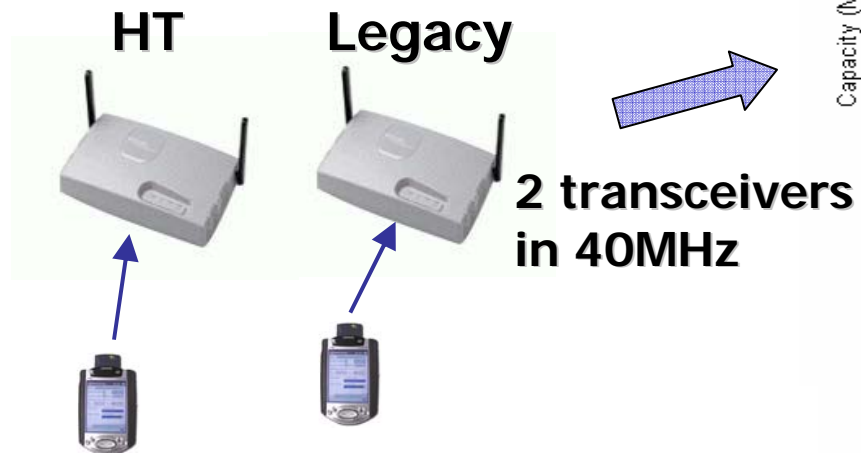
- HT (High Throughput) receivers: Use the best strategy among the 3 options
- Legacy receivers: Simply treat interference as noise



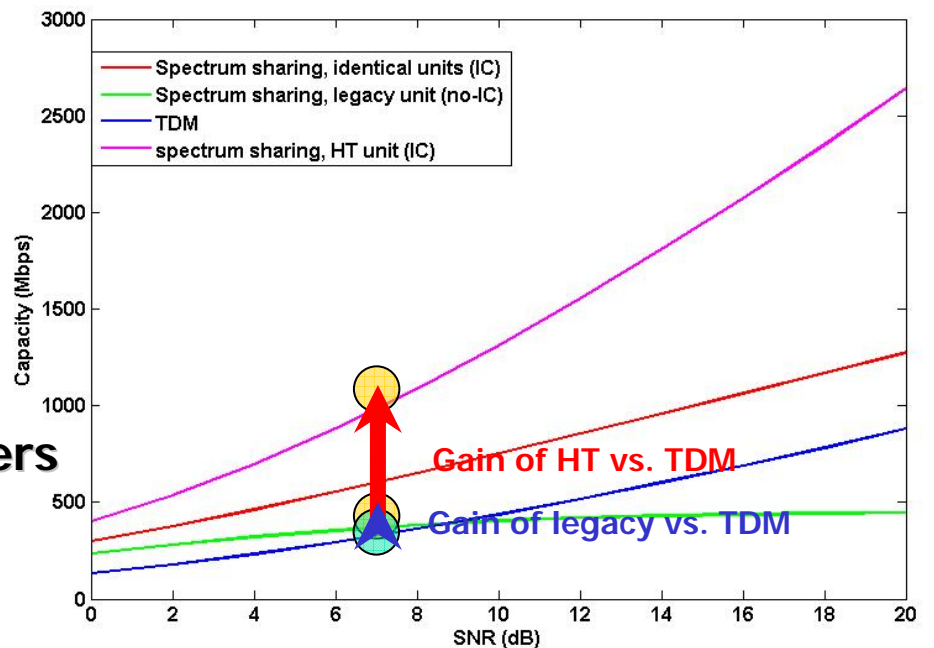
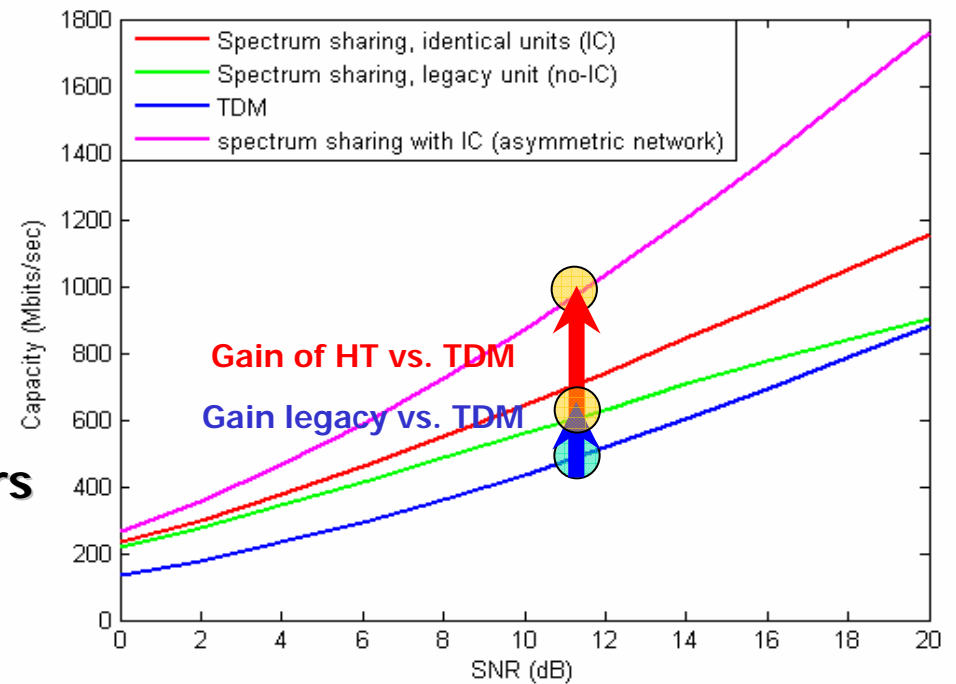
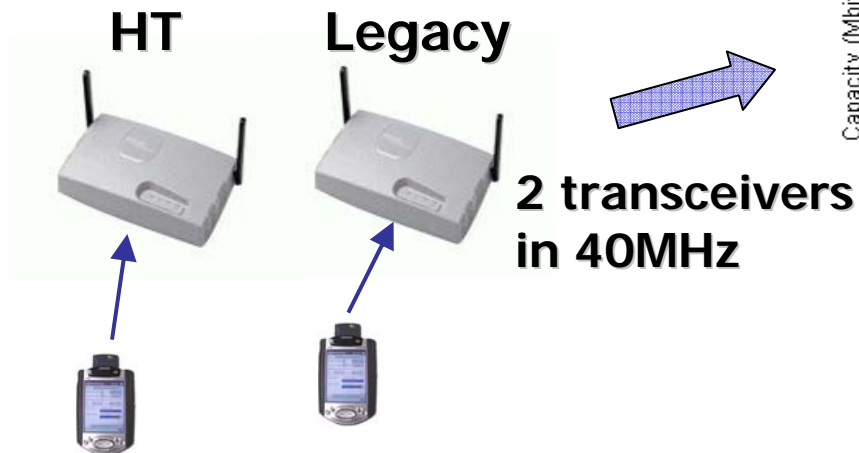
## Interference Channel: Single antenna units



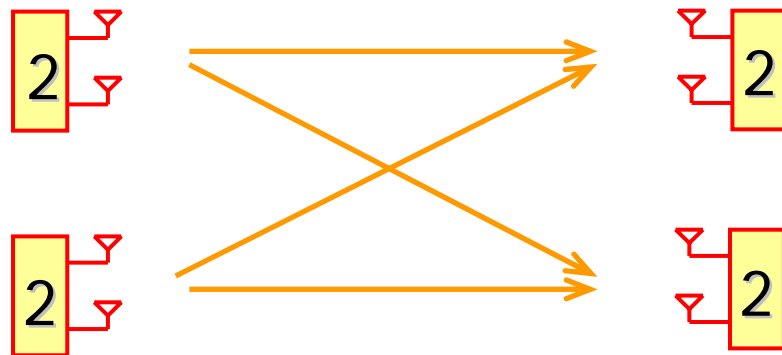
## Interference Channel: 4-antenna units



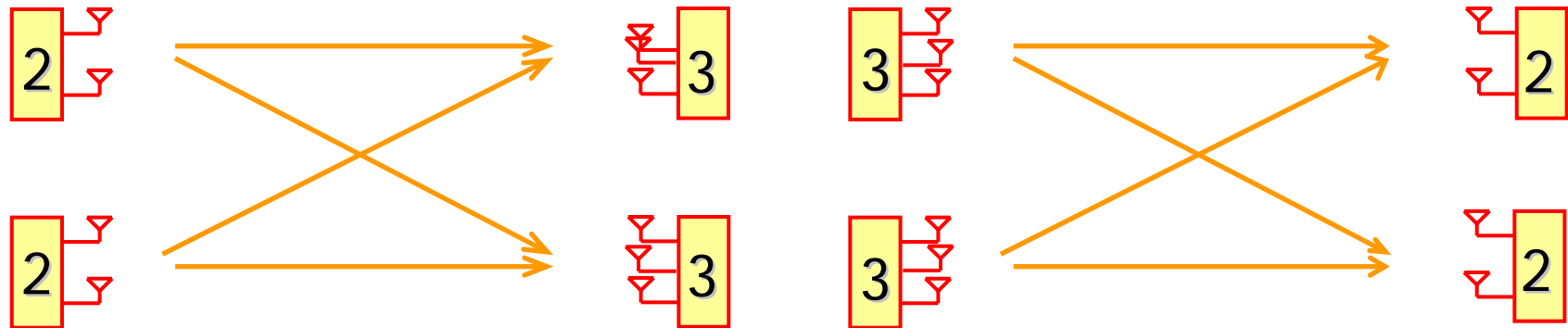
## Interference Channel: 8-antenna units



## A Surprising Result: One can achieve full MG without co-operation!

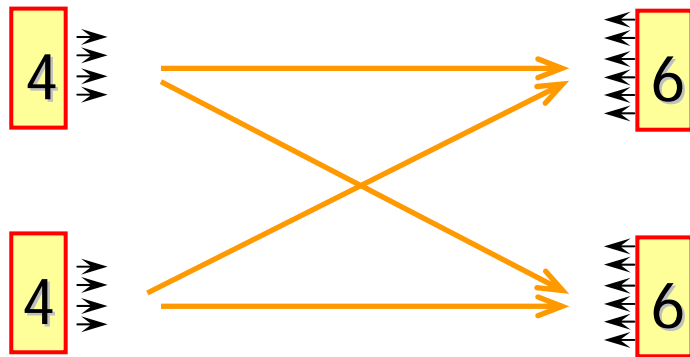


Can transmit 4 streams of data with a multiplexing gain of 2

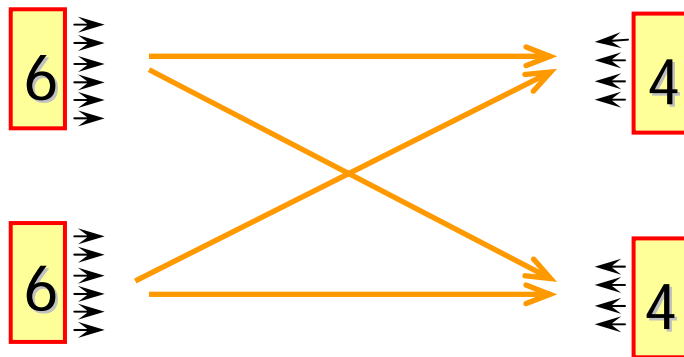


Can transmit 4 streams of data with a multiplexing gain of 4

## A Surprising Result: One can achieve full MG without co-operation!



Can transmit 8 streams of data with a multiplexing gain of 8

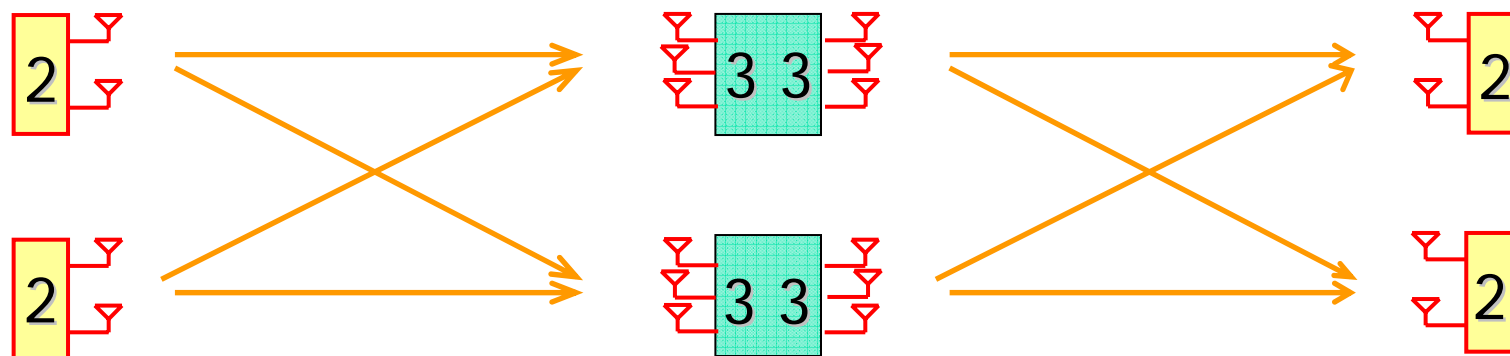


Can transmit 8 streams of data with a multiplexing gain of 8



## An Important Message:

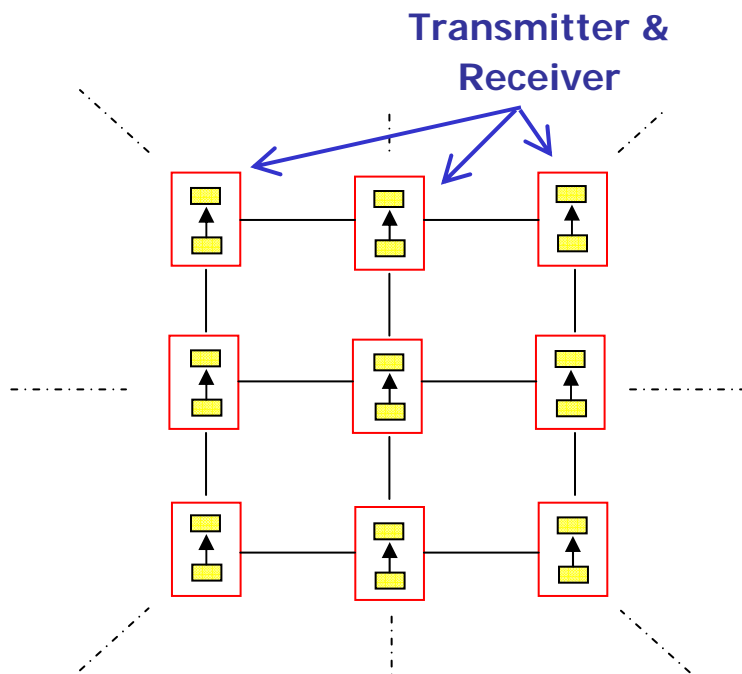
Shared relay is better than dedicated relay



- Transmits 4 streams with a multiplexing gain of 4
- By increasing the number of antennas in the relays from 2 to 3, the effective bandwidth is increased by a factor of two

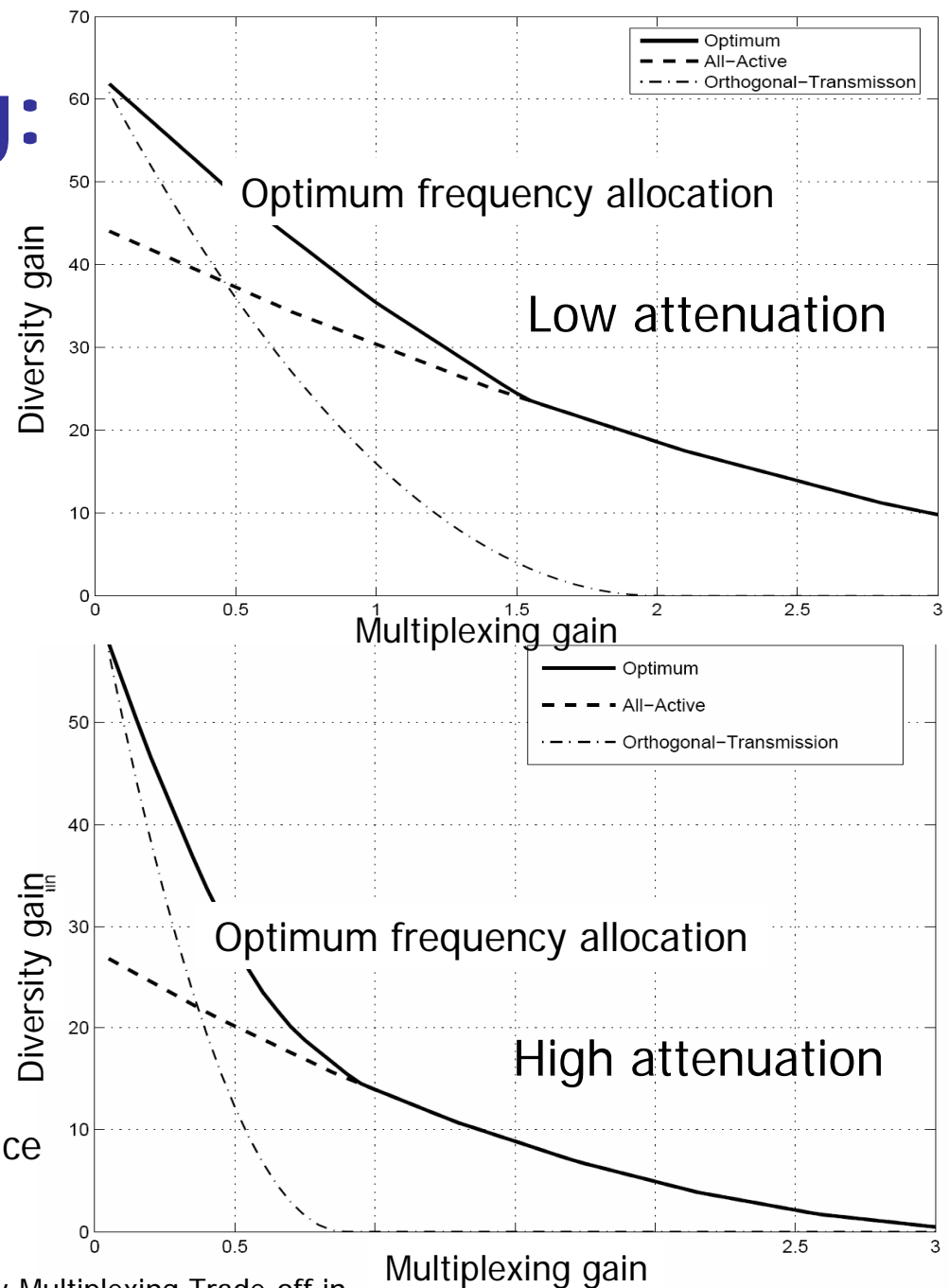
# Spectrum Sharing:

## ■ Network Model:



## ■ Simple Receiver:

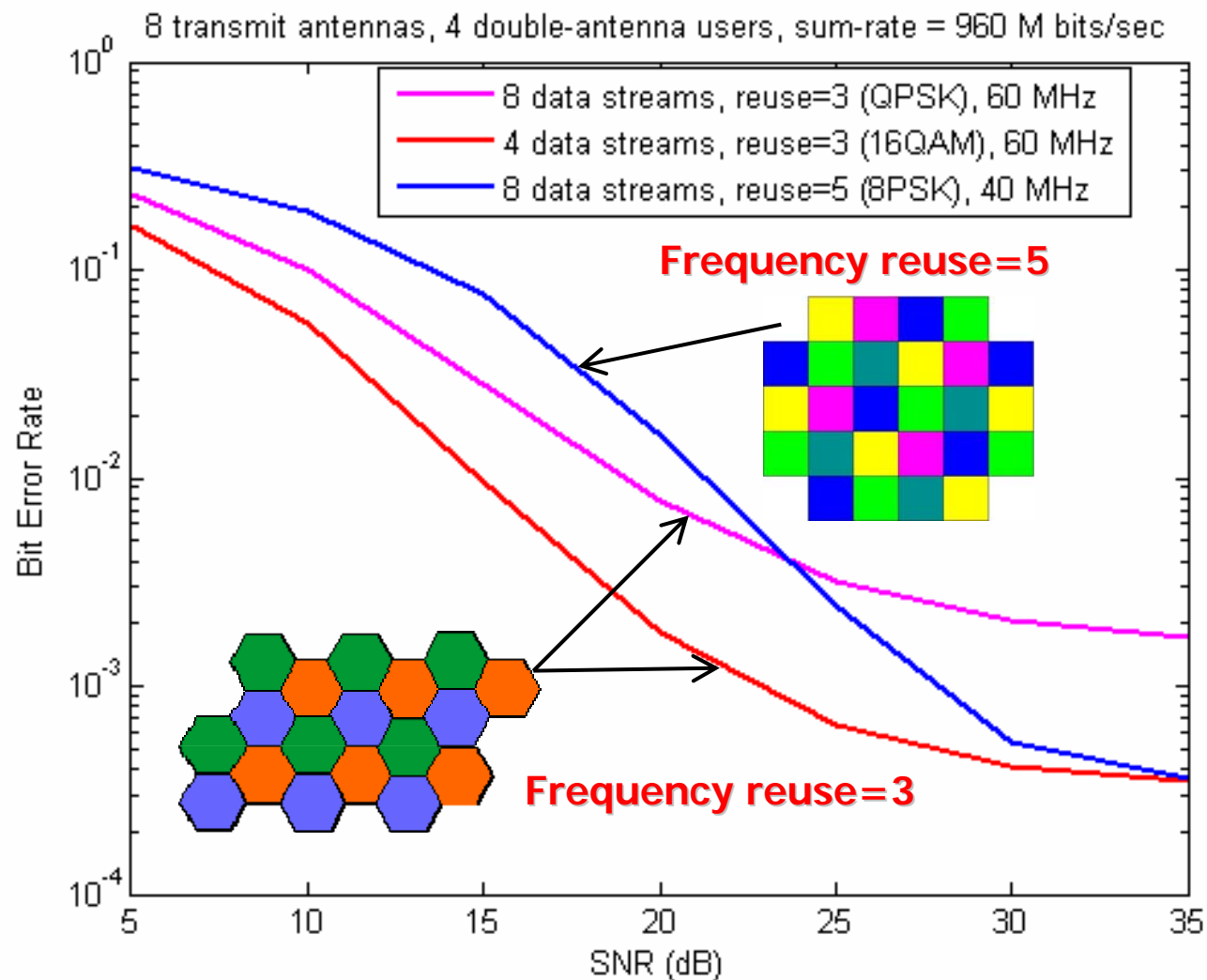
- Treat Interference as Noise
- Similar results obtained for more advanced receivers with Interference cancellation/joint detection



# Impact of Interference on MG/DG Tradeoff in Network: An example

## Message:

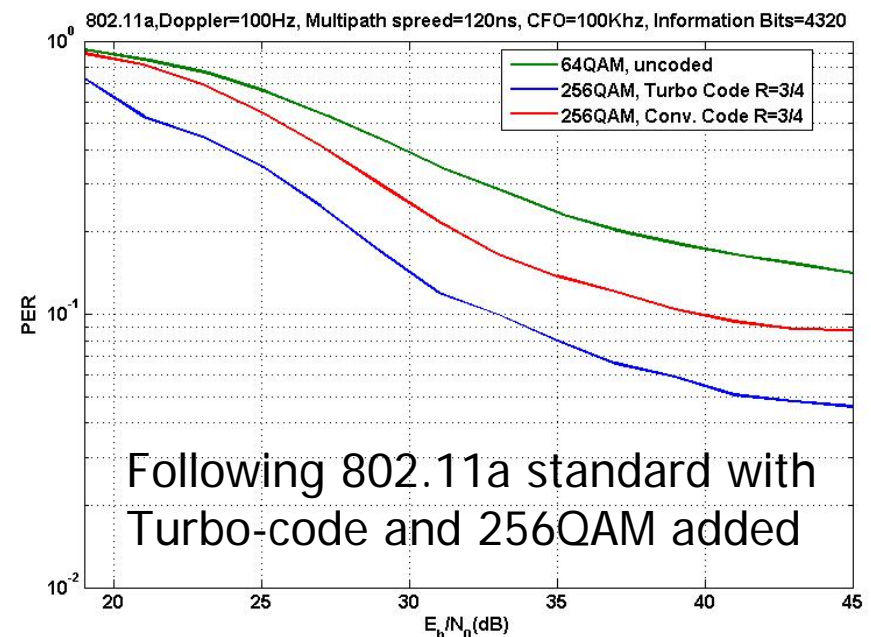
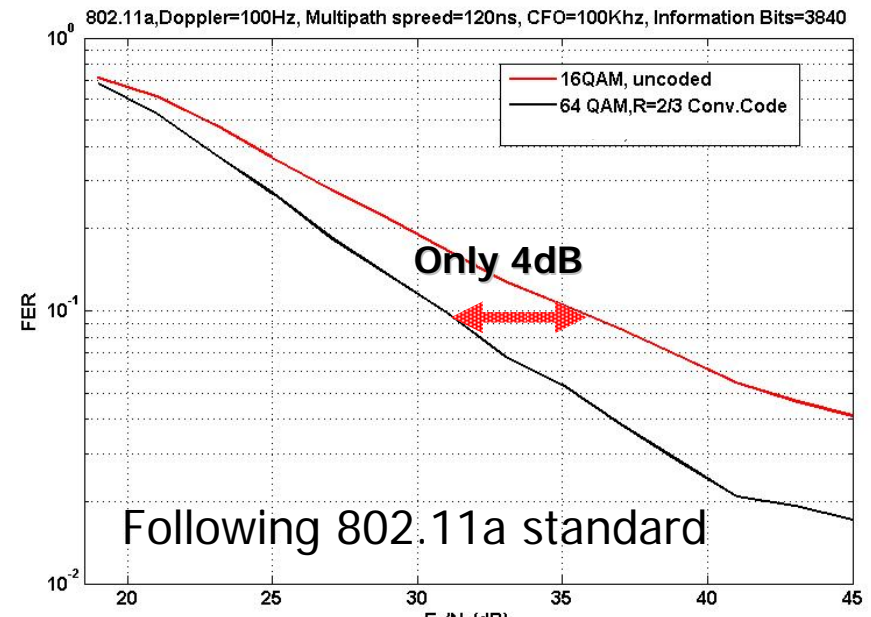
Revisit old  
design  
criterion  
before  
selecting  
BLAST vs.  
Alamouti!



# Is Coding & Modulation Dead?

- Higher gains possible using coset coding/shaping\*
- Error floor due to imperfections
  - Operate at higher error rates and use continuous feedback
- Coding over packets
  - Erasure Channel

**Two-way channel**



\* A. K. Khandani, W. Tong, Application of Shaping Technique with Turbo Coset Codes, IEEE Transactions on Vehicular Technology, to appear, Sept 07

As Marconi said,

*"It is dangerous to put limits on wireless"*

