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IEEE Task Group 802.11n : multiple-antenna techniques for high throughput wireless LANs

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Overview

- Introduction to 802.11n
  - Task Group PAR requirements
  - Candidate solutions
- MIMO for 802.11n
  - Measurements to assess potential capacity
  - Algorithms to bound achievable rate vs range

Motivation

Wireless LAN applications :

streaming media (HDTV, DVD)

interactive gaming, enterprise, hot-spots

Require hundreds of Mbps

Best data rates today

	IEEE Standard	Over the air	MAC-SAP
Today	802.11b	11Mbps	5 Mbps
Today	802.11a	54 Mbps	25 Mbps
Today	802.11g	54 Mbps	25 Mbps
2006	802.11n	200+ Mbps	100+ Mbps

802.11n represents a minimum 4x throughput enhancement

802.11n PAR

- IEEE Task Group 802.11n
  - Scope : define PHY and MAC modifications to enable at least 100 Mbps at the MAC SAP
- Purpose
  - Improve user experience with existing applications
  - Enable new applications and market segments

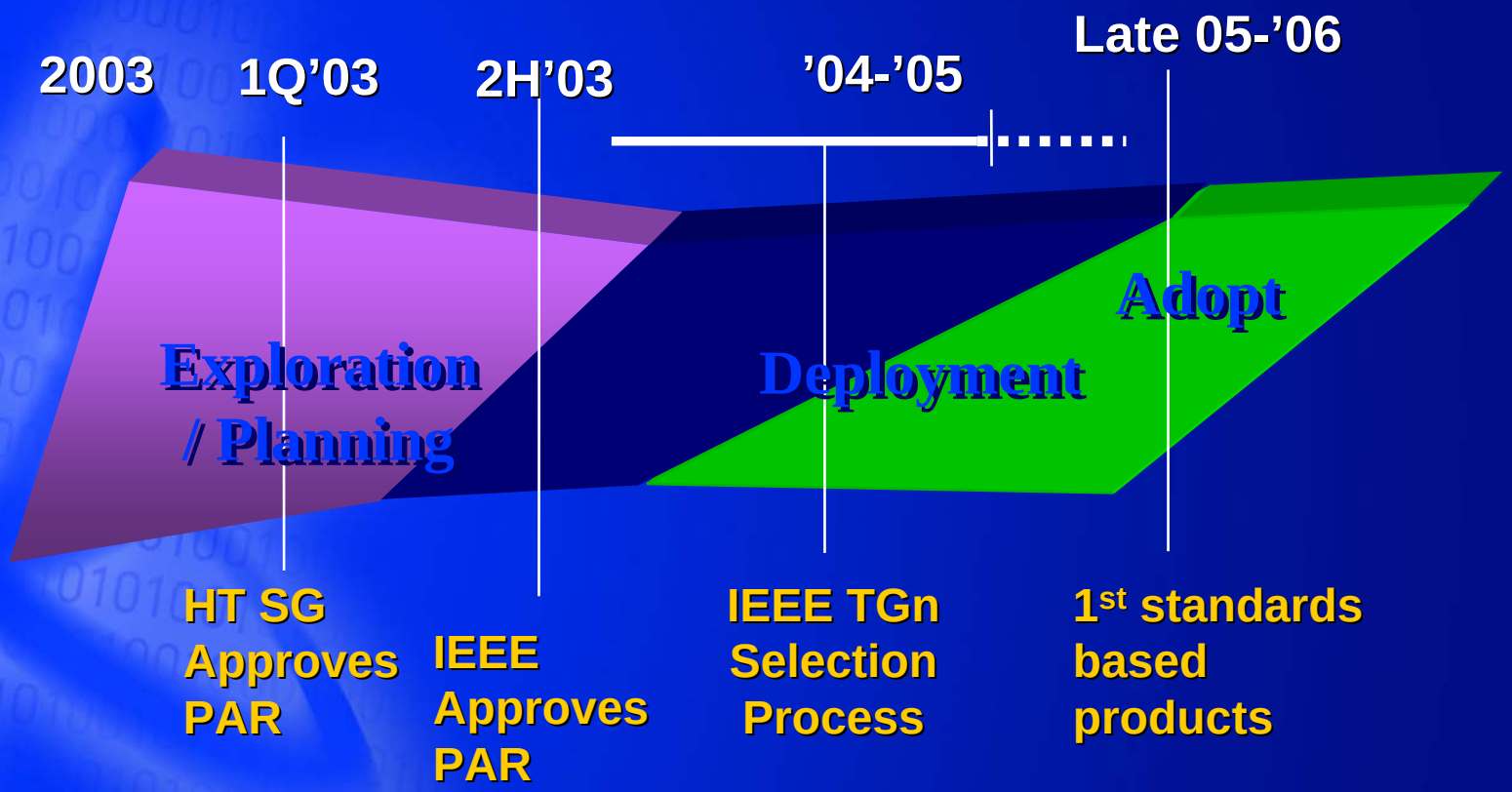
802.11n allows both PHY and MAC enhancements

802.11n functional requirements

- 20 MHz operation
  - 100 Mbps at MAC SAP in 20 MHz (at least 1 mode)
- Spectral efficiency
  - Highest mode achieves > 3 bps/Hz spectral efficiency
- Backward compatibility
  - Some modes backward compatible with .11a and .11g
  - .11n AP may refuse service to legacy STA
- 5 GHz bands required

Requirements suggest a MIMO-based solution

Deployment timeline approximation



802.11n standard expected in 2005-2006

Evolution of 802.11a/g to 802.11n

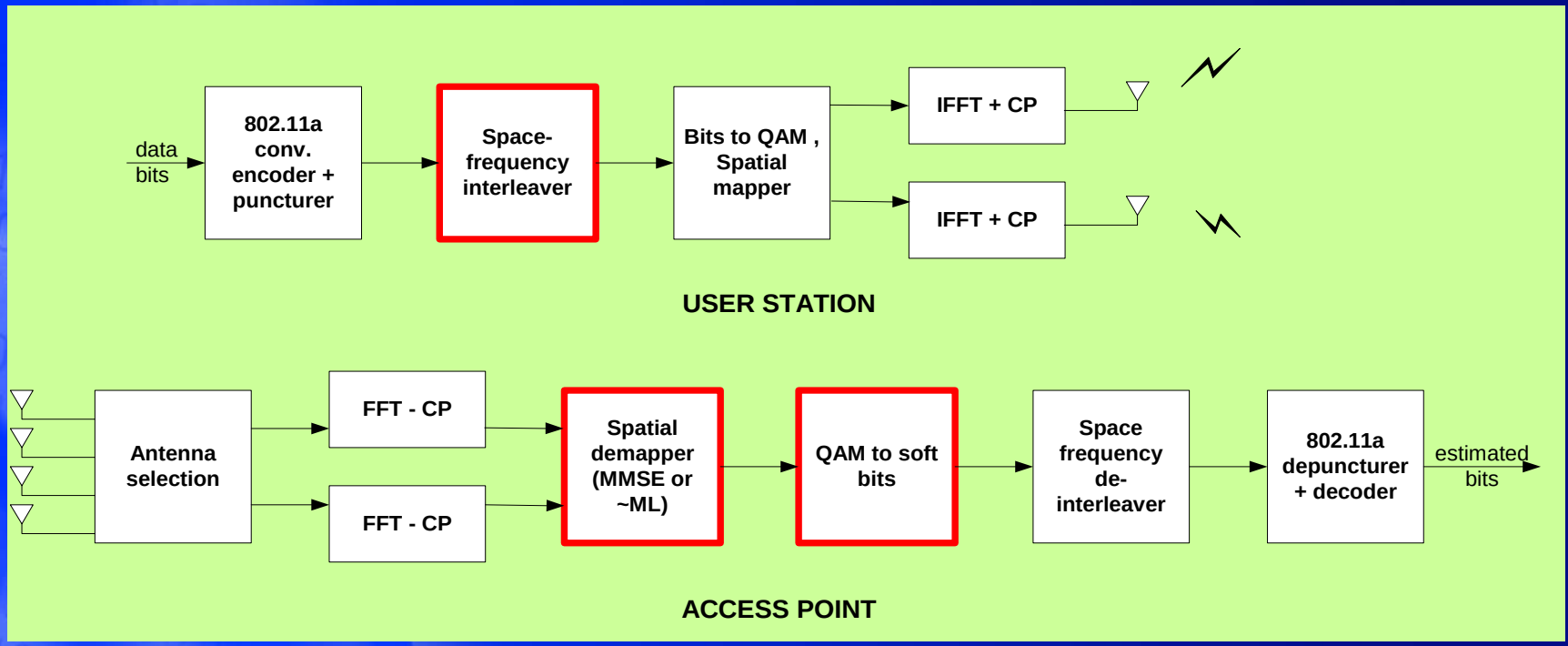
Characteristic	802.11a/g	802.11n
SISO/MIMO	SISO	2x2,…,4x4 MIMO ?
Bandwidth	20 MHz	40, 60 MHz ? (Channel bonding)
Packet size	1000 bytes	>>1000 bytes ? (Burst aggregation)
Coding	Convolutional code	LDPC/turbo code ?

802.11n is expected to build upon 802.11a OFDM

What is MIMO ?

- **MIMO**
  - **Multiple antennas and RF chains at receiver and transmitter**
  - **Multiple spatial streams transmitted simultaneously**
  - **Usually no feedback of channel information (open-loop)**
  - **Subsumes maximal ratio combining**
- **Beamforming**
  - **Usually multiple transmit antennas only at AP (or base station)**
  - **With feedback of channel information (closed-loop)**

MIMO block diagram



MIMO pros and cons

$$C = B \log_2 \det\left(I + \frac{P}{MBN_0}\mathrm{HH}^*\right)$$

- **Advantages**
  - **Linear increase in capacity with number of antennas**
  - **High spectral efficiency**
- **Disadvantages :**
  - **Cost of antennas and power amplifiers**
  - **High power consumption**

Channel bonding pros and cons

$$C = B \log_2 \left(1 + \frac{P}{BN_0} \right)$$

- **Advantages**
  - **Linear increase in Shannon capacity with bandwidth**
  - **Low cost of implementation**
- **Disadvantages :**
  - **Limited spectrum, e.g. Japanese regulations**
  - **Coexistence with 802.11a difficult**

No clear choice

MIMO	Channel bonding
Easy coexistence	Coexistence challenge
Spectrally efficient	Spectrum hungry
High cost RF	Cheaper to build
Complex receivers	Simpler baseband

Mixing technology options may be the answer

Measurements and algorithms

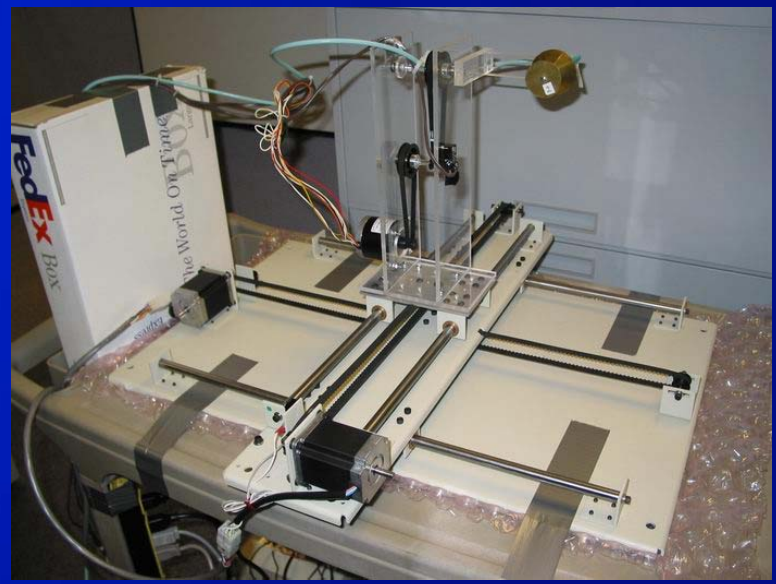
- Measurements
  - Help evaluate MIMO channel rank
  - Compare SISO capacity to MIMO capacity
- Algorithms
  - Help evaluate rate versus range
  - Provide upper bounds for advanced receivers

Intel measurement environment

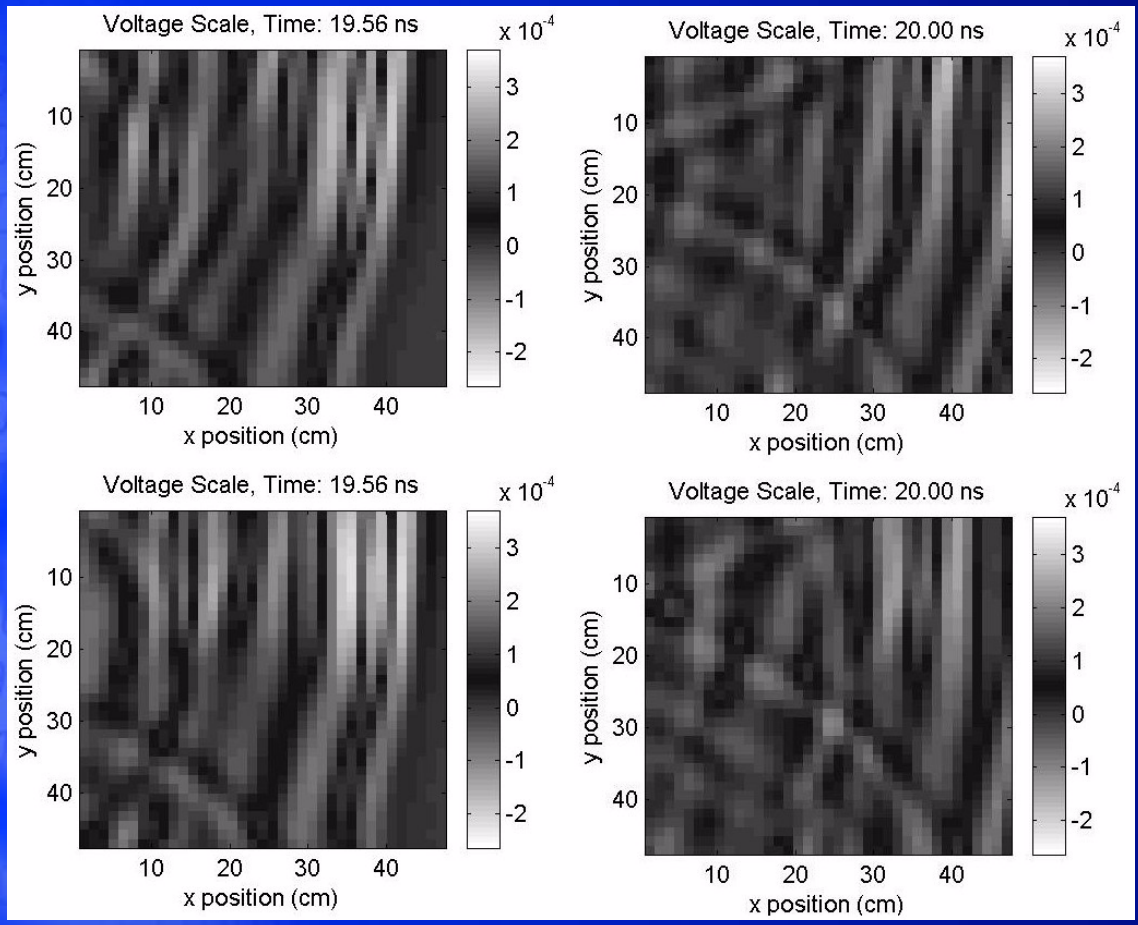
Scattering environment

WLAN "Access Point"

WLAN "STA"

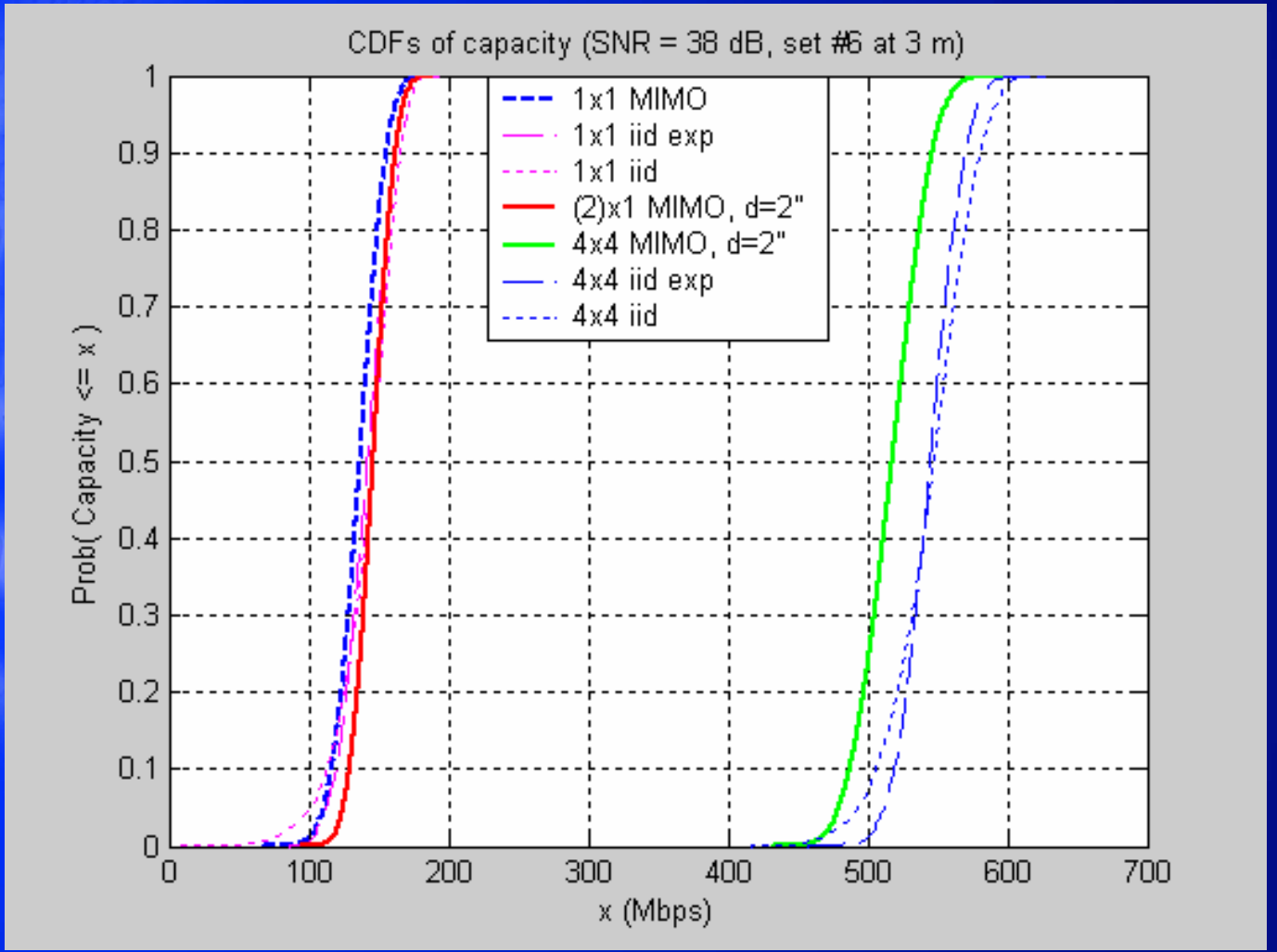


2-D channel impulse response

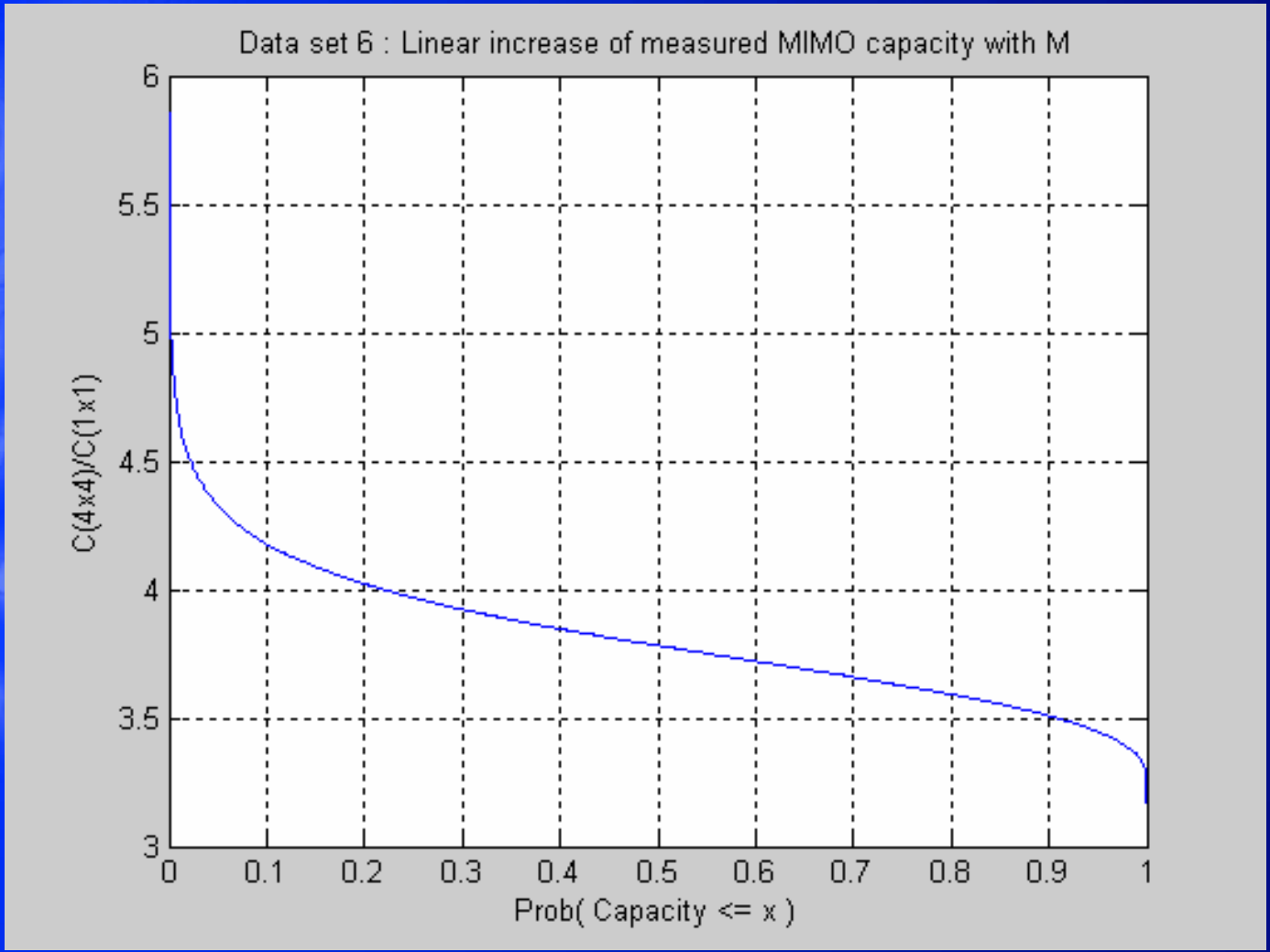


- **STA is LOS to AP at 3 m, separated by one soft partition**

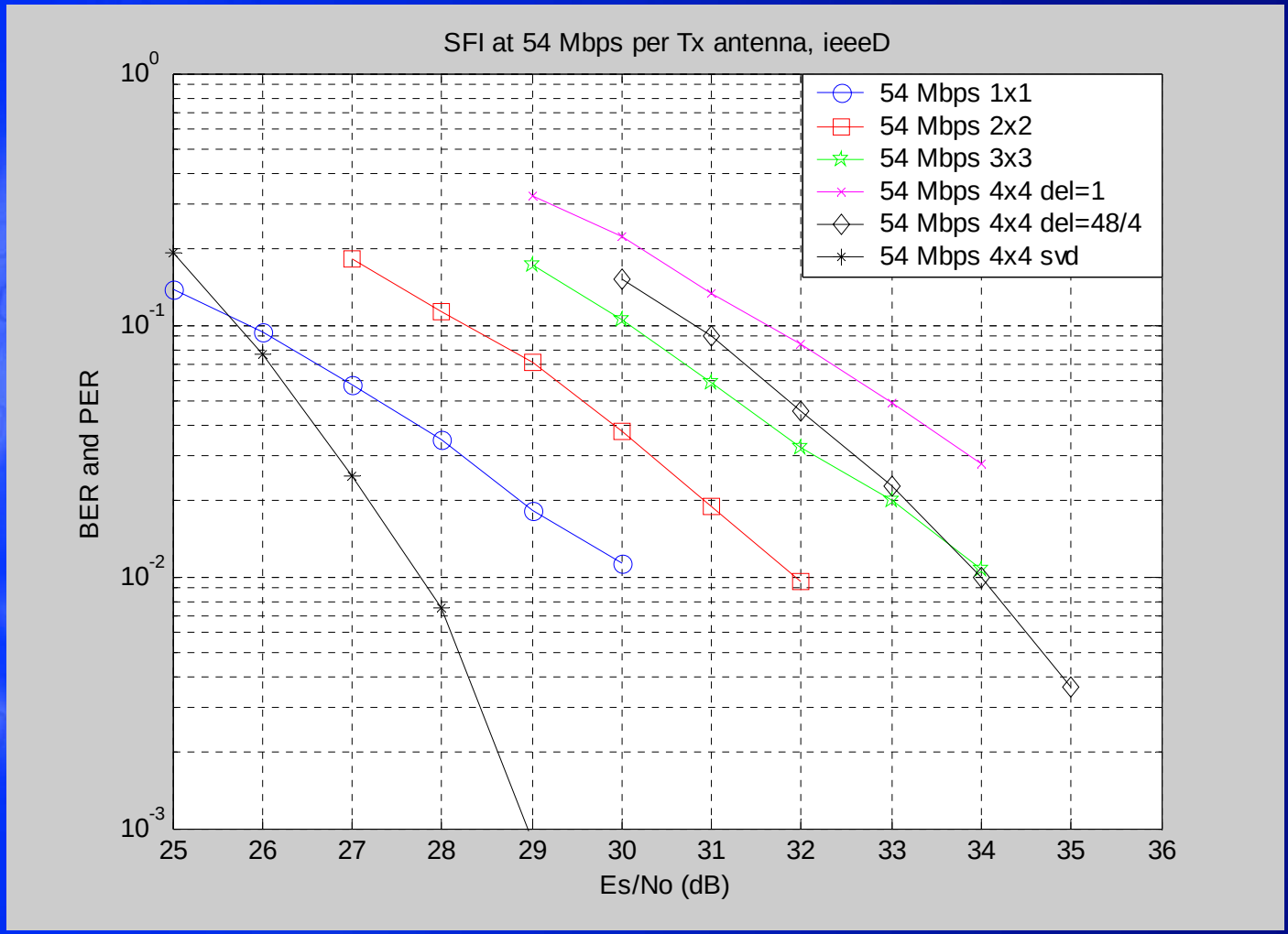
Capacity CDF : LOS channels



Multiplier from 1x1 to 4x4



Algorithm performance



- **Choice of interleaver affects performance by 1-2 dB**

Conclusions

- 802.11n throughput enhancement
  - MIMO and channel bonding are viable candidates
  - Example architecture : 2x2 MIMO, 40 MHz, MAC aggregation
- Candidates for range enhancement
  - Receive diversity : 2x3, 2x2/4
  - Advanced coding : LDPC/turbo
  - Link adaptation : SVD/Adaptive Bit Loading
  - Advanced receivers : ML/MAP/iterative

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