Going Space Diverse 802.11n

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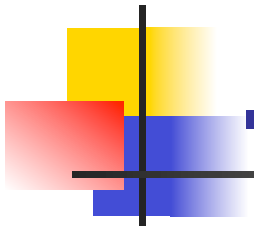
http://disi.unitn.it/locigno/index.php/teaching-duties/nomadic-communications



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The goal

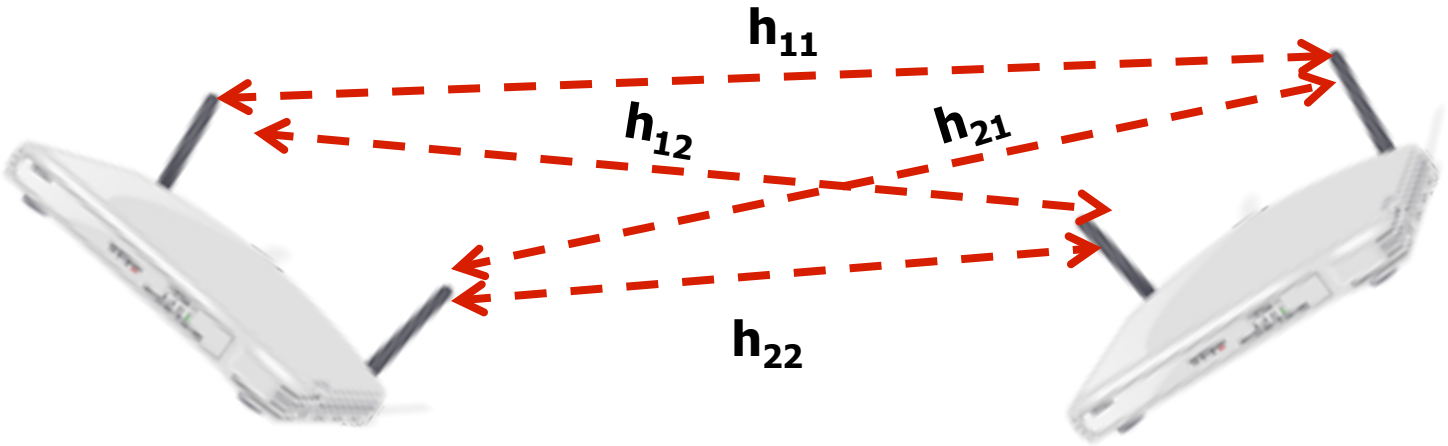
- The IEEE 802.11 WG on "high throughput" set out with the following goals
  - Achieve PHY rate speeds > 300Mbit/s
  - Achieve App-level throughputs > 100Mbit/s
- Stick to the ISM bands
- Remain reasonably compliant and compatible with existing systems
  - Similar PHY channel use
  - Basic CSMA capabilities for DCF
- OFDMA derived from 802.11a as a work baseline
  - Ultra Wide Band techniques are not considered → another WG is working on this 802.11ac

The key ideas

- Leave flexibility on channel width 10, 20, but also 40 MHz
  - The duration of OFDMA symbols reduces linearly with the channel bandwidth, increasing PHY speed
- Use recently "explored" space diversity techniques either to improve reliability or to increase throughput (more later)
- Make the most out of TXOPs and Block ACK techniques developed in 802.11e
- Further "trim" PHY layer possibilities
  - E.g., reduce ODFM symbol Guard Time (GI) to 400ns instead of 800ns as symbol spreading due to multipath is normally below 200ns

Space diversity

- Exploit multiple Tx and Rx antennas with a reasonable independent transmission path combining the different signals



Space Diversity

- h_{ij} are the (time varying) channel characterizations between Tx antenna i and Rx antenna j
- The scheme is known as MIMO (Multiple In Multiple Out)
- The multiple flows can be used to
  - Increase throughput
  - Increase data reliability
- 802.11n allows up to 4 antennas
  - STA have a minimum of 1
  - AP have a minimum of 2

Space Diversity

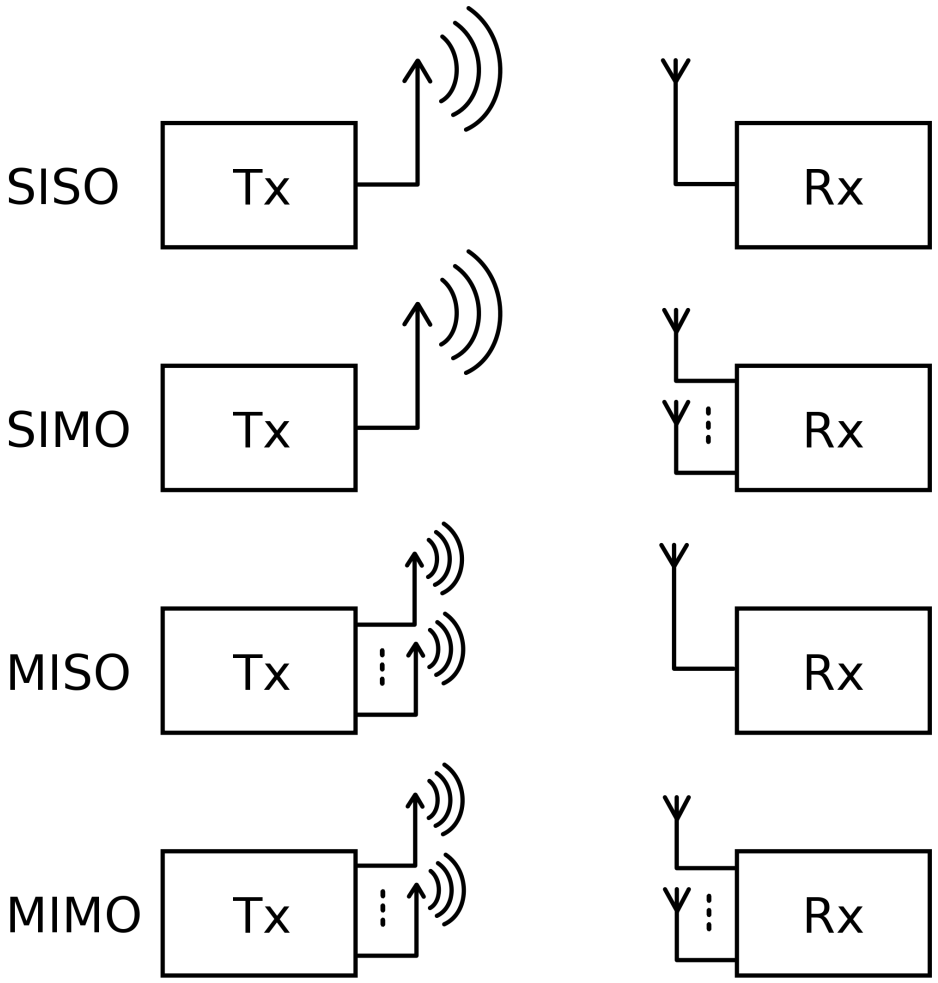
- A radio is characterized by the a 3-ple:

  a x b : c

  - a=max No. of Tx "chains"
  - b=max No. of Rx "chains"
  - c=max No. of independent spatial data streams
  - c<=a,b ; a,b <= No. of antennas
  - **a "chain" means the ability of processing an independent data flow**
- 2 x 3 : 2 identify a device with 3 antennas that can send at most 2 independent data flow, but receive with 3
- 2 x 2 : 1 has 2 antennas, but cannot use the diversity to increase throughput, only to improve reliability

SISO, MISO, SIMO, MIMO

- The number of antennas at devices is independent
- Complexity and performance increase with the number of Tx and Rx antennas
- In principle different Tx can go to different devices



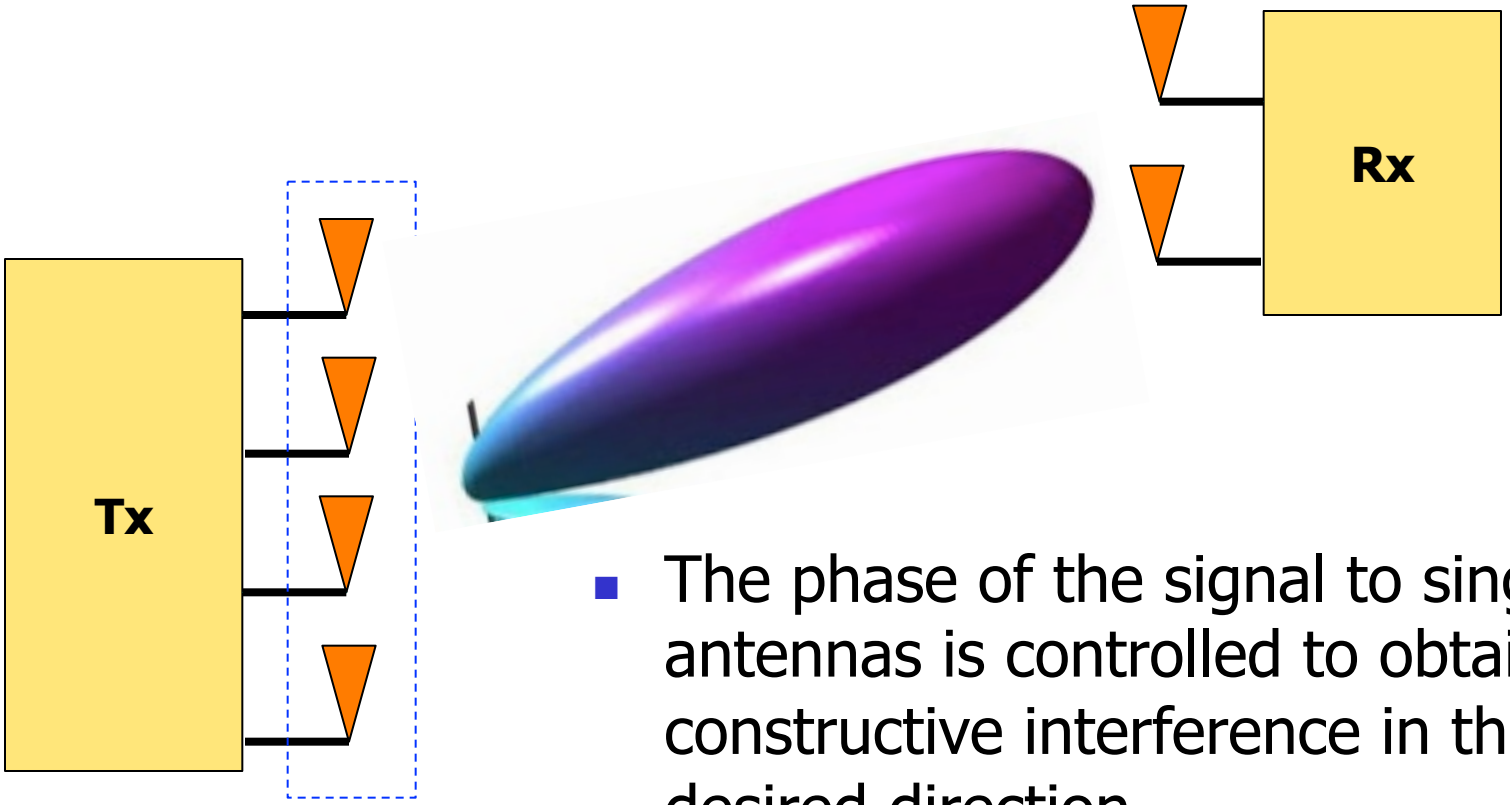
picture taken from wikipedia

MIMO

- Based on the coordinated processing of the data flows and signals to the antennas
- Many different ways to use the redundancy and increased processing power
  - Directional beams
  - Interference reduction
  - Multiple parallel data flows
- Moreover the behavior is as if antennas had a larger cross-section
  - More energy from the signal can be collected at the receiver

MIMO - Beamforming

- Tx antennas are used as a single phase-array antenna to obtain directionality



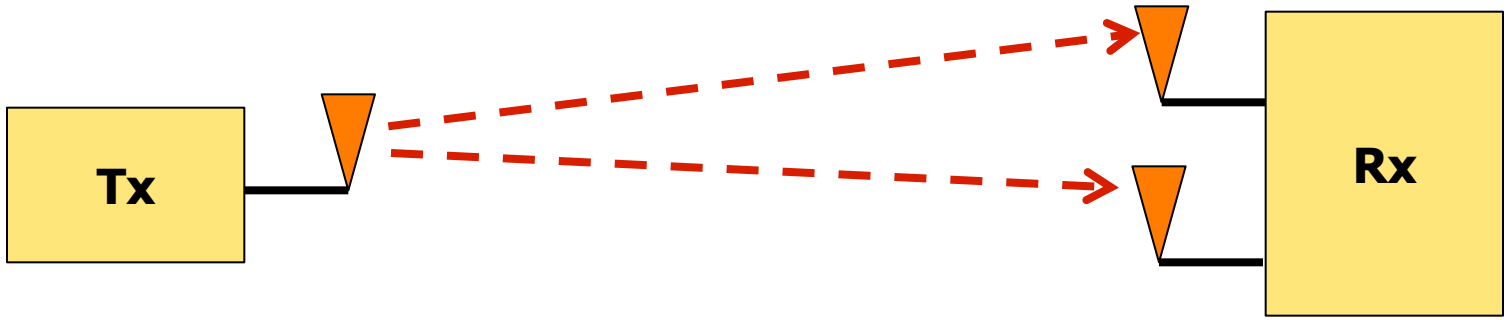
- The phase of the signal to single antennas is controlled to obtain constructive interference in the desired direction

MIMO - Beamforming

- Beamforming, i.e., using the Tx antennas as a single phase array is complex
- Requires full knowledge (estimation at the transmitter) of the channel state at the receiver: The CSI (Channel State Information)
- Signals must be pre-precessed to obtain the correct phase and amplitude at the antennas
- 802.11n can use beamforming, but often it is done with the "switched array technique"
  - Antennas are selectively switched on and off changing the antenna pattern
  - Patterns are limited and not "well formed"
  - They cannot be used to process received signals

MIMO – Receiver advantage

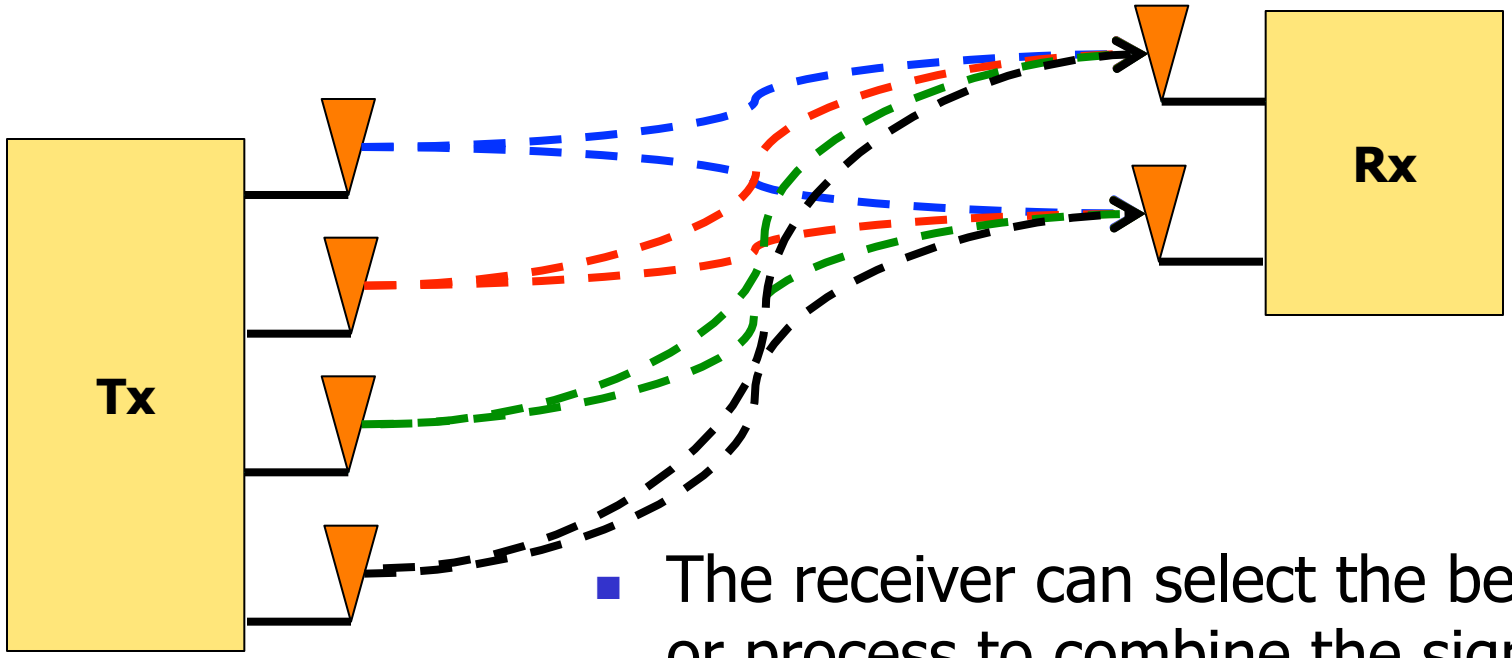
- If the receiver antennas are more than $\lambda/2$ apart (the more the better) the received signals have roughly independent fading and can be combined



  - The phase of the signal to single antennas is controlled to obtain constructive interference in the desired direction

MIMO – Space-Time Coding

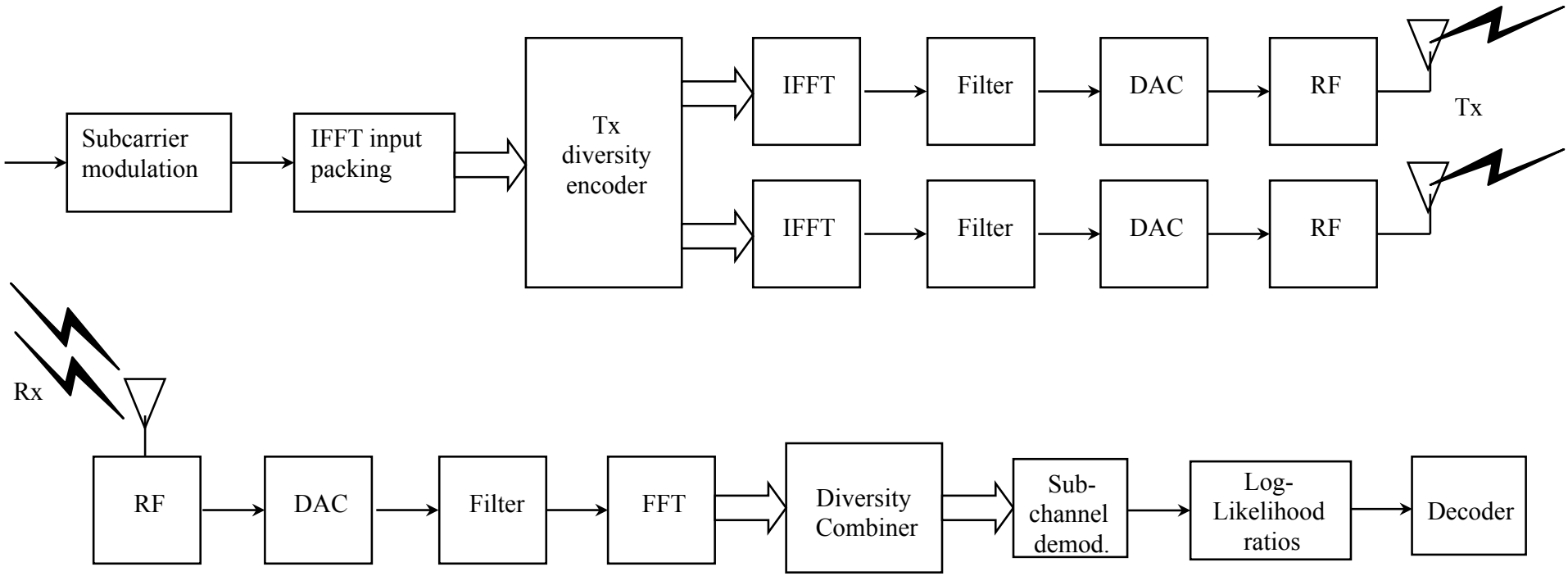
- Tx antennas are used independently, transmitting multiple-orthogonally-encoded version of the same information



  - The receiver can select the best on or process to combine the signals
    - Better performance
    - More complexity

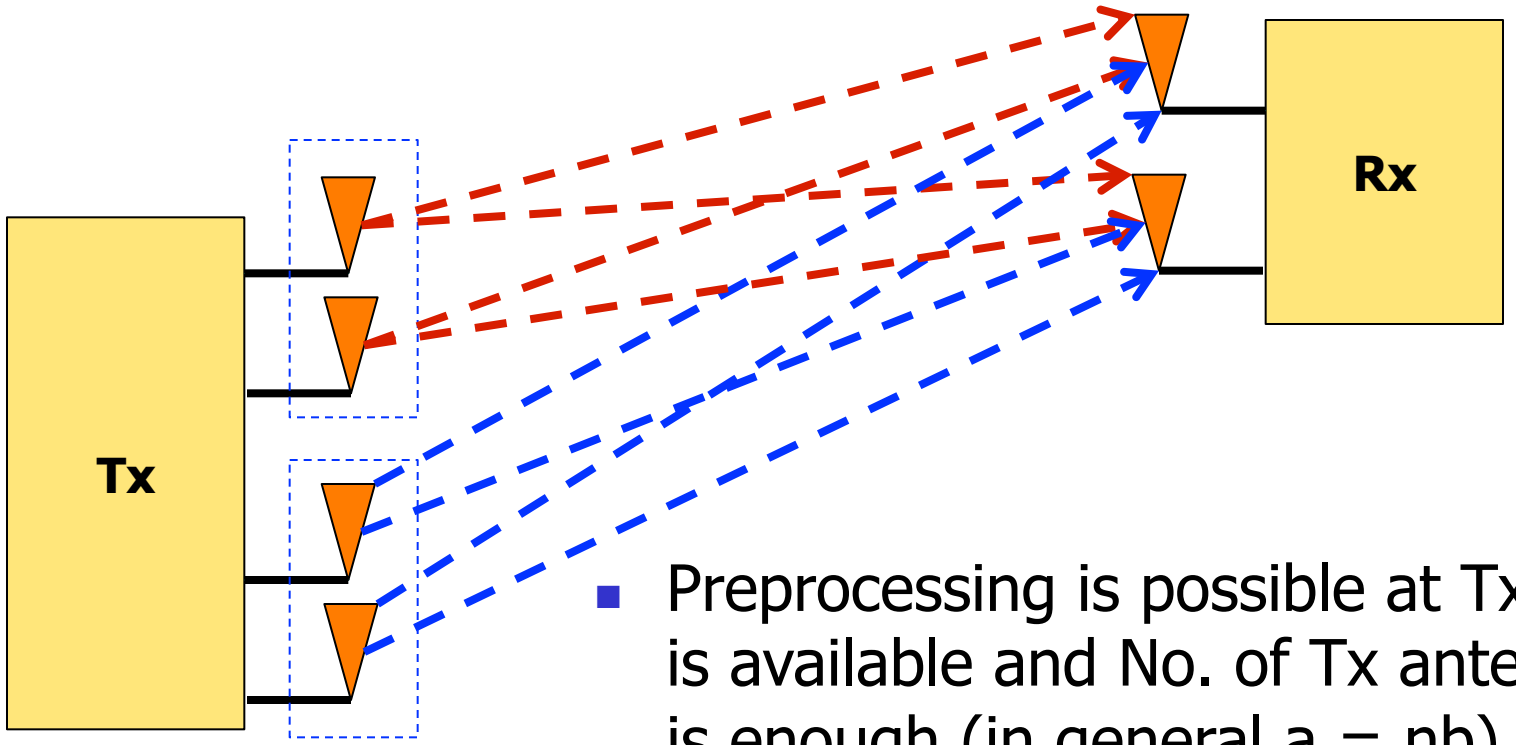
Example of Space Diversity use

- 2 Tx antennas, 1 Rx antenna
- Two chains are needed for the transmission



MIMO – Multiple Streams

- max(c) = min(a,b) → No. of streams is limited by the smallest number of antennas



- Preprocessing is possible at Tx if CSI is available and No. of Tx antennas is enough (in general a = nb)

Modulation and Coding

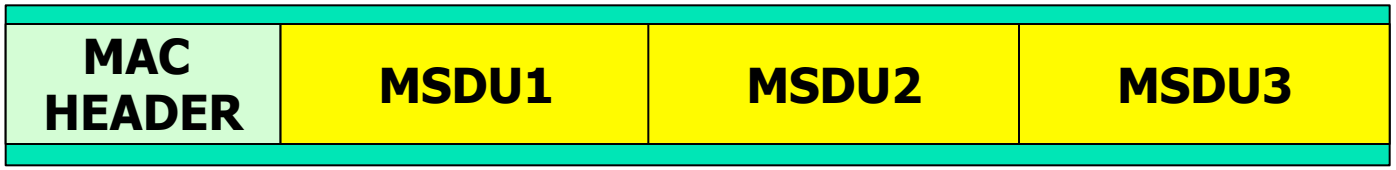
- Very similar to 802.11a but ...
- 20 and 40 MHz channels
- Up to 4 streams
- Overall 124 (31x2x2) possible schemes exist
  - 8 mandatory modulation schemes
  - Define basic/required rates
- Up to 600 Mbit/s,
  - with 400 ns GI
  - 4 spatial streams
  - 64-QAM modulation, 5/6 Convolutional encoding
- Data rate table ... is too large for a slide ☺ see wikipedia
  http://en.wikipedia.org/wiki/IEEE_802.11n-2009#Number_of_antennas

What MAC for MIMO?

- CSMA is not well adapted to MIMO and space diversity
- However there is not viable alternative for a DCF
  - TXOPs help
  - Block ACKs help
- MPDUs can be aggregated using Block ACKs
  - Can work also across multiple streams
- MSDUs can be aggregated within the same MPDU
  - MPDU size is now 64 kbytes! (up from 2.3kB)
- Block ACKs can refer to MPDUs on multiple streams

MSDU Aggregation – A-MSDU

- Multiple SDU within the same frame
  - One single MAC header



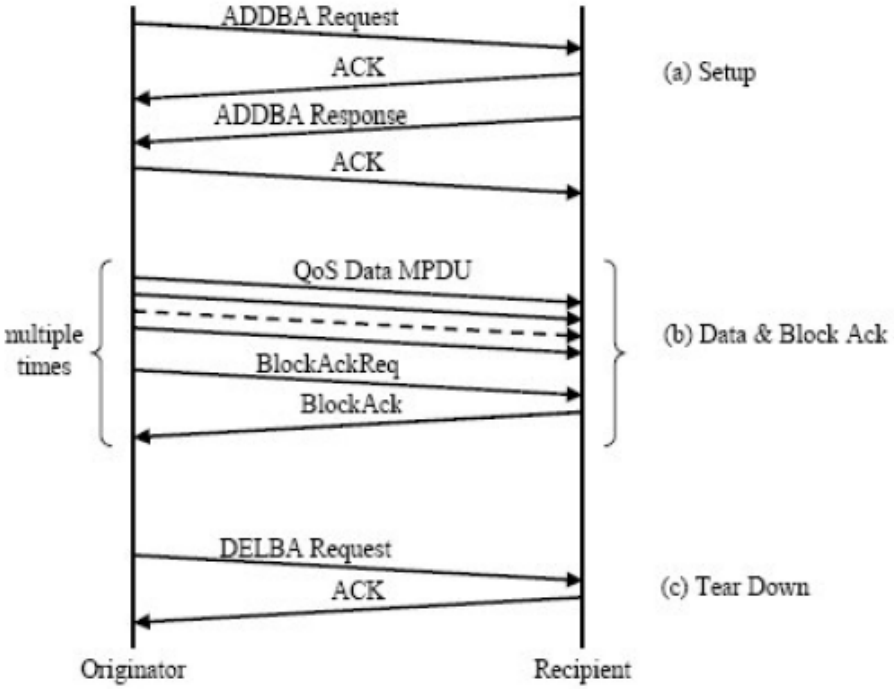
MPDU Aggregation – A-MPDU

- Multiple PDU within the same physical communication
  - One single PLPC header
  - Multiple (one per MSDU) MAC headers

- A-MSDU and A-MPDU can be nested
- Large gains for sustained transfers, STA/AP accumulate traffic for block transmission

Block ACK Usage

- Block ACK procedure is not trivial
- Must be initiated and terminated



ADDBA Request used to initiate BA session

ADDBA Response confirms/rejects the sessions

Frames of a session need NOT be sent consecutively

- They can be mixed with other frames of a station
- They can be interleaved with packets from other stations
- They can be sent in multiple .11e TXOPs

BlockAckReq used to solicit a BlockACK response frame

DELBA used to terminate a BA session

Compressed Block ACKs

- Block ACK message in 802.11e contains Block ACK field with 64 × 2 bytes
  - 2 bytes for each MSDU fragment to be acknowledged)
- Fragmentation of MSDU is not allowed in 802.11n A-MPDU
- 2 bytes reduced to 1 byte, and the block ACK bitmap is compressed to 64 bytes
  - Maximum number of MPDUs in 1 A-MPDU is limited to 64
- The TX STA can request one block ACK for all frames instead of using legacy acknowledgments to each frame
- Gain is in the reduction of SIFS