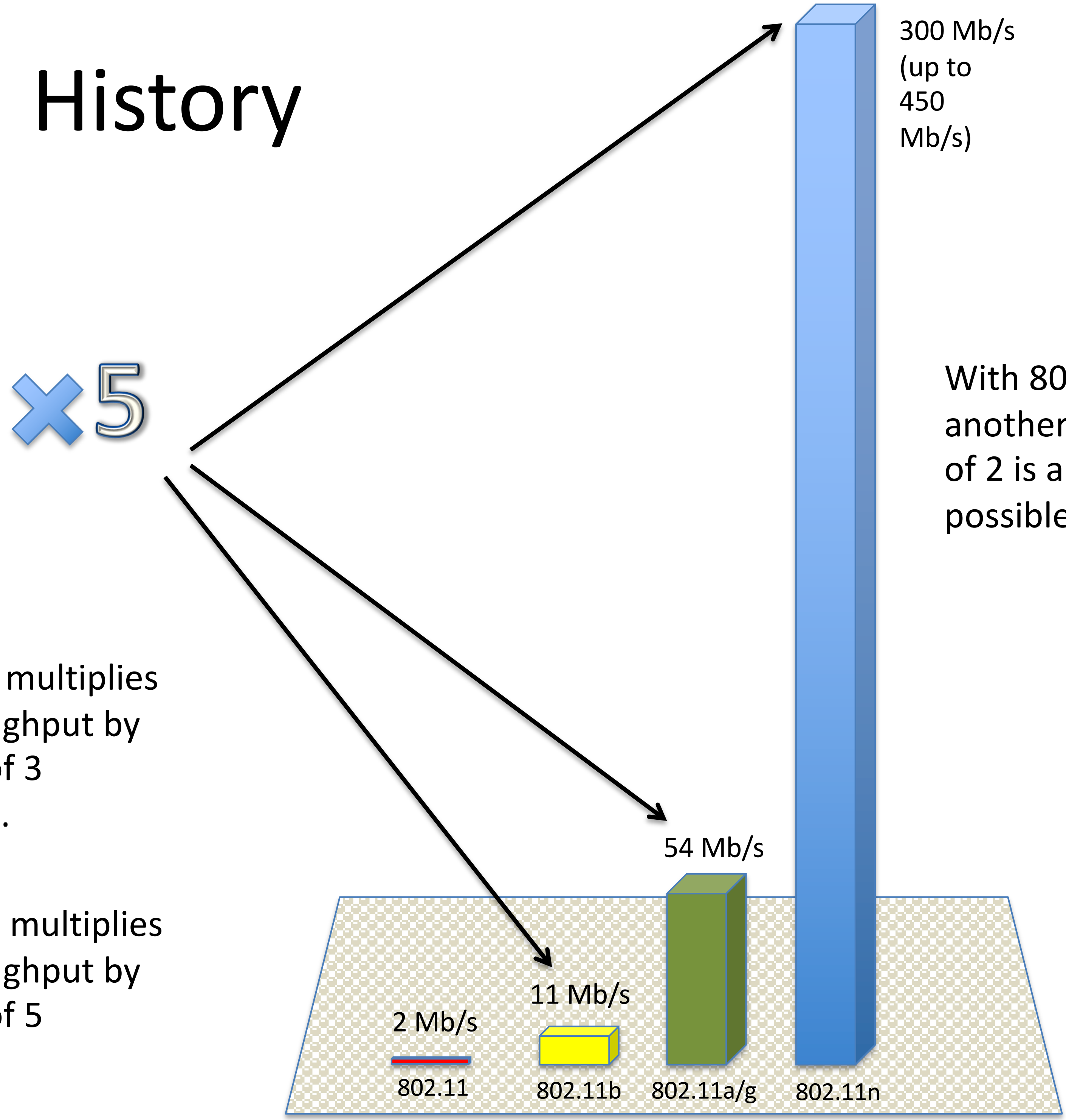
Introduction to 802.11n

Marcos Rubinstein

History



With 802.11n, another factor of 2 is also possible

802.11ac multiplies the throughput by a factor of 3 (1.3Gb/s).

802.11ad multiplies the throughput by a factor of 5 (7Gb/s).

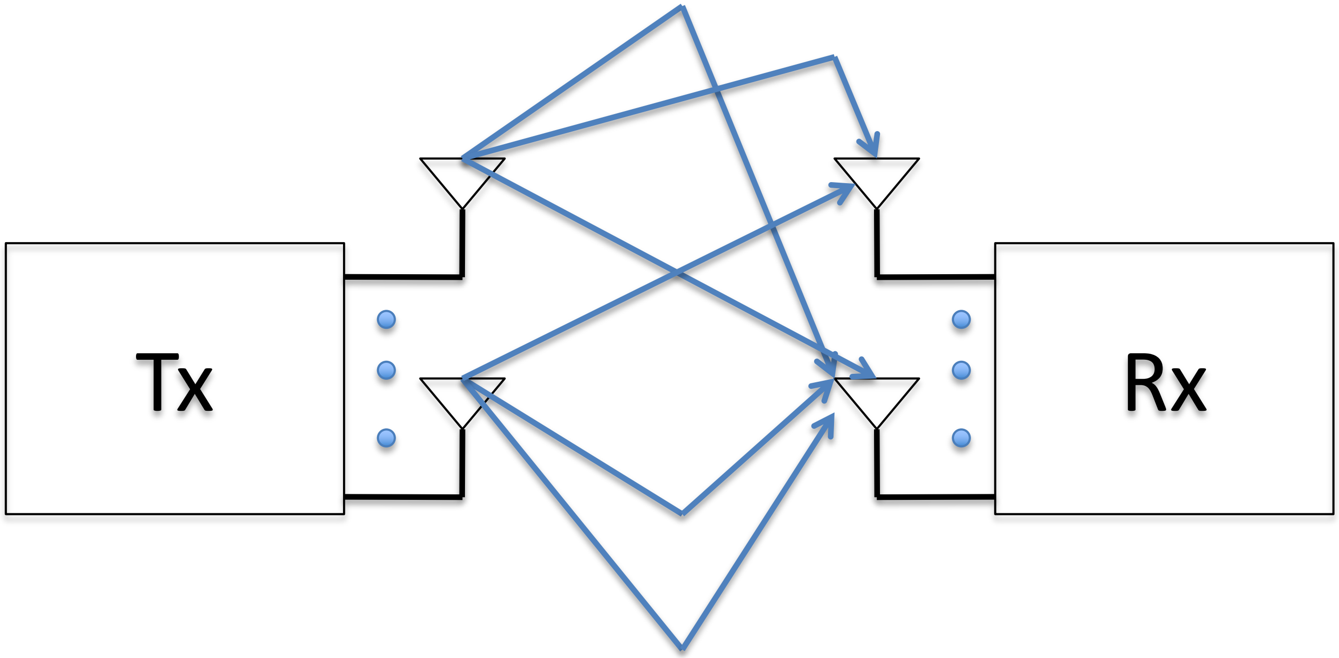
Data Rate Increase

- To increase speed for 802.11 and 802.11b, efforts concentrated mainly on the physical layer for 802.11a and 802.11g
- A loss of about 50% was due to the MAC layer
- In 802.11n, the physical layer was improved but very important efforts were made towards the improvement of the MAC layer

MIMO

- Before 802.11n, multipath was one of the main problems because destructive interference creates “hot spots” and “cold spots” which depend on the relative position of different stations and APs
- With MIMO (Multiple Input/Multiple Output), multipath is used to increase the data rate by transmitting different data streams in parallel

MIMO (Multiple Input Multiple Output)

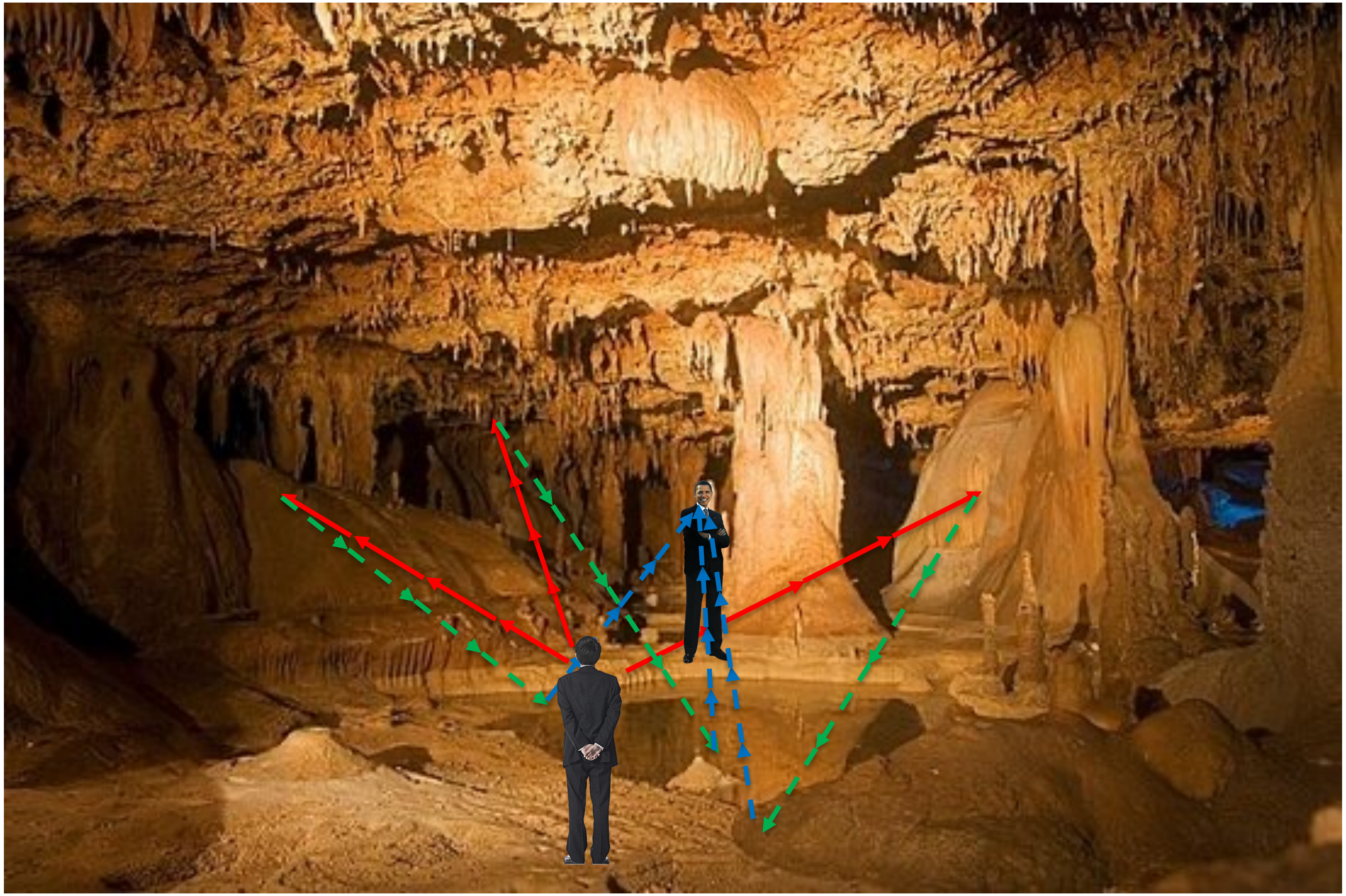


Spatial Multiplexing

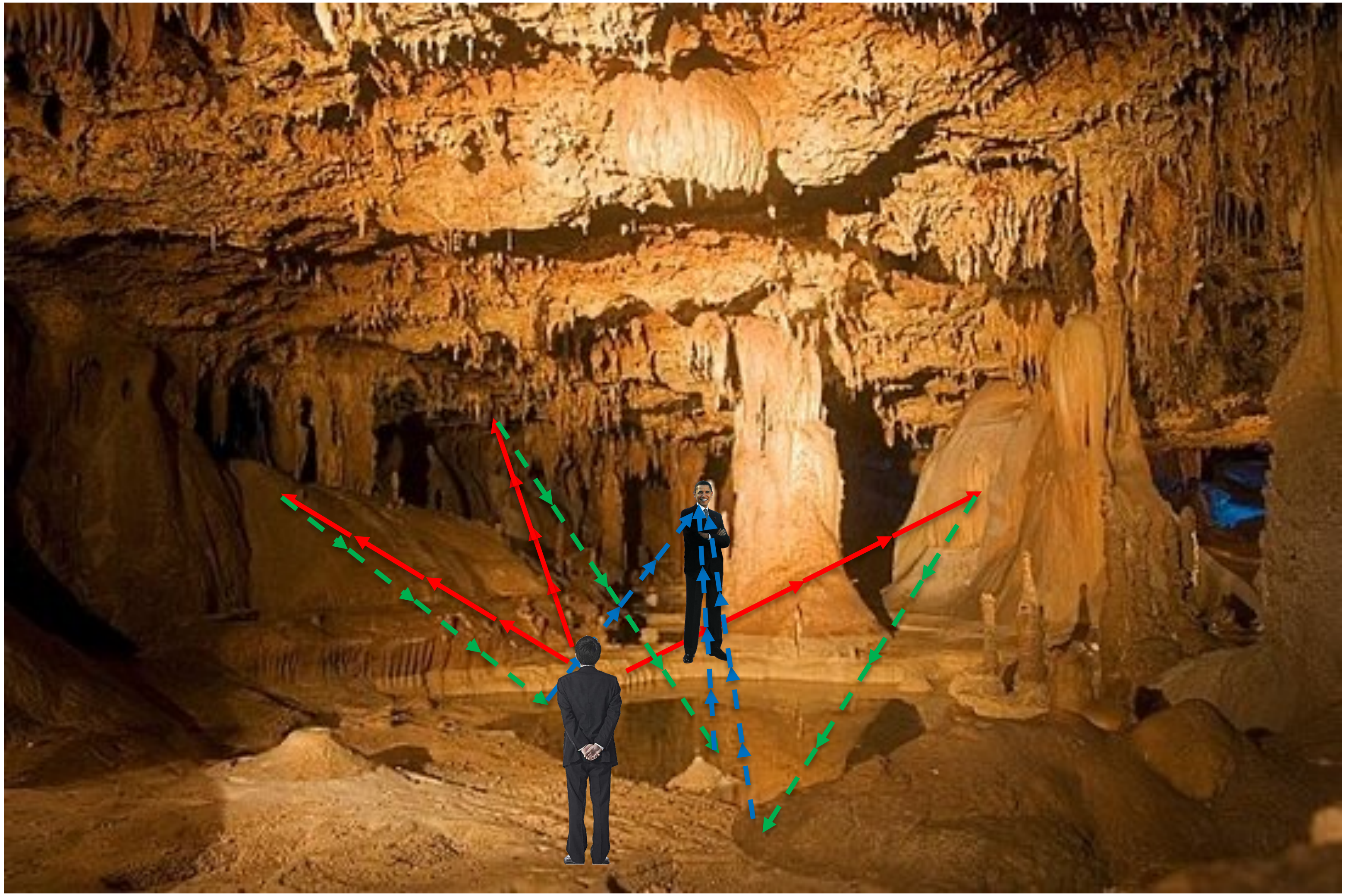
It is used in 802.11n, 802.11ac and 80211ad

Analogy using sound…

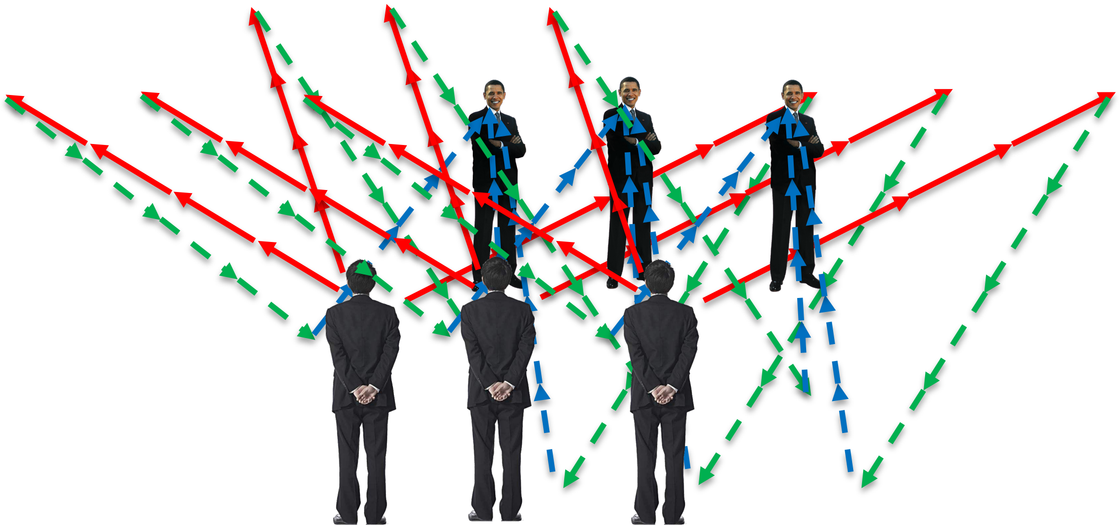
MIMO (Multiple Input Multiple Output)



MIMO (Multiple Input Multiple Output)



MIMO (Multiple Input Multiple Output)



Even if all three persons talk simultaneously, it is possible for the three listeners to separate the three speeches-

Frequencies in 802.11n

- In the words of Matthew Gast:
  - 802.11n is agnostic with respect to the operating frequencies because both, the 2.4 GHz and 5 GHz were available when the amendment was developed
- An 802.11n BSS can be established in any of those two frequency bands (but not simultaneously)
- To increase rates, 802.11n allows the use of channels twice as wide as before: 2x20 MHz = 40 MHz)
- The 40 MHz channels must be (and are) disabled by default at 2.4 GHz because there can be interference with other systems (e.g., BT)

Problems with MAC pre-802.11n

- For each transmission, there are fixed costs in terms of waiting intervals SIFS, DIFS, and PLCP headers
- These costs become more important as the data rates increase:
  - A SIFS interval of 10 μs represents how many bits of overhead (i.e., “lost”) at 11 Mbps ?
  - And at 300 Mbps?

Before 802.11n, there was 802.11e

- 802.11e is an amendment introduced to give a certain Quality of Service (QoS) for WLAN networks
- It was a step in the good direction and 802.11n took inspiration from 802.11e to go even further

One of the Problems

- <u>Each frame</u> a station sends competes with the other stations: There is a DIFS and a random backoff every time
- Two possibilities. What would you do?
  a. Kill CSMA/CA and redefine MAC access protocols from zero
  b. Allow stations to transmit several frames in a row without competing with the others

How to allow the transmission of several frames?

a. Develop a method that allows stations to transmit simultaneously?
b. If a station obtains the right to transmit a first frame, it should be allowed to transmit all frames in queue before releasing the channel?
c. A station is allowed to reserve the channel for a given amount of time. This time will be used to transmit several frames?

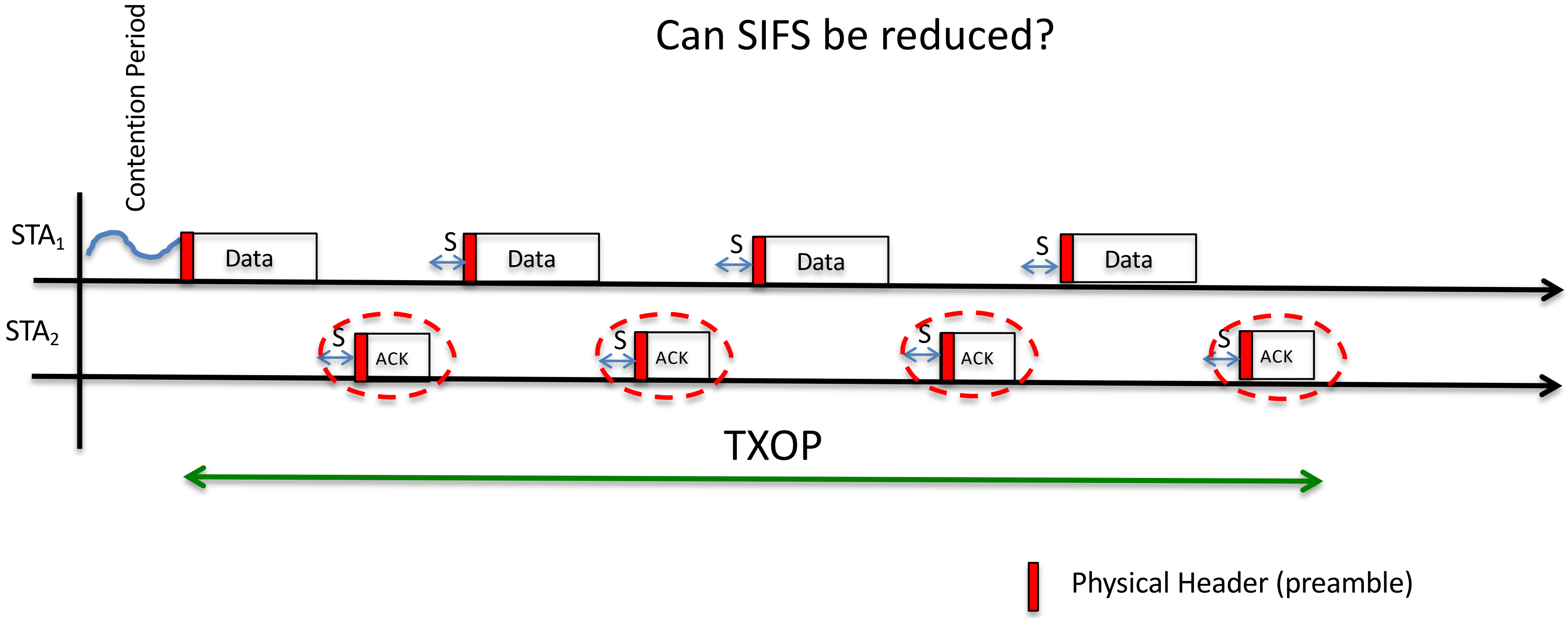
Already implemented in 802.11e with TXOP

Improvements Introduced with 802.11e

- Concept of TXOP and Data Bursting

One ACK after each frame

Can SIFS be reduced?



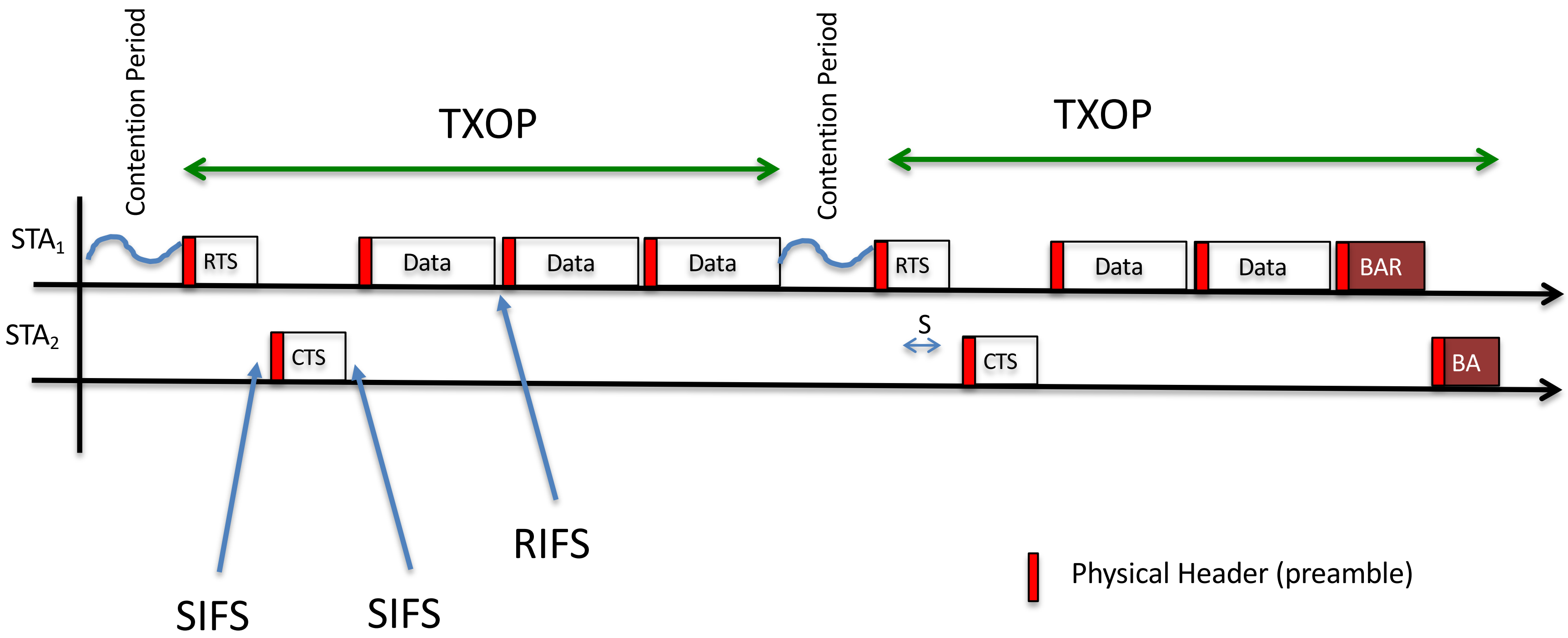
There's an ACK for each Frame. What to do ?

a. Do as in Ethernet cabled networks and do not use ACKs (let the upper layers deal with errors and retransmissions)?
b. Invent a new type of ACK that can be used to acknowledge several frames at the same time?

Concept of *Block ACK Request* and *Block ACK*

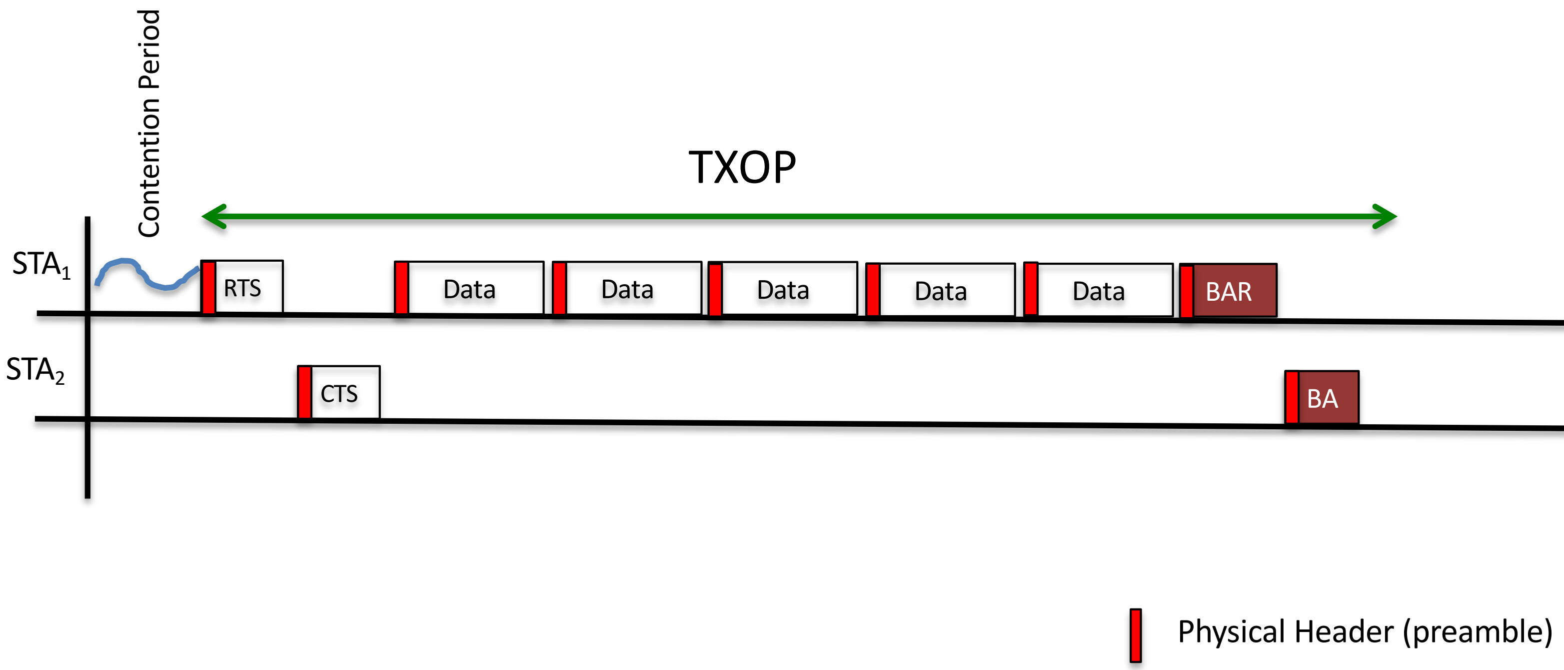
Use a new, shorter interframe spacing RIFS (reduced interframe spacing: 2µs)

RIFS only if no change from transmitter to receiver (or Rx to Tx)



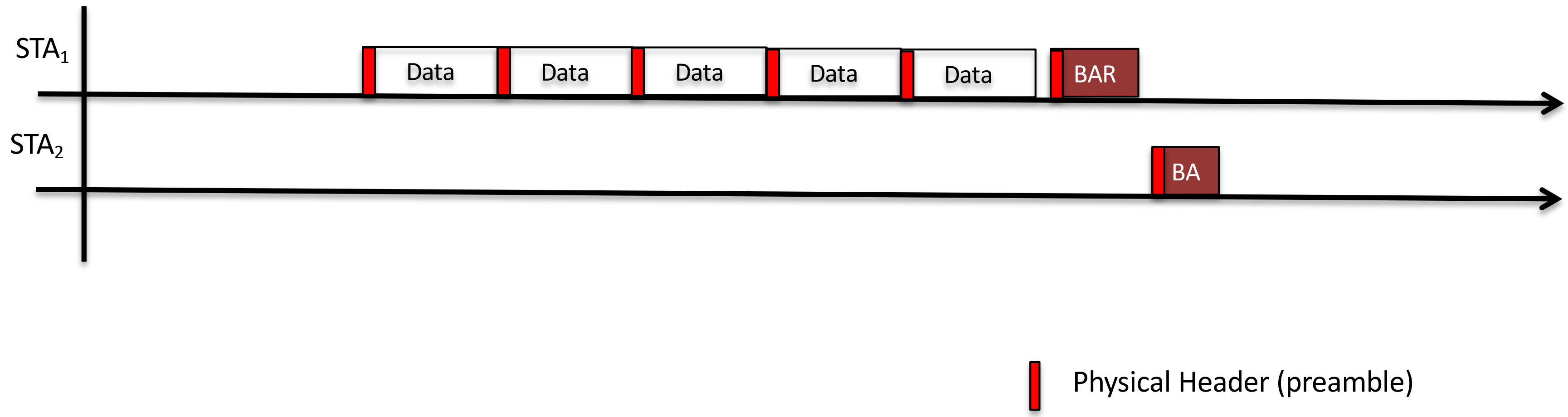
Improvements of 11n with respect to 11e

- Reduce the interframe time if there is no Rx->Tx or Tx->Rx changes. The new interval is called RIFS (reduced interframe spacing: 2μs)

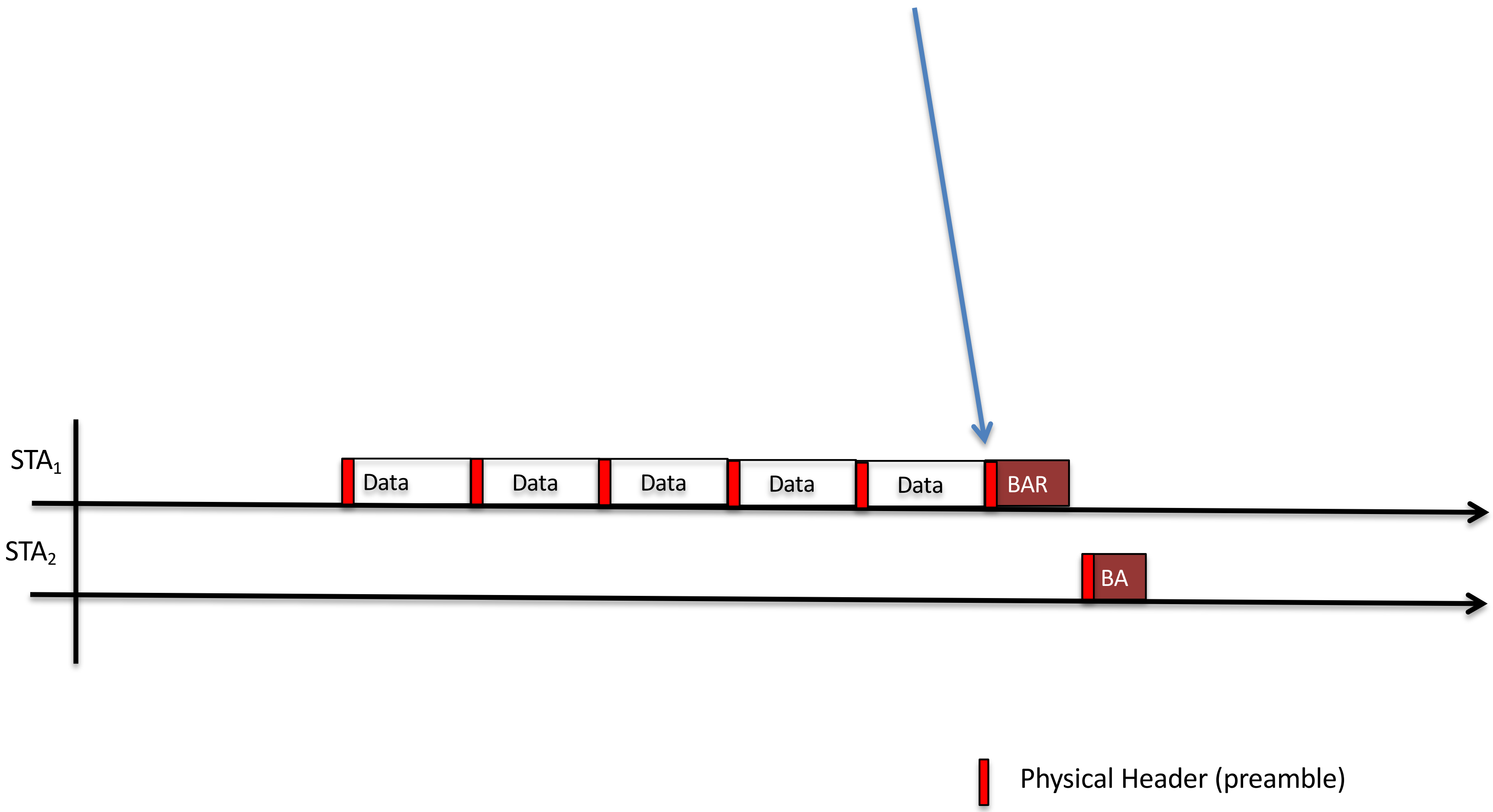


Data frame aggregation

- Pack several frames together into a single frame



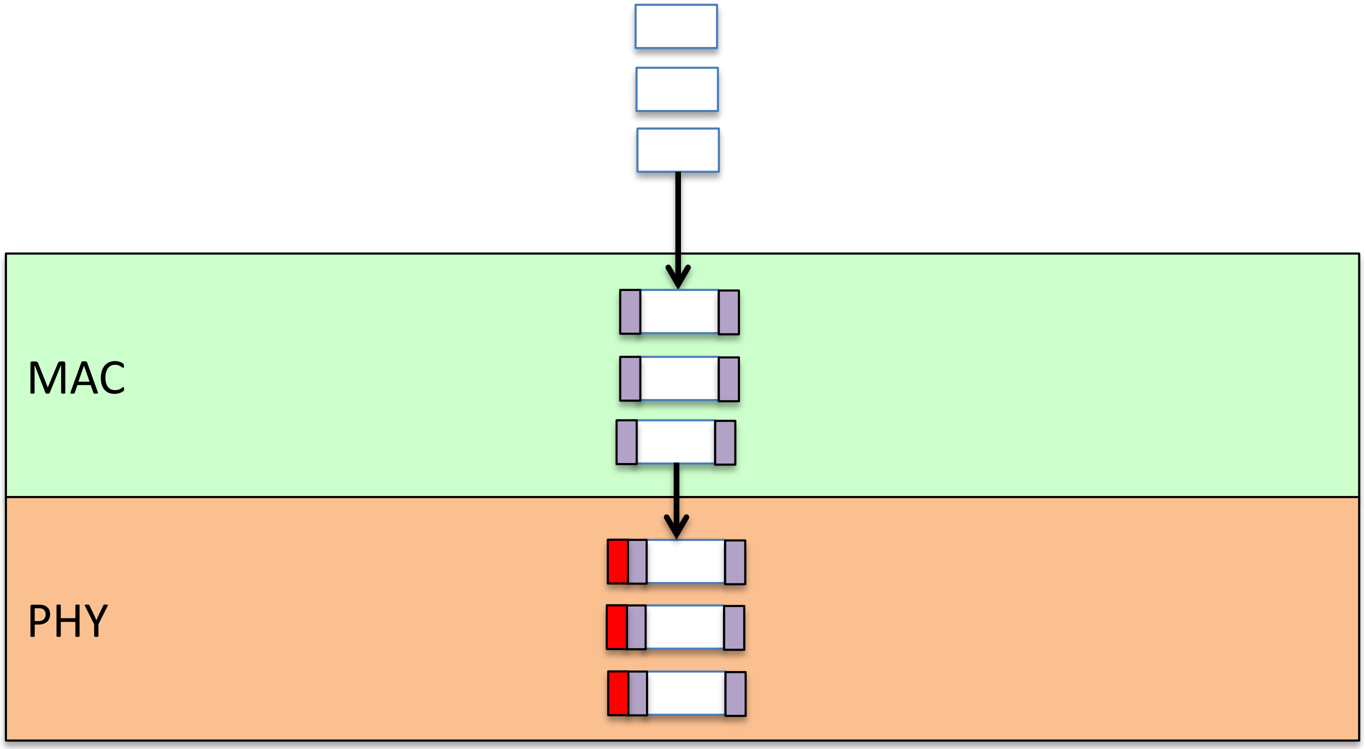
Control frame aggregated to data PDUs



A little more detail on the implementation of improvements at the MAC level…

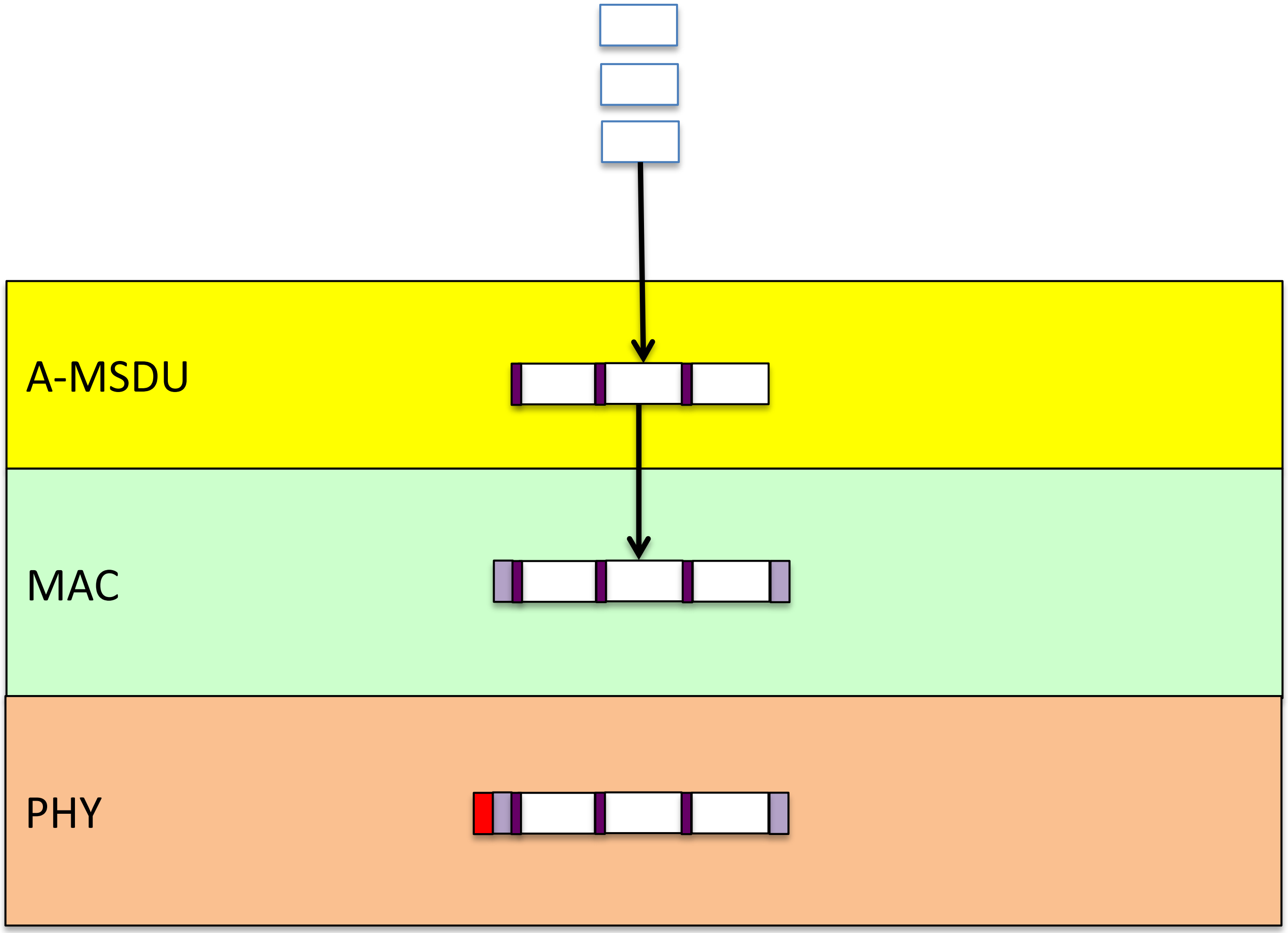
Aggregation - Why ?

- With *n* LLC PDUs, *n* x channel access procedures are required



MSDU Aggregation

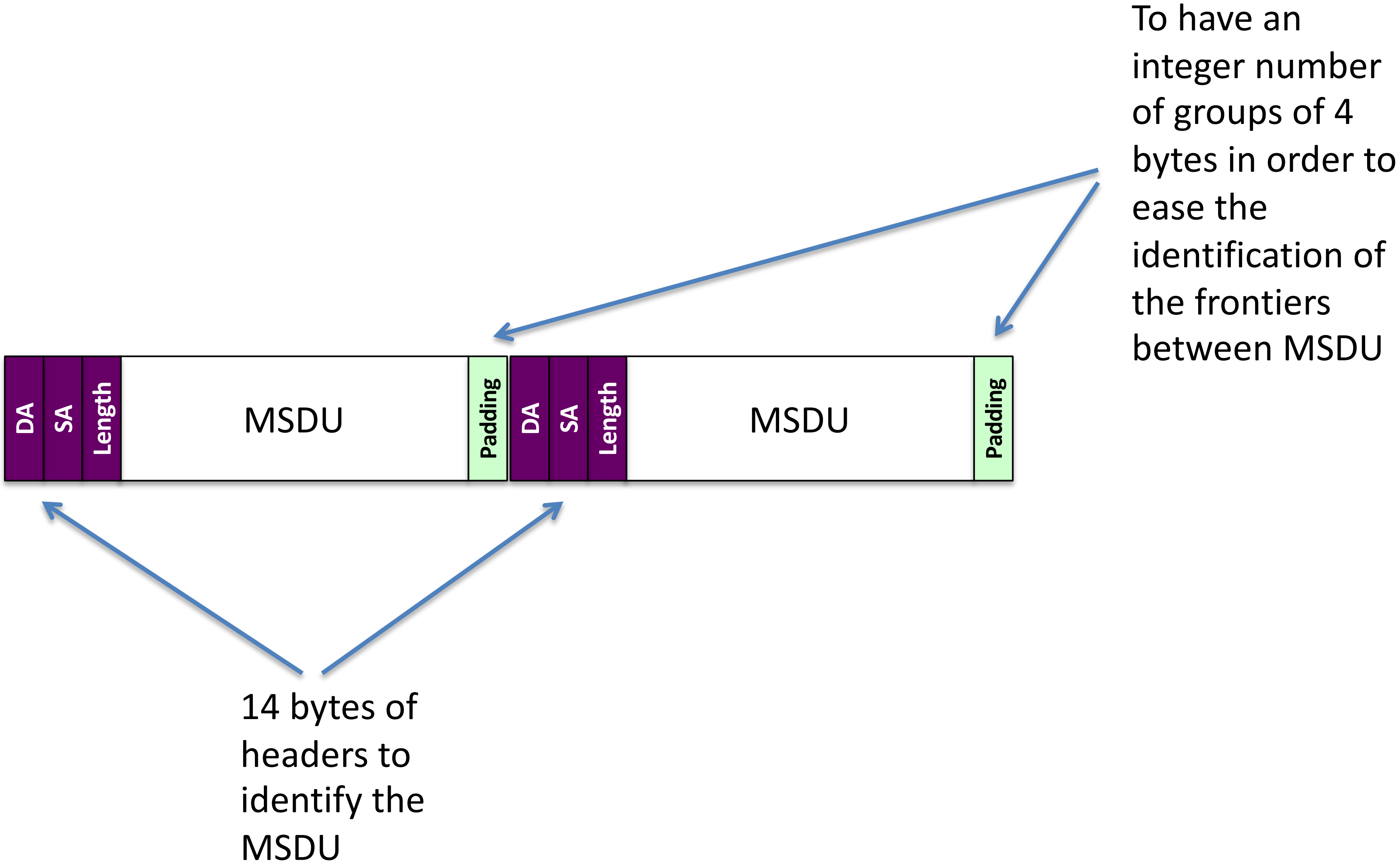
- New A-MSDU layer located over MAC



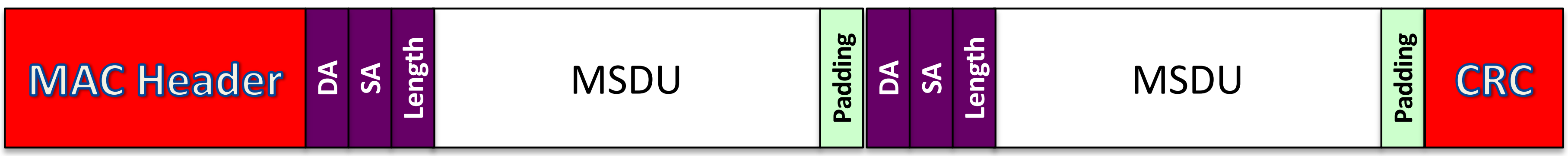
A-MSDU

- The MSDU aggregation concatenates MSDUs (MAC Service Data Units) together and encapsulates the results to create a single MPDU.
- Only one access to the channel is necessary

A-MSDU (MSDU Aggregation)



A-MSDU (MSDU Aggregation)

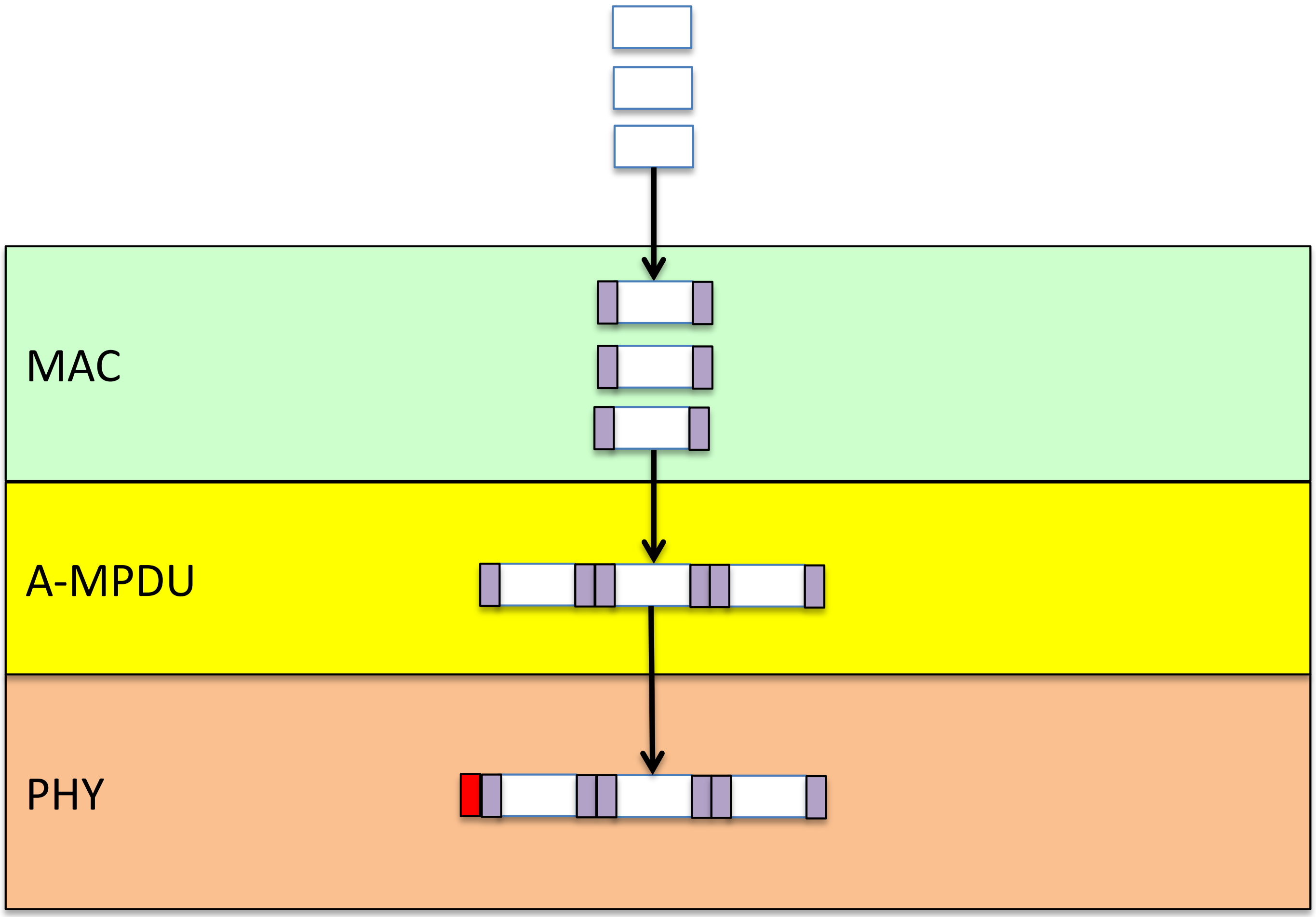


Disadvantages of the A-MSDU

- There’s only one FCS (CRC) for all the original MSDUs
- In case of error, there’s no way to know which MSDU is malformed.
- Retransmission will be needed for the whole group of MSDU

MPDU Aggregation

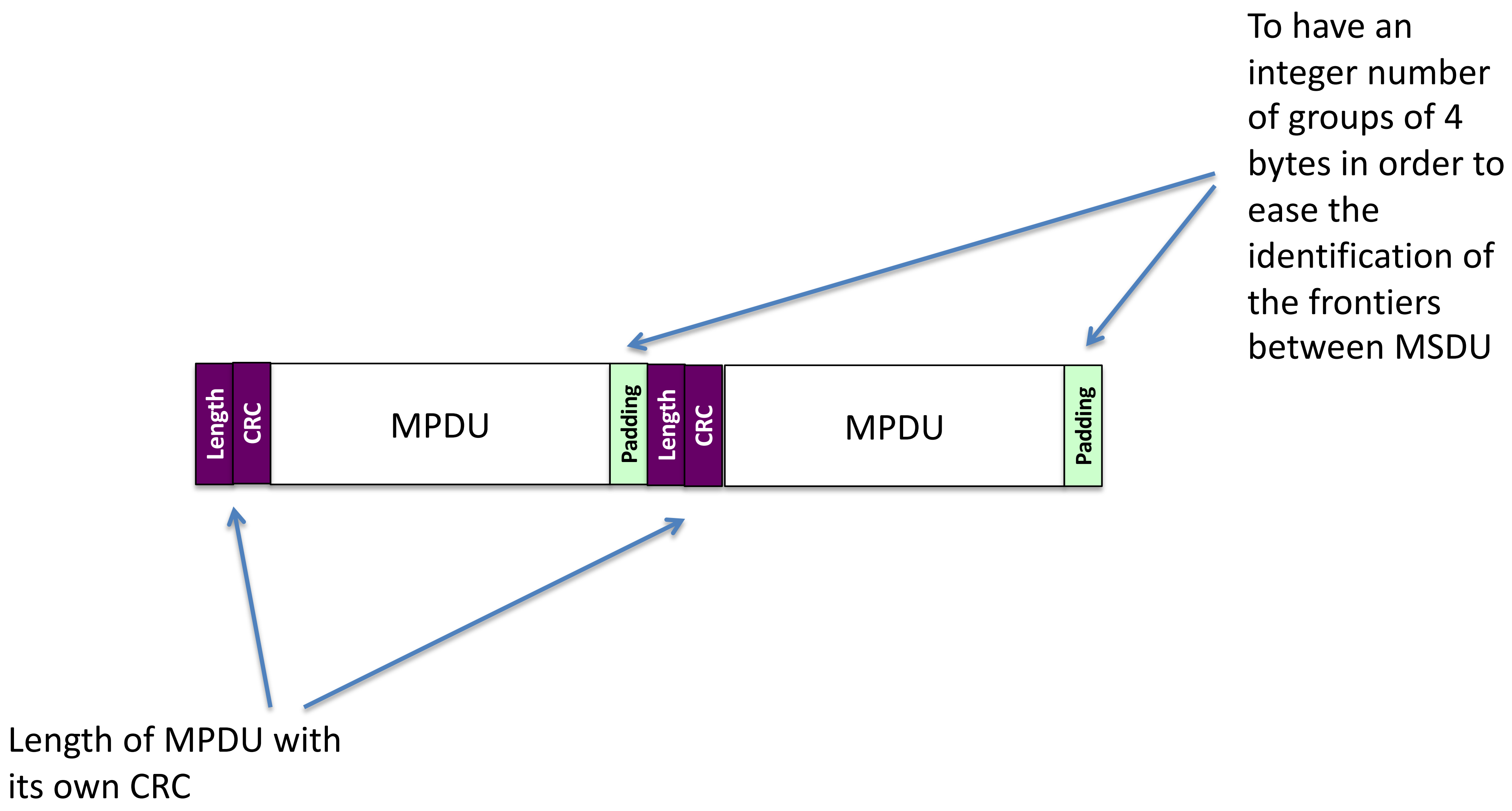
- A new A-MPDU layer is placed under MAC



A-MPDU

- MPDU aggregation puts MPDUs together to create what will become a single PSDU that PHY will send as a single PPDU

A-MPDU (MPDU Aggregation)



For A-MPDU

- There’s the possibility to retransmit only the malformed MPDUs