Performance Analysis of the IEEE 802.11e Block ACK Scheme in a Noisy Channel

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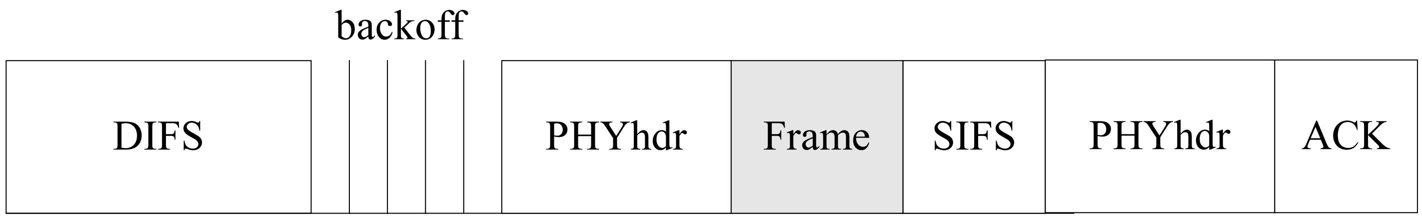
Motivation (1/4)

- Block ACK (BTA) proposed in IEEE 802.11e, aiming to improve MAC efficiency, but how much?
- Recently proposed again in IEEE 802.11n, why?
- Few related work

Motivation (2/4)

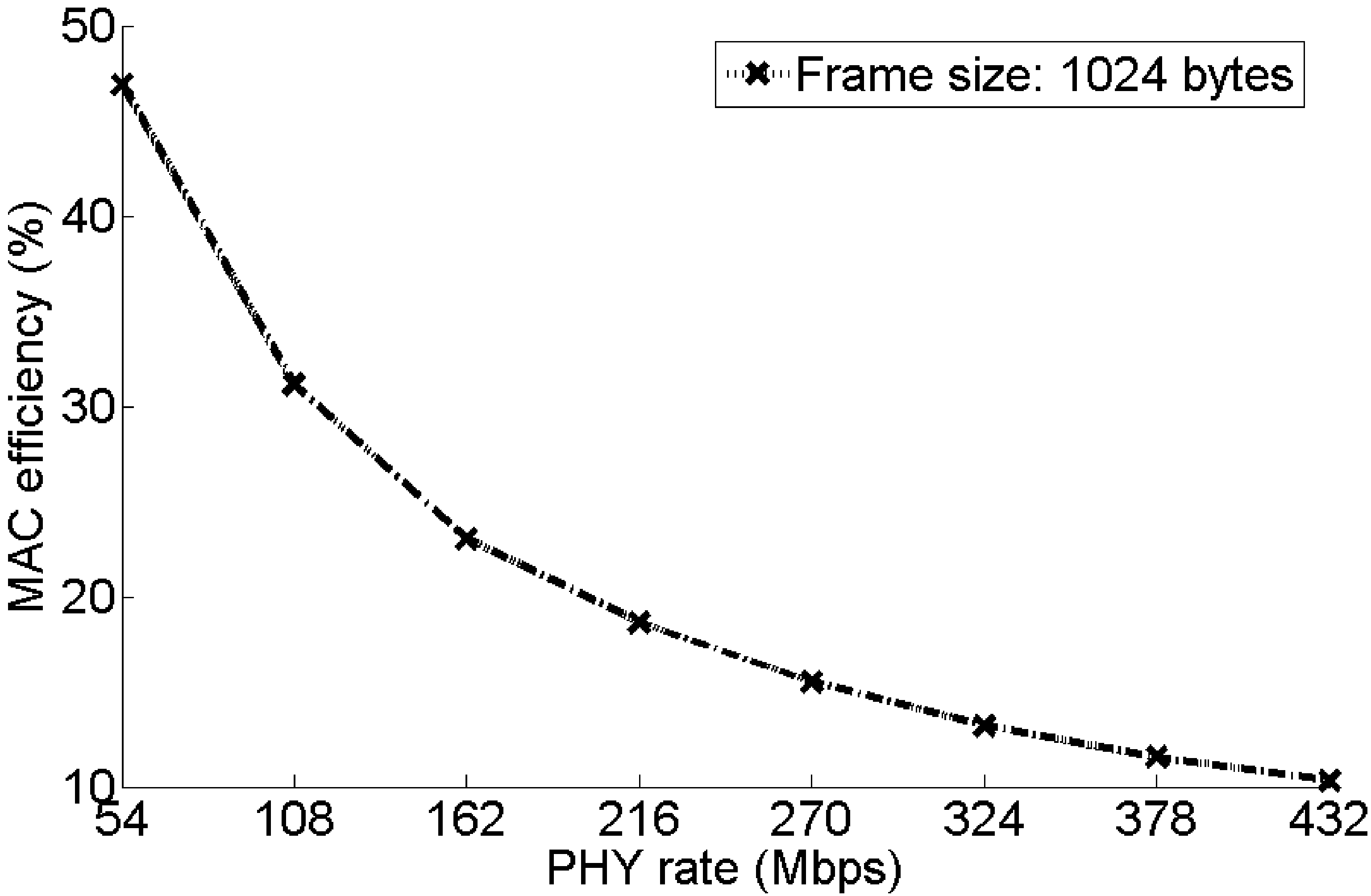
- IEEE 802.11 MAC:
  - DCF



  - Freezing: actual slot duration > default slot
- Problems of DCF:
  - Idle slot: all STAs wait in a slot
  - Collision: multiple STAs transmit in a single slot
  - Other overhead: DIFS, SIFS, PHY headers, ACK.

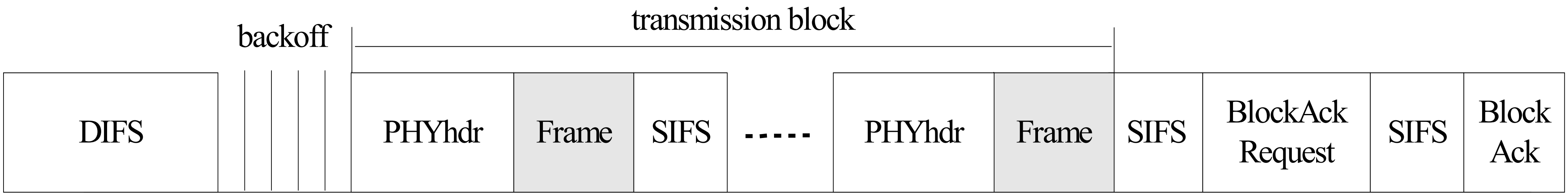
Motivation (3/4)

- No collisions, no errors and freezing, average slot = $CW_{min}/2$
- Efficiency bounded by a maximum value [*Xiao and Rosdahl, 2003*]



Motivation (4/4)

- Block ACK



- Block ACK Request (BAR): Inform the end of a block
- Block ACK (BA): acknowledge the reception
- Multiple frames are acknowledged by BAR and BA, so DIFS, PHY headers, backoff and ACK are removed for frames in a block.

Related work & contributions

- Related work:
  - DCF
    - Saturated + collision [*Bianchi, 2000*]
    - Saturated + errors and collisions [*Ni, et al., to appear*]
  - BTA
    - Burst ACK: a similar scheme with BTA [*Vitsas, et al.,, 2004*]
    - Ideal case: no collisions, no errors [*Xiao and Rosdahl, 2003*]
- Contributions:
  - A BTA model: saturated + errors and collisions.
  - *NS* simulation for BTA

Rationale (1/3)

- Saturation throughput (S):
  - S: The throughput of the whole *system, not a single STA*
  - Saturation: whenever the system needs a frame to transmit in a slot, a frame will be available!

$$S = \frac{E[L_{payload}]}{E[T]}$$

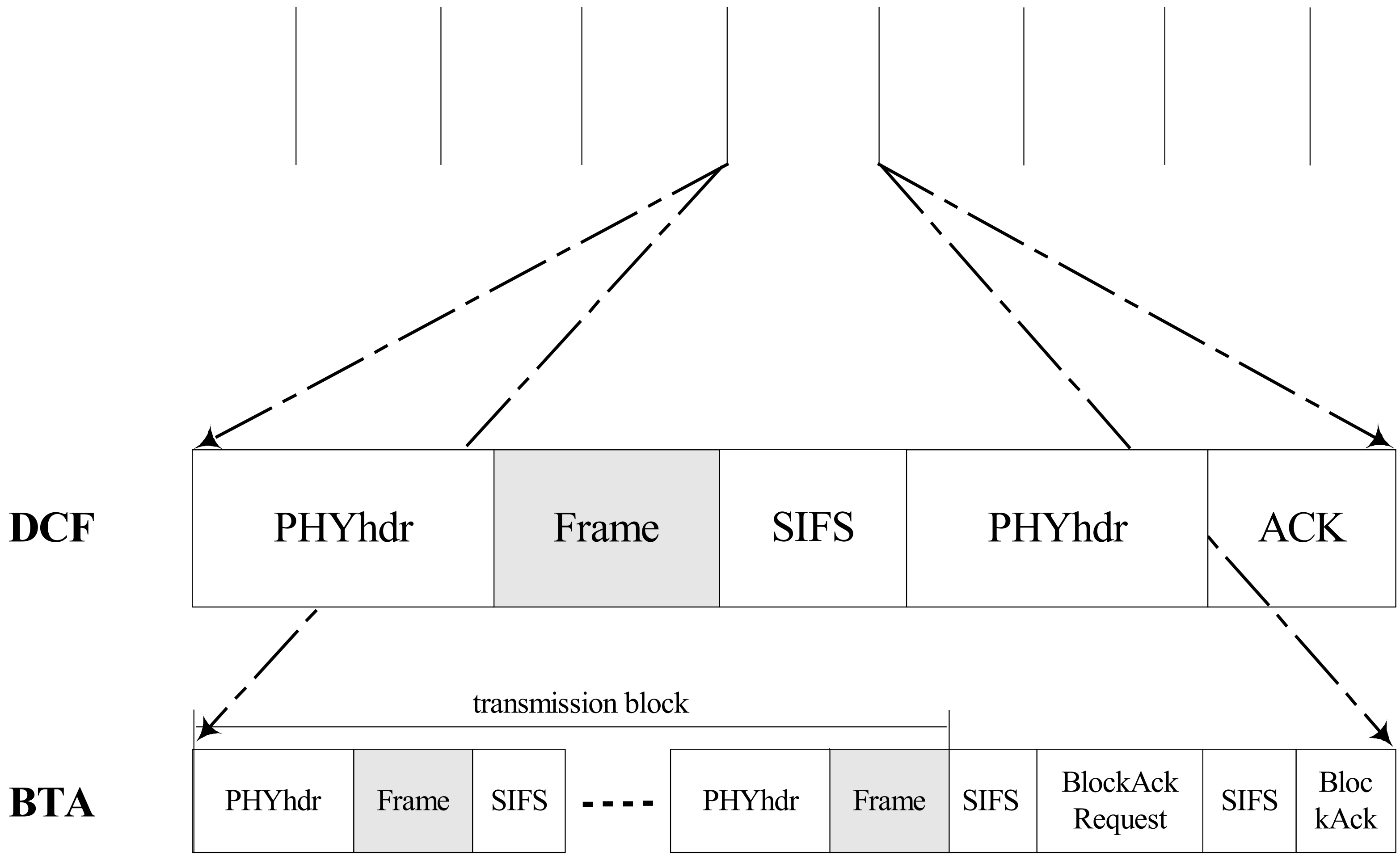
  - $E[L_{payload}]$: Expected payload size
  - $E[T]$: Expected slot duration

Rationale (2/3)

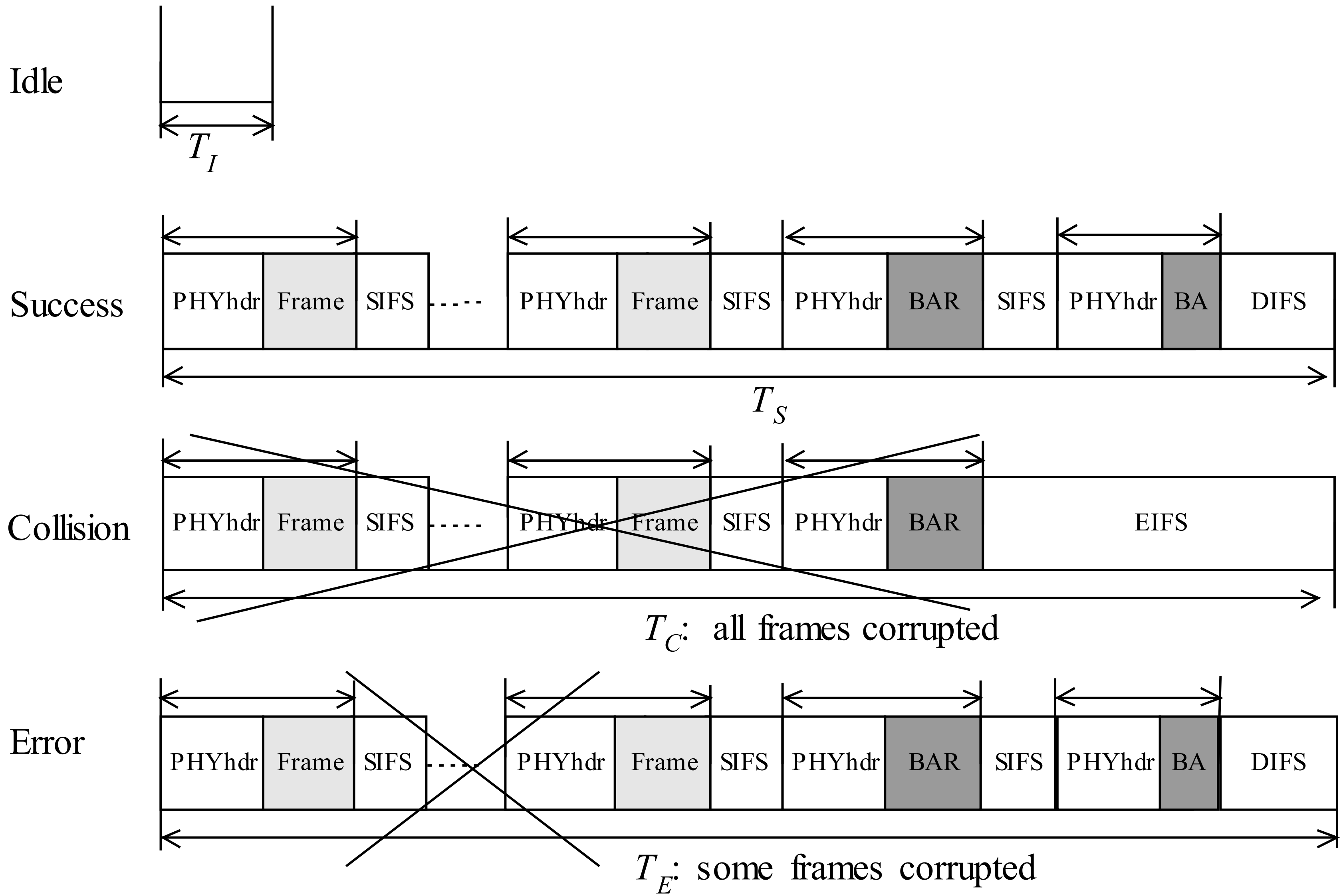
- DCF: After winning contention of the medium access, a frame is transmitted in a slot.
- BTA: After winning channel contention, a block is transmitted in a slot.

- Rationale: A BTA block ≈ A DCF frame

Rationale (3/3)



Durations



Idle
T_I
Success
PHYhdr
Frame
SIFS
PHYhdr
Frame
SIFS
PHYhdr
BAR
SIFS
PHYhdr
BA
DIFS
T_S
Collision
PHYhdr
Frame
SIFS
PHYhdr
Frame
SIFS
PHYhdr
BAR
EIFS
T_C: all frames corrupted
Error
PHYhdr
Frame
SIFS
PHYhdr
Frame
SIFS
PHYhdr
BAR
SIFS
PHYhdr
BA
DIFS
T_E: some frames corrupted

Corresponding probabilities

- $P_{I:}$ Probability of n idle STAs
- $P_{S:}$ Probability of one and only one STA transmits, and succeds
- $P_{C:}$ Probability of more than one STAs are in transmission
- $P_{E:}$ Probability of one and only one STA transmits, but fails

$$P_I = (1-\tau)^{\mathrm{n}}$$
$$P_S = n \cdot \tau \cdot (1-\tau)^{(\mathrm{n}-1)} \cdot (1-p_e^{bta})$$
$$P_C = 1 - P_I - P_S - P_E$$
$$P_E = n \cdot \tau \cdot (1-\tau)^{(\mathrm{n}-1)} \cdot p_e^{bta}$$

Variables (1/2)

- p_e^{bta}: error probability of a block, frame errors follow independent and identical distribution in a block.

$$p_e^{bta} = 1 - (1 - p_e)^{Nb}$$

- p_e: error probability of a frame, bit errors follow independent and identical distribution in a frame.

$$p_e = 1 - (1 - p_b)^{L_f}$$

Variables (2/2)

- τ:
  - Transmission probability in a slot for a *single STA*
  - Same concept as in Bianchi model, but different value
  - τ and p_f are solved together by two formulas
  - p_f: Probability of doubling CW

- First formula: $$p_f = p_c = 1 - (1 - \tau)^{n-1}$$
- Second formula: $$\tau = \sum_{i=0}^{m} b_{i,0}$$
  - Where *m* is the maximum backoff stage *i* as defined by $CW_{max} = 2^m \cdot CW_{min}$
  - $b_{i,0}$ is the probability of the contention window decreases to zero at the stage *i*, obtained from a 2-D Markov chain similar to in previous work, so ignore here

Saturation throughput (S_{bta})

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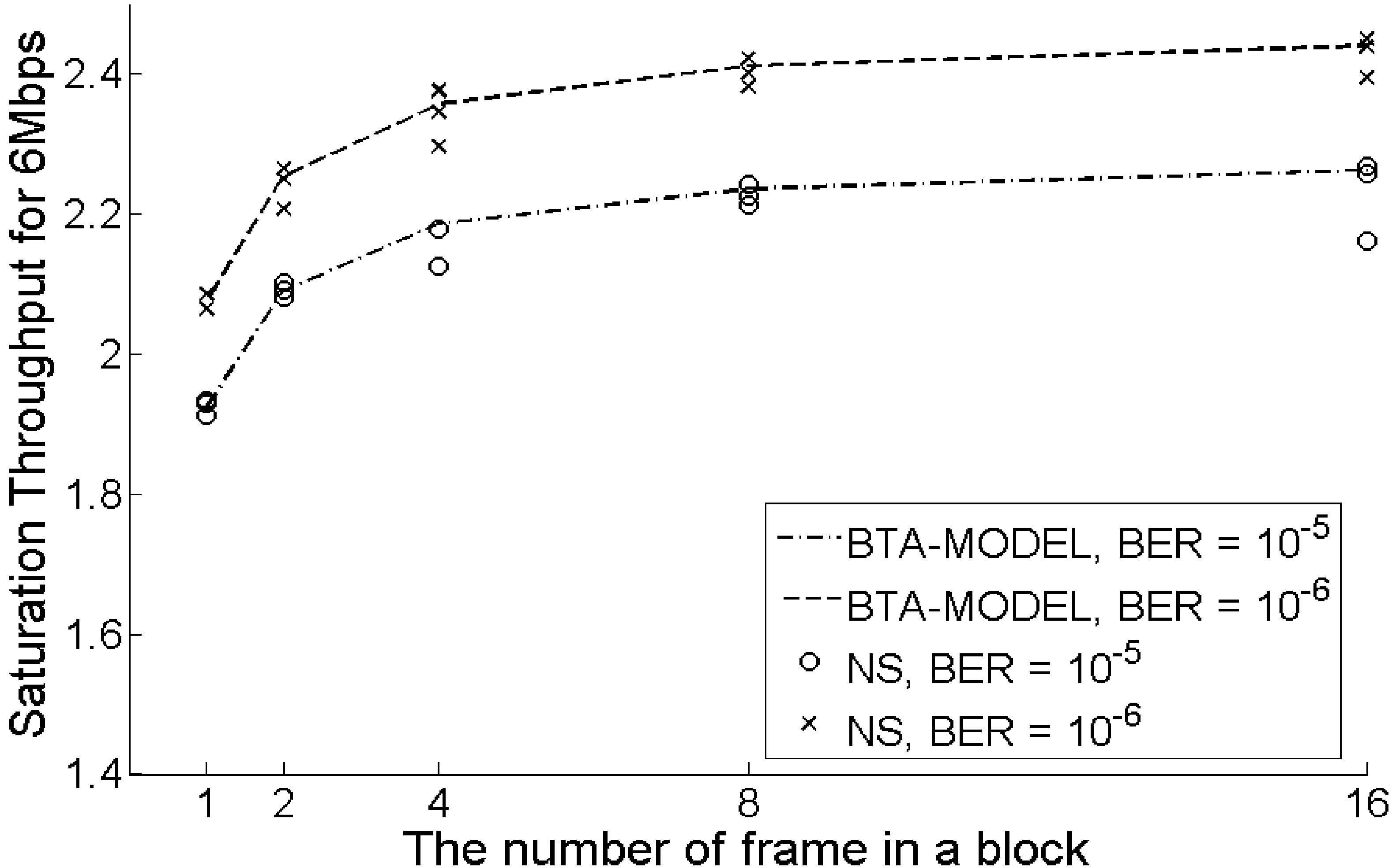
  - *E[L]* denotes the expected frame size transmitted in an erroneous block.

$$S_{bta} = \frac{P_S \cdot N_b \cdot L_f + P_E \cdot E[L]}{P_I T_I + P_S T_S + P_E T_E + P_C T_C}$$

$$E[L] = \sum_{i=1}^{N_b} [\binom{N_b}{i} \cdot (p_e)^i \cdot (1 - p_e)^{(N_b - i)} \cdot (N_b - i) L_f]$$

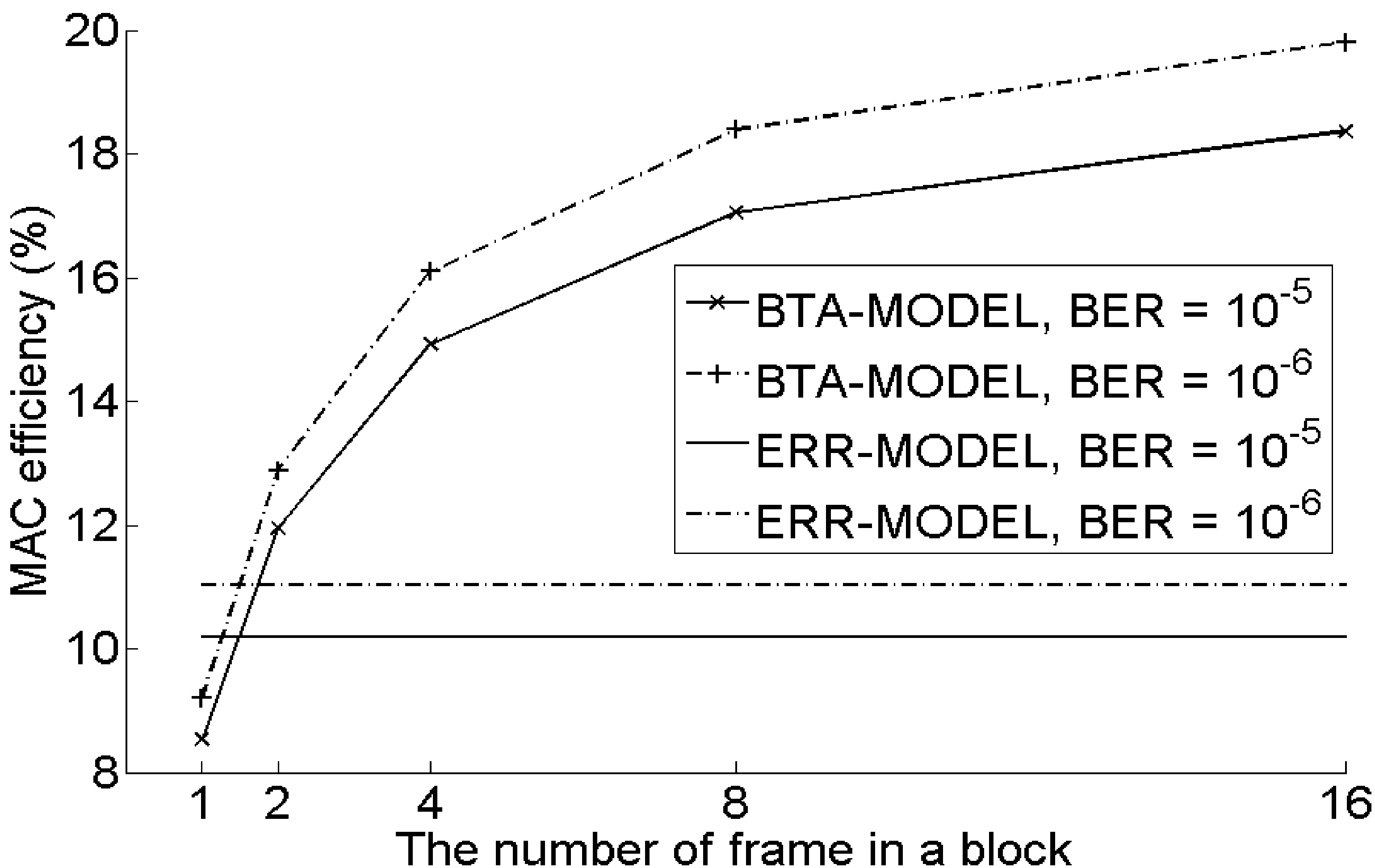
Model validation

- 50 STAs, frame size = 1024 bytes, PHY = BAR = BA = 6 Mbps



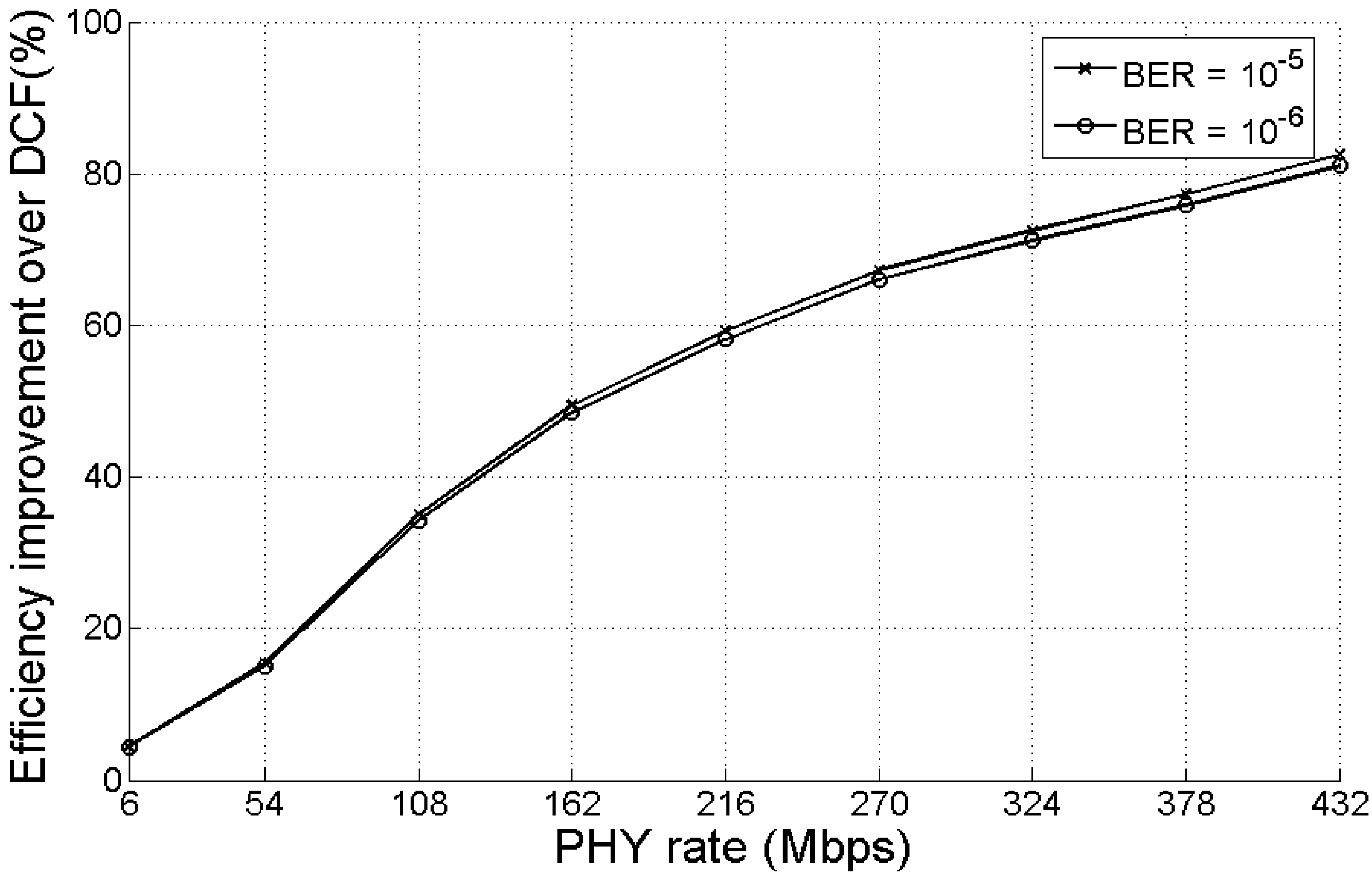
BTA vs DCF (1/2)

- 50 STAs, frame size = 1024 bytes, PHY = BAR = BA = 216 Mbps



BTA vs DCF (2/2)

- Frame size = 1024 bytes, block size = 8



Conclusions

- Conclusions
  - A theoretical model for Block ACK
  - *NS* implementation of it
- Future work
  - Non-saturation case
  - Compare with aggregation based schemes

Thanks!