UBI Covilhã Portugal

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IEEE 802.15.4 MAC Layer Performance Enhancement by employing RTS/CTS combined with Packet Concatenation

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Outline

- Introduction
- IEEE 802.15.4 MAC Channel Access
- IEEE 802.15.4 in the presence/absence of RTS/CTS
  - Best-Case Scenario (no collisions);
  - Retransmissions Scenarios.
- Conclusions

Introduction

- One of the fundamental reasons for the IEEE 802.15.4 standard Medium Access Control (MAC) inefficiency is overhead.
- Within IEEE 802.15.4, the possible use of RTS/CTS, by itself, facilitates packet concatenation and leads to performance improvement.
- By considering IEEE 802.15.4 basic access mode with RTS/CTS combined with the packet concatenation feature we improve channel efficiency by decreasing the deferral time before transmitting a data packet.

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IEEE 802.15.4 MAC Channel Access

- Parameters, symbols and values for IEEE 802.15.4 by considering the DSSS PHY Layer for the 2.4 GHz band.

Description	Symbol	DSSS PHY
PHY length overhead	L_{H_PHY}	6 bytes
MAC overhead	L_{H_MAC}	9 bytes
Symbol Rate	T_{SR}	62.5 ksymbol/s
Symbol duration	T_S	16 μs
TX/RX or RX/TX switching time	T_{TA}	192 μs
Short Interframe spacing (SIFS) time	T_{SIFS}	192 μs
Long Interframe spacing (LIFS) time	T_{LIFS}	640 μs
Backoff period duration	T_{BO}	320 μs
Data Rate	R	250 kb/s

IEEE 802.15.4 MAC Channel Access

Clear Channel Assessment (CCA)

Channel BUSY	Channel IDLE
$NB = NB + 1$	$NB = 0$
$cw_{NB} = [2^{BE_i} - 1]$	$cw_{NB} = [2^{BE_i} - 1]$

$BE_i = 3$, i=0

$BE_i = 4$, i=1

$BE_i = 5$, i≥2

$cw_{NB} = 15$ ⟵ (i=1) ⟶ $cw_{NB} = 7$

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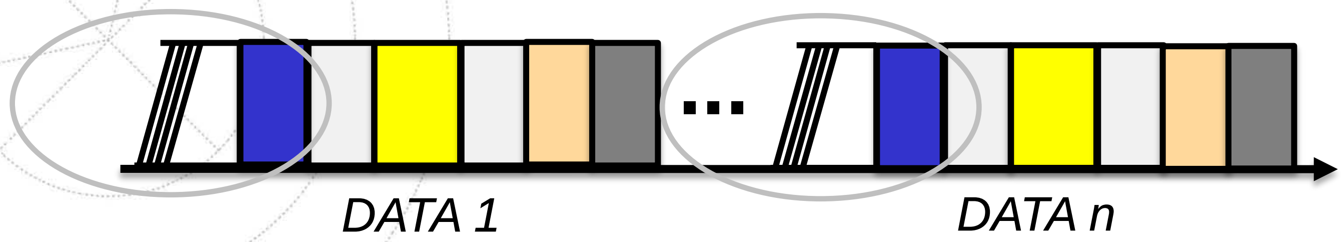
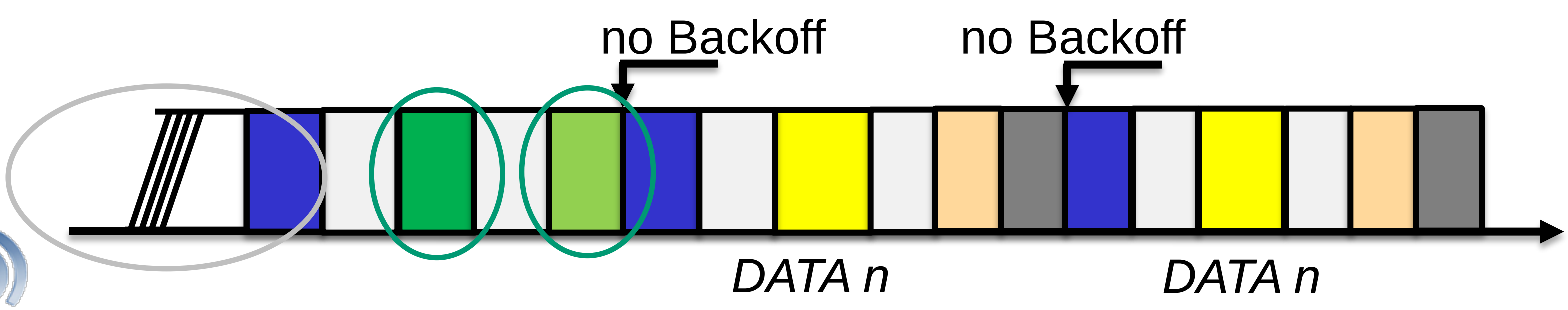
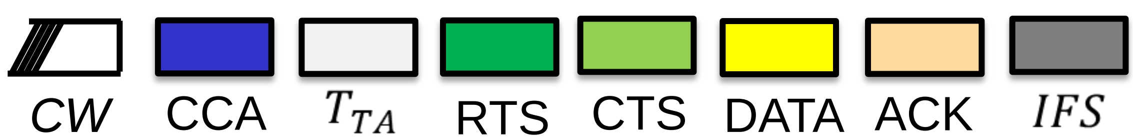
IEEE 802.15.4 in the presence/absence of RTS/CTS

- IEEE 802.15.4 at the Best-Case Scenario (**no collisions**).



- IEEE 802.15.4 **in the presence of RTS/CTS** (**no collisions,**



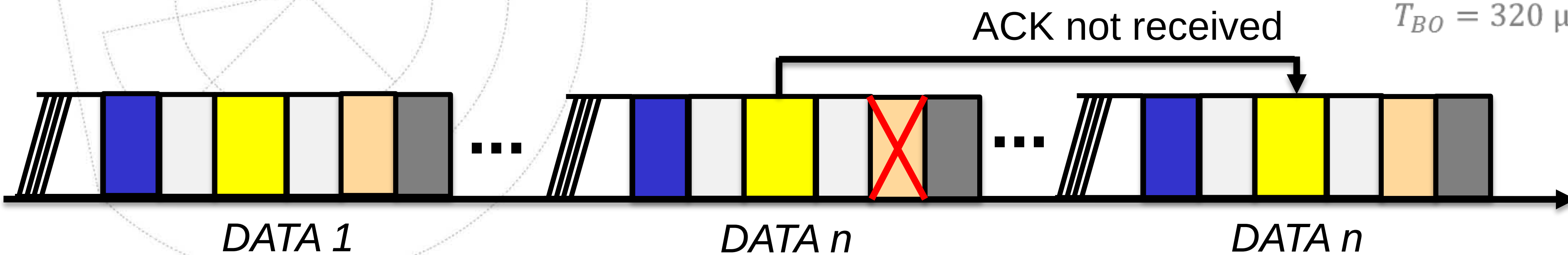


IEEE 802.15.4 in the presence/absence of RTS/CTS

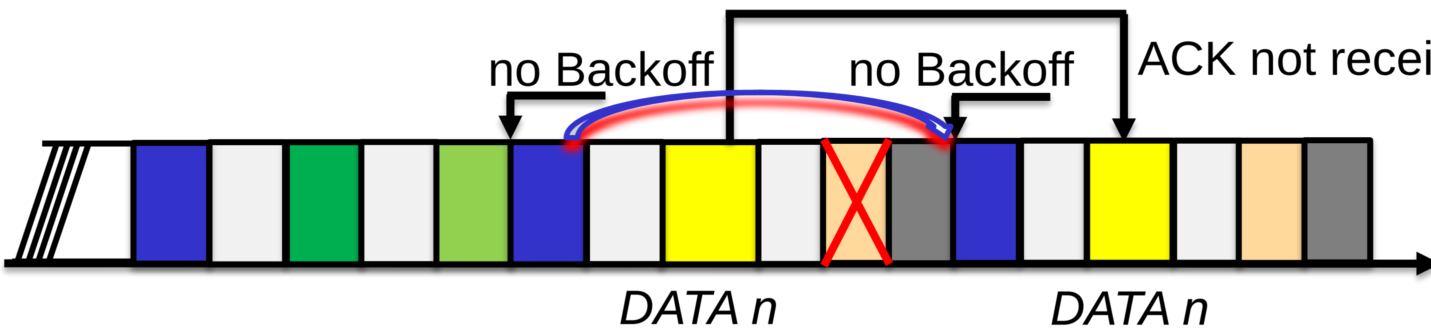
- IEEE 802.15.4 **in the absence of RTS/CTS (with collisions,** $BE \geq 3$, $CW_{max} \geq 7$)

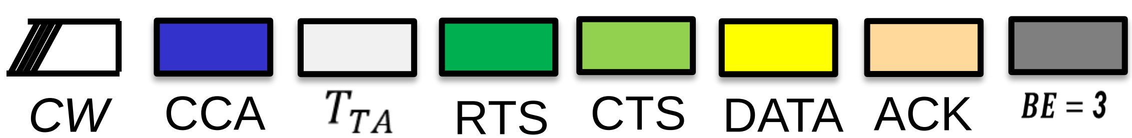
$$CW_{max} = (2^{BE} - 1) \Rightarrow \overline{CW} = \left(\frac{CW_{max}}{2}\right) \times T_{BO}$$

$T_{BO} = 320\ \mu s$



- IEEE 802.15.4 **in the presence of RTS/CTS (with collisions,** $BE \geq 3$, $CW_{max} \geq 7$)





IEEE 802.15.4 in the presence/absence of RTS/CTS

IEEE 802.15.4 with no RTS/CTS in an erroneous channel (**with collisions**, $BE \geq 3$, $CW_{max} \geq 7$)

Minimum delay due to Clear Channel Assessment (CCA)

$$D_{min\_CCA} = \sum_{i=1}^{n} \sum_{k=0}^{k \leq NB} (\overline{CW}_k + ccaTime) \quad , \quad NB \in [0, NB_{max}]$$

Minimum delay due to non received ACK within T_{AW}

$$D_{min\_Data\_Ret} = \sum_{i=1}^{n} K_i$$

$$K_i = \begin{cases} H_1 & , \quad j = 0 \\ H_2 + (j-1) \times H_4 + H_3 & , \quad j \in [\,1, MaxRet] \end{cases}$$

$$H_1 = T_{TA} + T_{DATA} + T_{TA} + T_{ACK} + T_{IFS}$$

$$H_2 = T_{TA} + T_{DATA} + T_{AW}$$

$$H_3 = \overline{CW_0} + ccaTime + H_1$$

$$H_4 = \overline{CW_0} + ccaTime + H_2$$

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IEEE 802.15.4 in the presence/absence of RTS/CTS

- **IEEE 802.15.4 with RTS/CTS** in an erroneous channel (**with collisions**, $BE \geq 3$, $CW_{max} \geq 7$)

Minimum delay due to Clear Channel Assessment (CCA)

$$D_{min\_CCA\_RTS} = \sum_{i=1}^{n/Nagg} \sum_{k=0}^{k \leq NB} (\overline{CW}_k + ccaTime) \quad , \qquad NB \in [0, NB_{max}]$$

Minimum delay due to non received ACK within T_{AW}

$$D_{min\_Data\_Ret\_RTS} = \begin{cases} H_5 & , \quad j = 0 \\ H_6 & , \quad j \in [1, MaxRet] \end{cases}$$

$$H_5 = T_{TA} + T_{RTS} + T_{TA} + T_{CTS} + \sum_{i=1}^{N_{agg}} (ccaTime + H_1)$$

$$H_6 = T_{TA} + T_{RTS} + T_{TA} + T_{CTS} + \sum_{i=1}^{N_{agg}-m} (ccaTime + T_{TA} + T_{DATA} + T_{TA} + T_{ACK} + T_{IFS}) + \cdots + \sum_{i=1}^{m} (j_i) \times (ccaTime + T_{TA} + T_{DATA} + T_{AW}) + \sum_{i=1}^{m} (ccaTime + T_{TA} + T_{DATA} + T_{TA} + T_{ACK} + T_{IFS})$$

IEEE 802.15.4 in the presence/absence of RTS/CTS

- **If an erroneous channel is considered** (with collisions, $BE \geq 3$, $CW_{max} \geq 7$)

Minimum average delay

$$D_{min} = (D_{min\_CCA} + D_{min\_Data\_Ret})/n$$

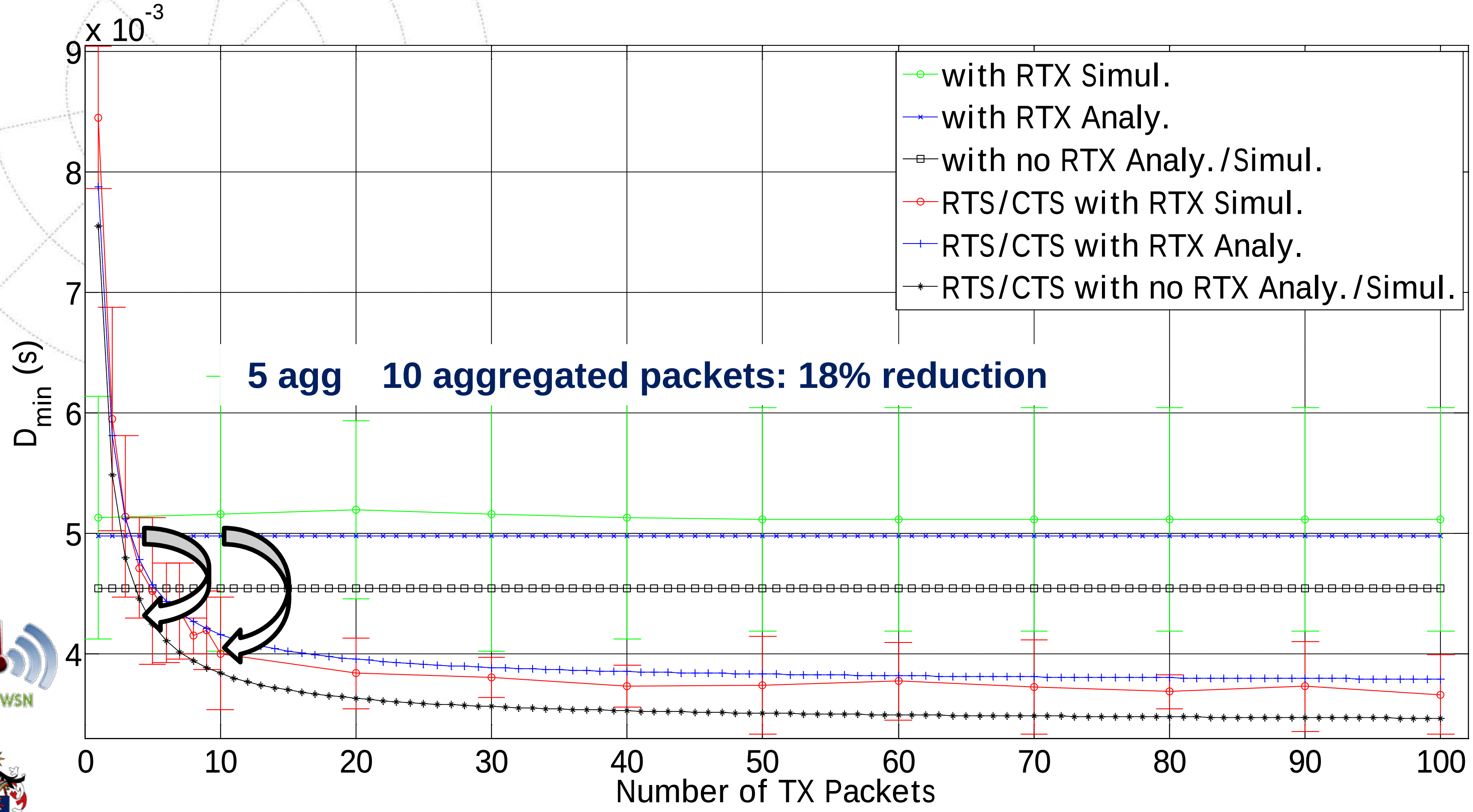
$$D_{min\_RTS\_CTS} = (D_{min\_CCA\_RTS} + D_{min\_Data\_Ret\_RTS})/n$$

Maximum average throughput

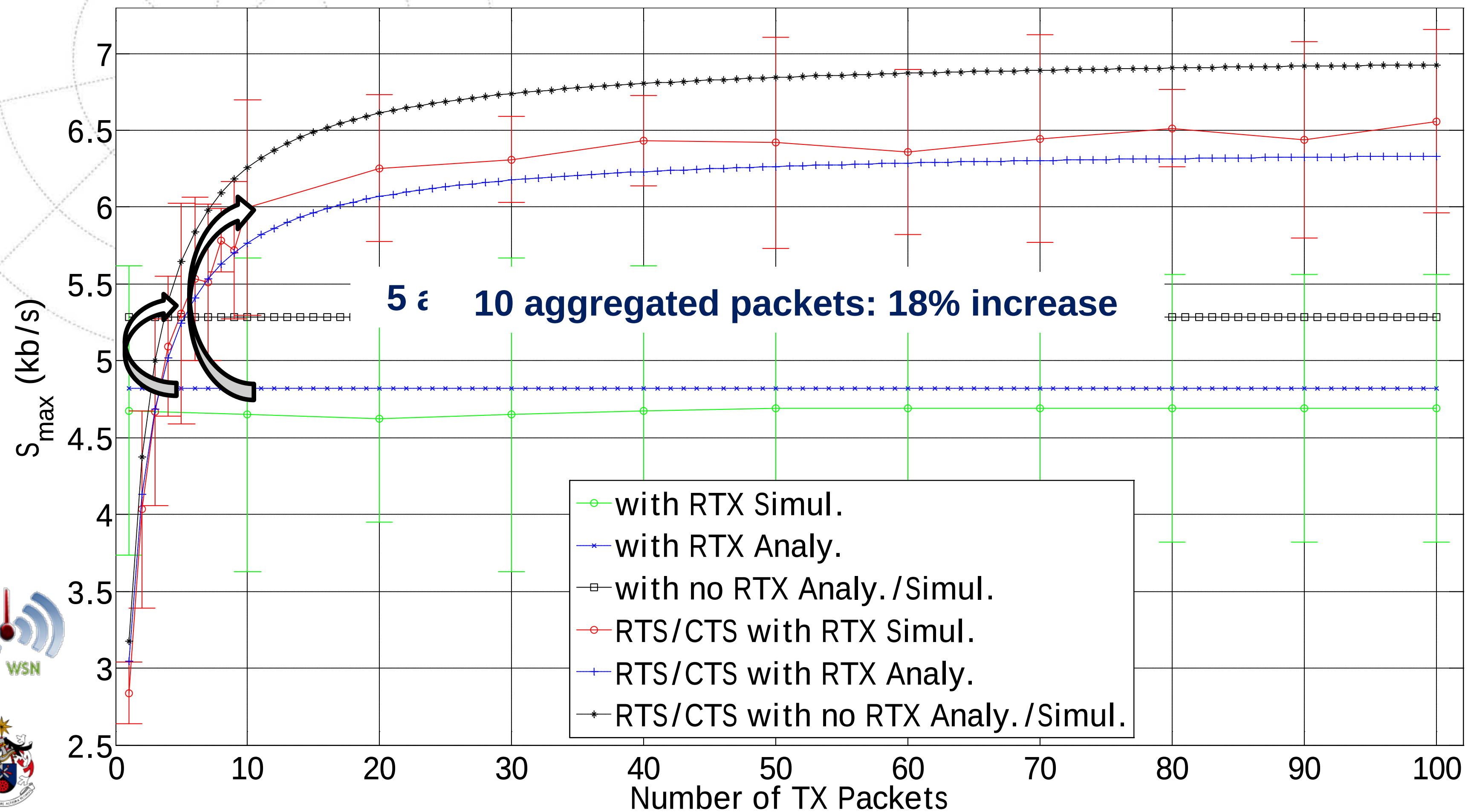
$$S_{max} = \frac{8L_{DATA}}{D_{min}}$$

$$S_{max\_RTS\_CTS} = \frac{8L_{DATA}}{D_{min\_RTS\_CTS}}$$

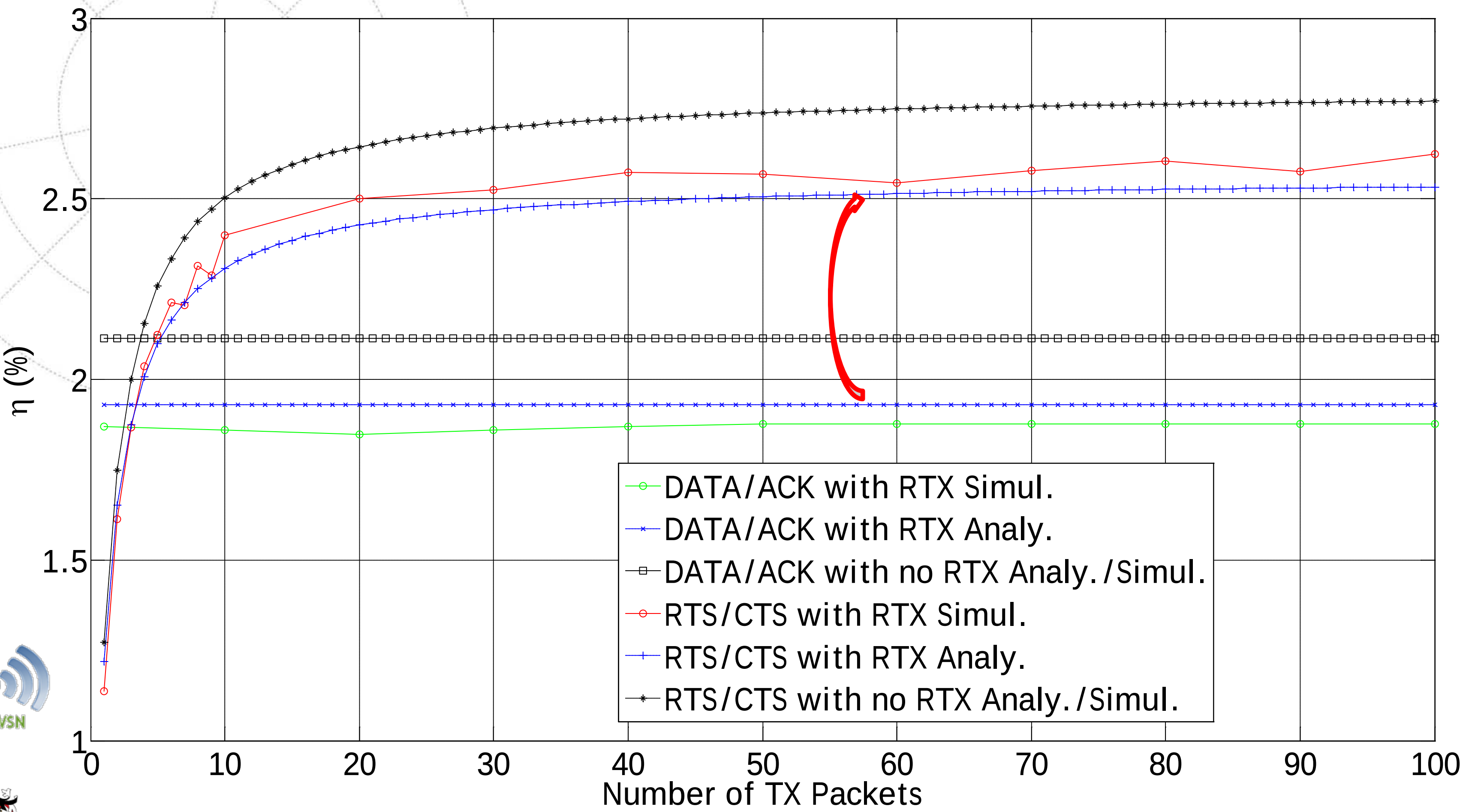
Minimum average delay comparison of IEEE 802.15.4 with and with no RTS/CTS *(fixed payload 3 bytes)*



Maximum average throughput comparison of IEEE 802.15.4 with and with no RTS/CTS (fixed payload 3 bytes)



Bandwidth efficiency comparison of IEEE 802.15.4 with and with no RTS/CTS (fixed payload 3 bytes)



Conclusions

- The IEEE 802.15.4 MAC layer employing RTS/CTS combined with packet concatenation enables to reserve the channel and avoids to repeat the backoff phase for every consecutive transmitted packet and reduce overhead.

- The advantage comes from not including the backoff phase into the retransmission process like IEEE 802.15.4 basic access mode (i.e., $BE = 0$).

Conclusions

- The proposed solution has shown that even for the case with retransmissions, if the number of TX packets is lower than 5 (i.e., the number of aggregated packets), IEEE 802.15.4 with RTS/CTS and the application of packet concatenation achieves higher values for the throughput, in comparison to IEEE 802.15.4 with no RTS/CTS, even for shorter packet sizes.

Thank you,
Questions are Welcome