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TCP DCM+ (DYNAMIC CONGESTION MANAGEMENT PROTOCOL) FOR ENHANCING PERFORMANCE IN MOBILE AND WIRELESS NETWORKS

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CONTENT

1. INTRODUCTION

- CONGESTION CONTROL:

CONTROLS THE E2E DATA RATE ON THE LINK THROUGH:

1- PACKET LOSSES, OR

2- ARRIVAL OF ***N*** DUPLICATE ACKNOWLEDGEMENT PACKETS (UNORDERED ARRIVAL OF PACKETS).

- FLOW CONTROL:

ENSURES THAT A SENDER IS NOT OVERWHELMING THE RECEIVER.

(IF IT SENDS PACKETS FASTER THAN THE RECEIVER BUFFER CAN HANDLE.)

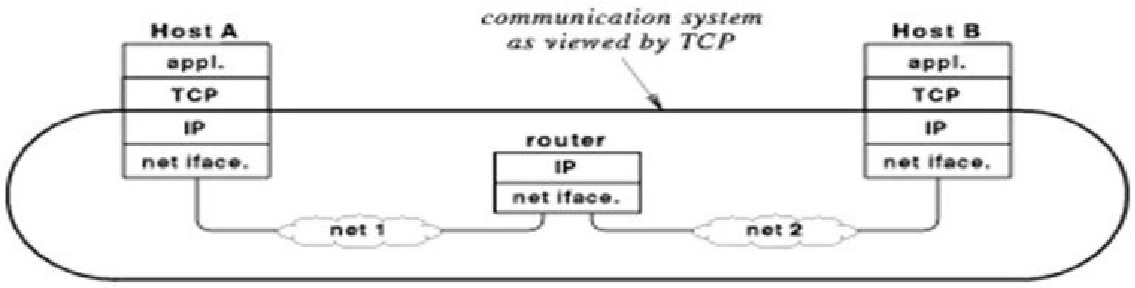
1. INTRODUCTION (CONT.)

- E2E (END-TO-END) :

1. ONLY TCP SOURCE AND TCP DESTINATION MANAGE THE CONNECTION. (SETTING WINDOW SIZE OF THE TRANSMISSION).
2. INTERMEDIATE NODES (ROUTERS) DON'T CARE ABOUT LOST PACKETS OR CONGESTION EVENTS.
3. TCP DCM+ STANDS FOR (***D***YNAMIC **C**ONGESTION CONTROL PROTOCOL FOR ***M***OBILE AND WIRELESS NETWORKS)
4. DCM+ IS AN E2E PROTOCOL, THAT IS DESIGNED TO CONTROL THE DATA RATE IN WIRED, WIRELESS AND MANETS.

1. INTRODUCTION (CONT.)

End to end communication [1]



- TCP has no knowledge of the underlying Internet structure

CONTENT

2. ORIGINS OF TCP DCM+

- TCP DCM+ [6] FOLLOWS THE PARADIGM (AIADD) LIKE TCP WESTWOOD+
- AIADD : ADDITIVE INCREASE/ ADAPTIVE DECREASE

- **ADDITIVE INCREASE** : LIKE TCP NEWRENO BEHAVIOR IN SLOW-START (***SS***) REGION.

- **ADAPTIVE DECREASE** : UNLIKE TCP NEWRENO :

1- NO DROP TO THE HALF OF CONGESTION WINDOWS (***CWND***)

2- NETWORK CONGESTION DETECTED: NEW ***CWND*** DEPENDS ON THE AVAILABLE CHANNEL CAPACITY, ALSO KNOWN AS SLOW-START THRESHOLD (***SSTHRESH***).

3- NEW ***SSTHRESH*** CALCULATION USING A BANDWIDTH ESTIMATION (***BWE***) ALGORITHM.

2. ORIGINS OF TCP DCM+ (CONT.)

TCP NewReno behavior (AIMD)

Additive Increase / Multiplicative Decrease

Congestion Avoidance ***(CA)*:**

- Lost Packet

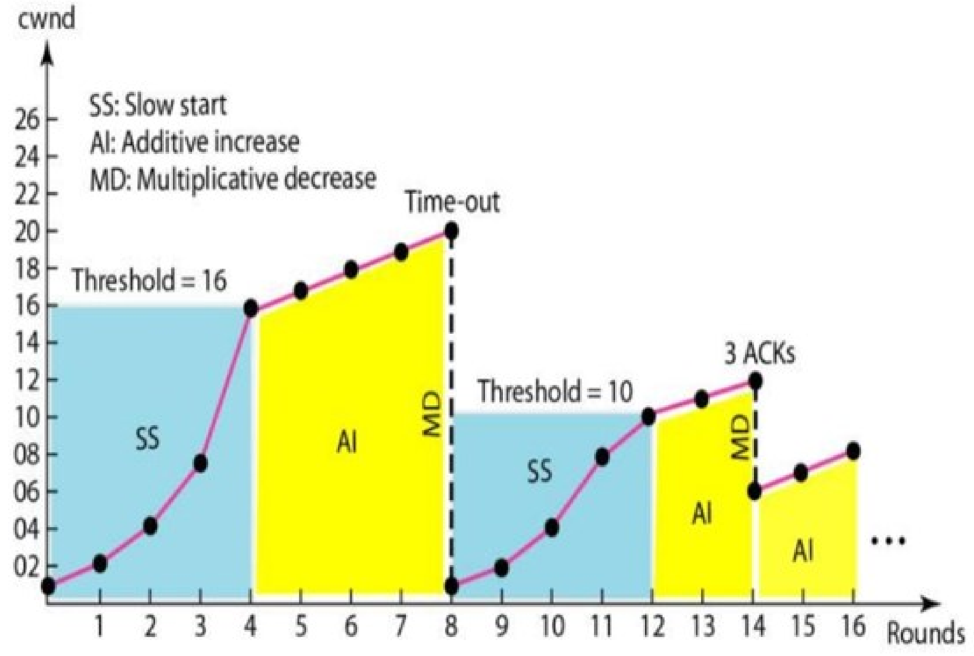
  -> retransmission timeout, set ***cwnd*** to 1 segment and enters ***SS*** .

- Unordered arrival of data packets

  -> receiver sends 3 DUPACK packets to sender, set cwnd to new ***ssthresh*** and enters ***SS***.

$$Ssthresh_{new} = cwnd_{old} / 2$$

TCP Congestion Control [2]



2. ORIGINS OF TCP DCM+ (CONT.)

- At the discrete time (T_n):

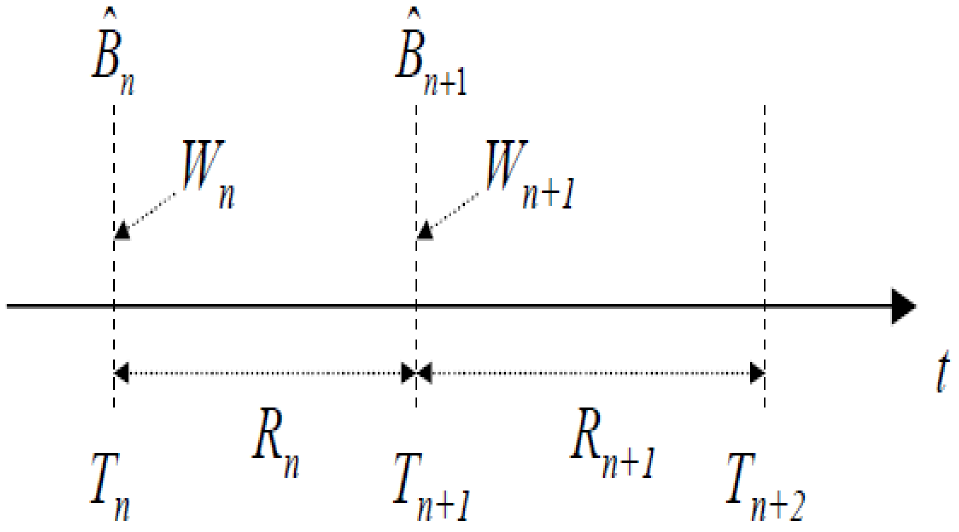
W_n : Congestion Window (***cwnd***),

$\hat{B}_n$: Estimated BW (***BWE***),

R_n : round-trip-time (***RTT***) at time n

New ***cwnd*** is inverse proportional to the measured ***RTT*** :

$$W_n \propto \frac{1}{R_n}$$



BWE in the network [3]

2. ORIGINS OF TCP DCM+ (CONT.)

- TCP WELCOME [4]

(WIRELESS ENVIRONMENT, LINK LOSSES, CONGESTION MODELS)

PROPOSED (2009) FOR IMPROVING PERFORMANCE OF NETWORKS WITH DYNAMIC TOPOLOGY.

AIM: CONGESTION CONTROL IN MOBILE ADHOC NETWORKS (MANETS)

- IDEA: $RTO_{OLD} / RTO_{NEW} = RTT_{OLD} / RTT_{NEW}$ (RTT ↑ ↔ RTO ↑)

2. ORIGINS OF TCP DCM+ (CONT.)

- ***DCM***: DYNAMIC CONGESTION MODEL [5]

- PROPOSED: MAY 2015 (MSC. THESIS)

  R. A. HAMAMREH AND M. BAWATNA.

- AIM: ADDRESSES THE WEAKNESS OF TCP ***WELCOME*** TO USE CONVENTIONAL TCP NEWRENO CONGESTION CONTROL TECHNIQUES IN ***MANETS***.

- IDEA: USE THE RESULTS OF ROUTE REQUEST (RREQ) TO DETECT CONGESTION AND DYNAMICALLY SELECT A DIFFERENT PATH, IF AVAILABLE.

- DCM REQUIRES THE COOPERATION OF L3 AND L4 IN THE OSI MODEL.

2. ORIGINS OF TCP DCM+ (CONT.)

- DCM EQUATIONS (ALGORITHM):

1- CONGESTION_THRESHOLD = 1.8 * RTT_{MIN}

2- RTT > CONGESTION_THRESHOLD -->

L3 NOTIFIES L4 TO SELECT ANOTHER PATH WITH LOWER ***RTT***.

3- IF NEW PATH FOUND -> IT IS SET AS THE NEW MAJOR PATH.

4- ESTIMATE THE CHANNEL CAPACITY (***BW***) TO FIND NEW ***SSTHRESH*** ACCORDING TO TCP ***WESTWOOD.*** ALSO, SET NEW ***CWND.***

5- *EQUATIONS :*

$$BWE = \frac{ACK\_SIZE}{ACK\_INTERVAL} \quad , SSTHRESH_{NEW} = MAX(2, BWE * \frac{RTT_{MIN}}{SEGSIZE})$$

$$RTO_{NEW} = RTO_{OLD} * \frac{RTT_{NEW}}{RTT_{OLD}}, CWND_{NEW} = \beta * \frac{RTT_{OLD}}{RTT_{NEW}} * SSTHRESH_{NEW} \quad , \quad \text{WHERE } (\beta = 0.8)$$

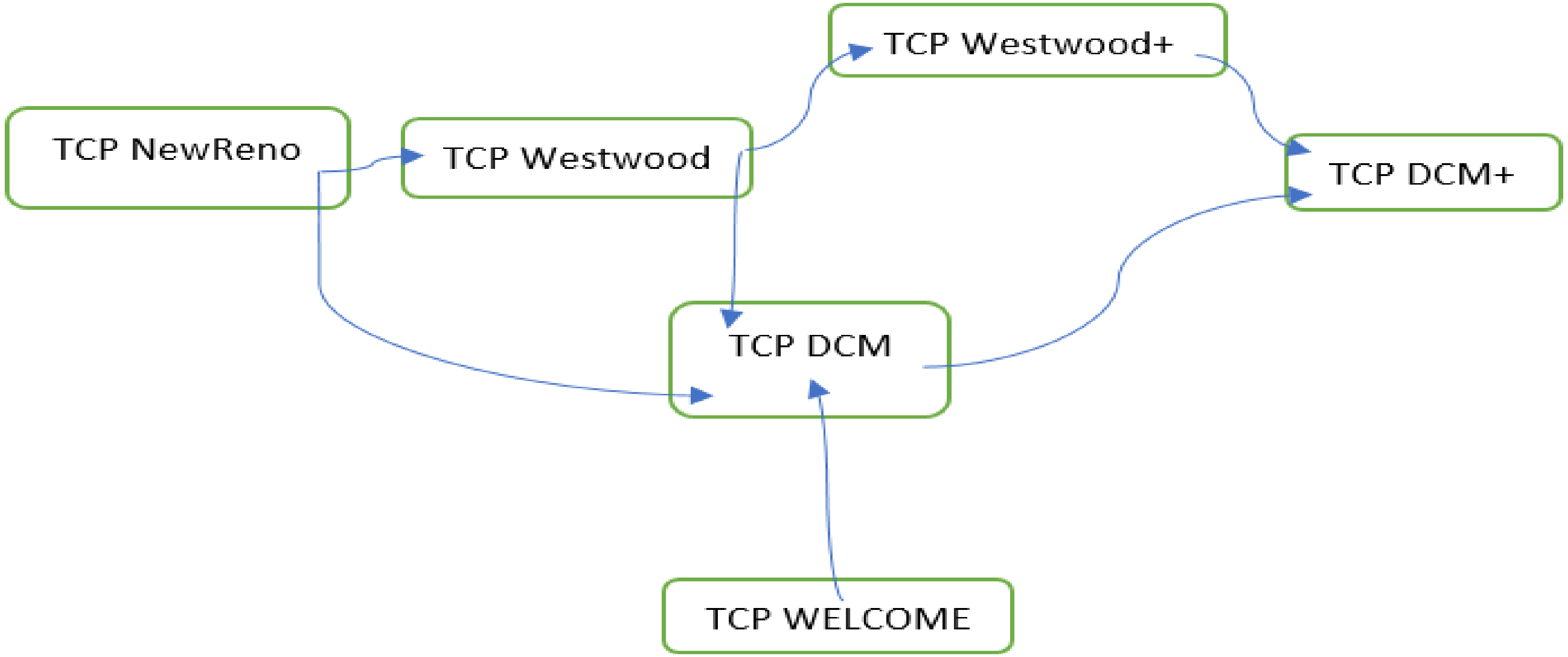
2. ORIGINS OF TCP DCM+ (CONT.)

5- IF NO PATH IS FOUND WITH LOWER ***RTT*** **:**

$$CWND_{NEW} = \begin{cases} CWND_{OLD} + \dfrac{RTT_{OLD}}{RTT_{NEW}} * 0.9 & ; \quad CWNDOLD < SSTHRESH \\ CWND_{OLD} + \dfrac{RTT_{NEW}}{RTT_{OLD}} * \dfrac{1}{CWND_{OLD}} & ; CWNDOLD \geq SSTHRES \end{cases}$$

2. ORIGINS OF TCP DCM+ (CONT.) [6]

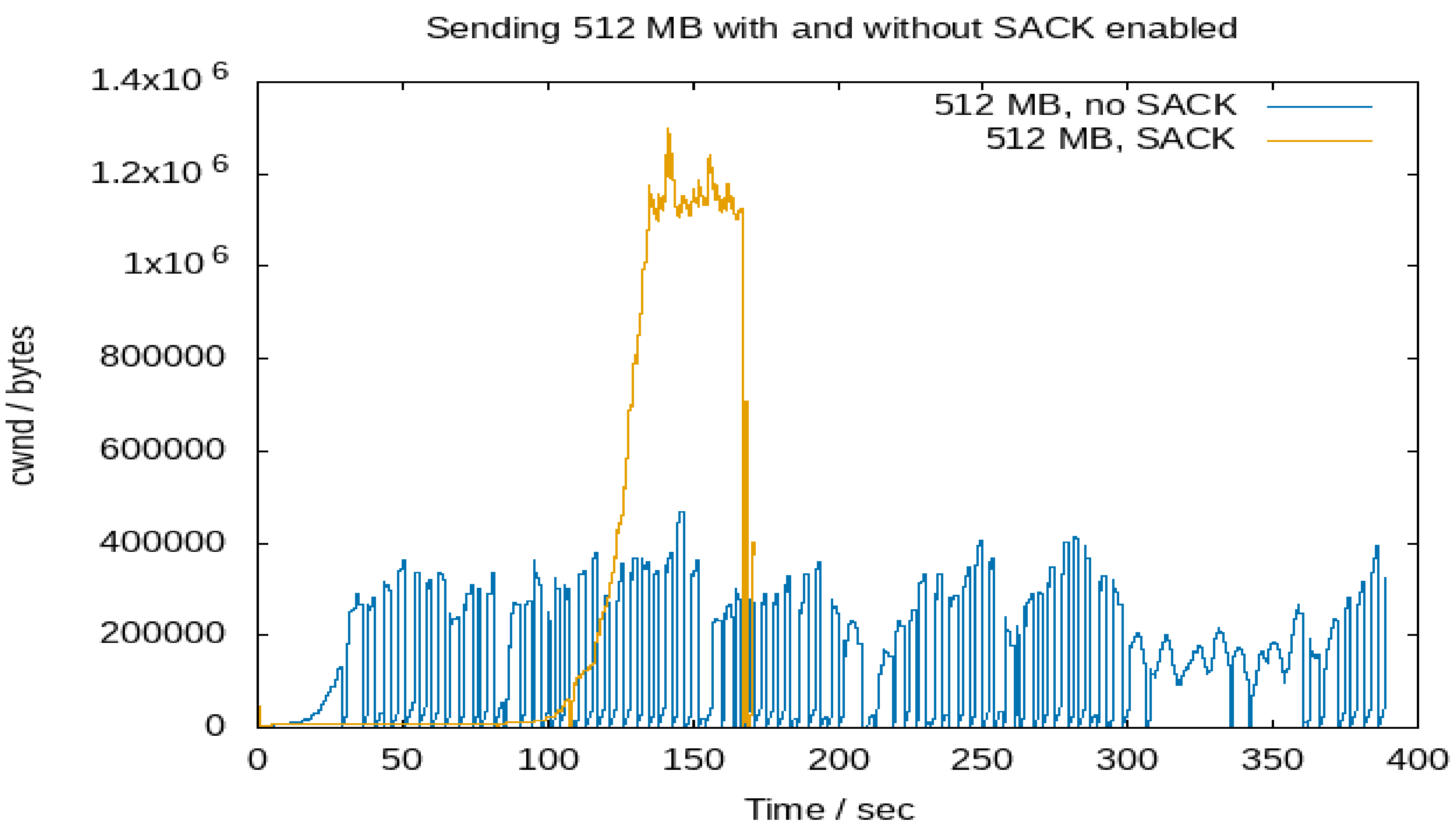
TCP DCM+ HAS ITS ROOTS IN DIFFERENT APPROACHES, MAINLY TCP WESTWOOD+, WHICH DELIVERS THE TECHNIQUE FOR BANDWIDTH ESTIMATION.



2. ORIGINS OF TCP DCM+ (CONT.) – SACK OPTION

- TCP DCM+ PERFORMS BEST WITH SACK OPTION ENABLED FOR LARGE FILES.

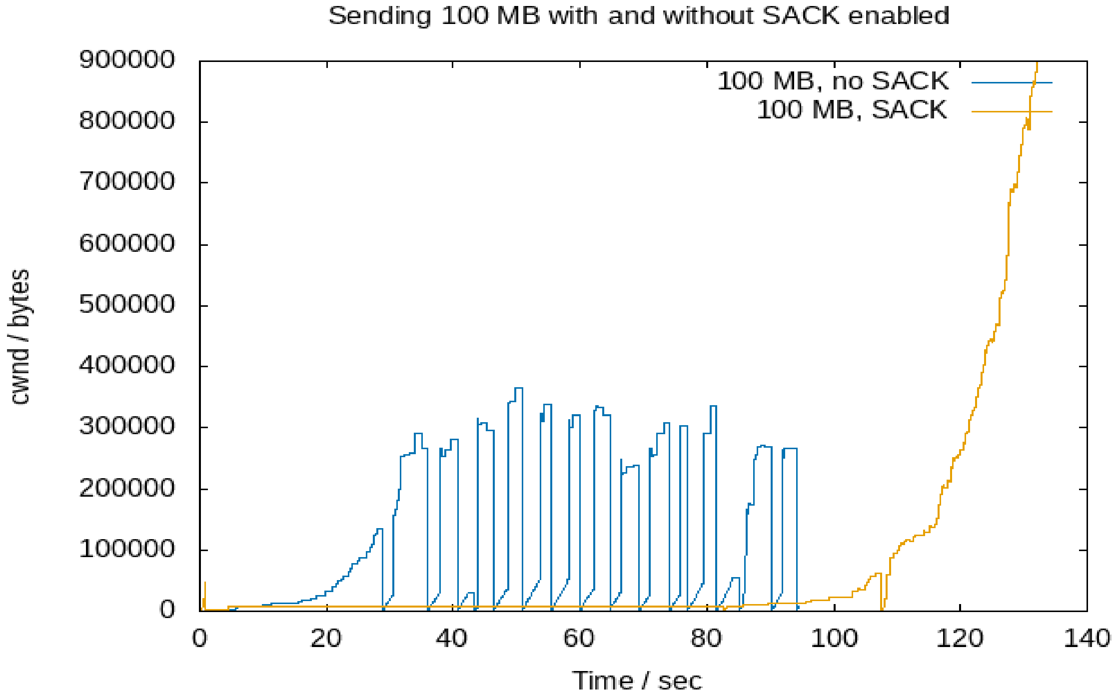
LARGE FILE



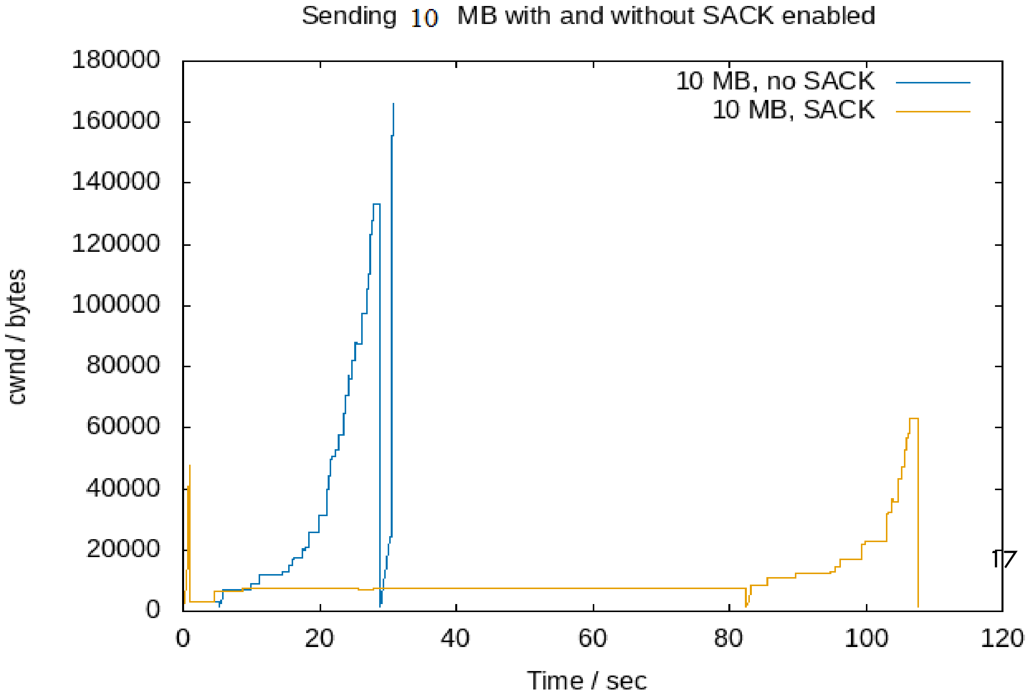
2. ORIGINS OF TCP DCM+ (CONT.) – SACK OPTION

- THE ADVANTAGES NOTICED FOR MID-SIZED FILES ARE THE STABILITY AND THE MINIMAL NUMBER OF *CWND* DROPS, BUT THE TRANSMISSION TAKES LONGER TIME.
- SMALL FILES ARE BEST SENT WITH DCM+ WITHOUT SACK OPTION ENABLES.

MID-SIZED FILE



SMALL FILE



CONTENT

3. BANDWIDTH ESTIMATION (BWE) [19]

- WESTWOOD:

BWE SAMPLES CALCULATED AFTER EACH ***ACK***

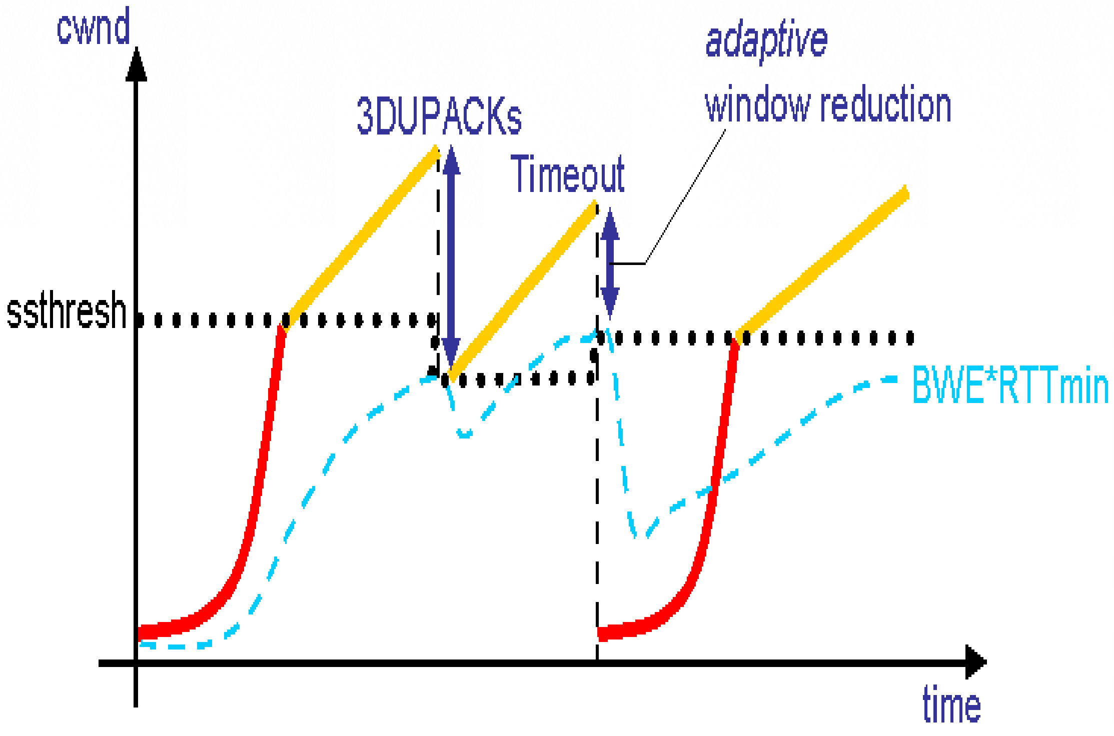
→ OVERESTIMATION → WRONG ESTIMATION.

- WESTWOOD+ : ***BWE*** SAMPLES CALCULATED

AFTER EACH ***RTT***.

→ MORE ACCURATE

→ REFLECTS THE AVAILABLE CHANNEL CAPACITY.



3. BANDWIDTH ESTIMATION (CONT.)

- BWE IN TCP WW+ [7][8]: USING A LOW-PASS FILTER (*LP*) 1ST ORDER.

ANTI-ALIASING FILTER (***AAF***) IS USED AS ***LP*** FILTER → LIMITING SIGNAL ***BW***.

- CALCULATION: $$SSTHRESH = MAX\left(2, \frac{BWE * RTT_{MIN}}{SEG\_SIZE}\right);$$

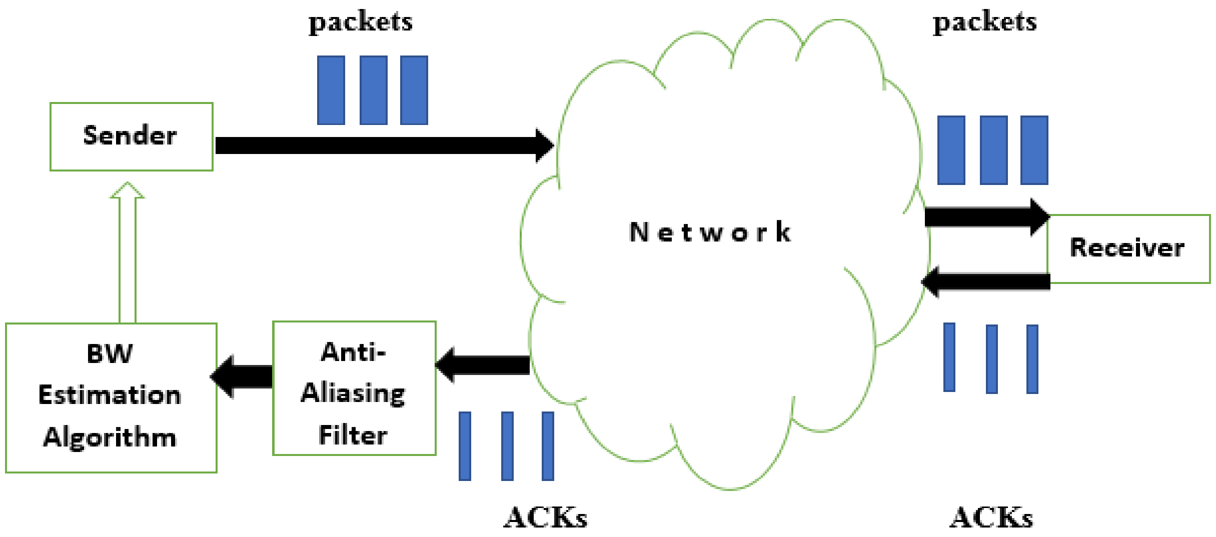
- 3 DUPACKS → ***CWND*** = ***SSTHRESH*** (SEGMENTS)

- RETRANSMISSION TIMEOUT (RTO) → ***CWND*** = 1 (SEGMENT)

3. BANDWIDTH ESTIMATION (CONT.)

- OUTPUT OF ***AAF*** ARE B_l SAMPLES

$$B_l = \frac{d_i}{RTT_i}$$



- B_l: ANTI-ALIASING ***BW*** SAMPLE
- D_l: ACKNOWLEDGED DATA
- FILTER EQUATION:

$$\hat{b}_k = \alpha * \hat{b}_{k-1} + (1 - \alpha) * b_k \ ;$$

$\hat{b}_k$: ESTIMATED ***BW*** SAMPLE ; α = FILTER CONSTANT

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- ORIGINS OF TCP DCM+
- BANDWIDTH ESTIMATION
- **COMPONENTS OF TCP DCM+**
- DCM+ ALGORITHM
- SIMULATION RESULTS
- FUTURE WORK

4. COMPONENTS OF TCP DCM+

1- $RATECA = \frac{RTT_{OLD}}{RTT_{MIN}}$

RATECA : CONGESTION RATE

RTT_{MIN} : MINIMUM TIME NEEDED FOR THE TCP TRANSMISSION WITH EMPTY TCP BUFFER AT THE DESTINATION.

$$RTT = \sum_{i=1}^{4} D_i$$

D_1 : TRANSMISSION DELAY (D_{TR})

D_2 : PROPAGATION DELAY (D_{PROP})

D_3 : PROCESSING DELAY (D_{PROC})

D_4 : QUEUEING DELAY (D_Q)

$$RTT_{MIN} = \sum_{i=1}^{3} min(D_i) \quad ;(D_4 = D_Q = 0)$$

4. COMPONENTS OF TCP DCM+ (CONT.)

NOTE: $\begin{cases} rateCA > 1 \rightarrow TCP\ buffer\ decreasing \\ rateCA < 1 \rightarrow TCP\ buffer\ increasing \end{cases}$

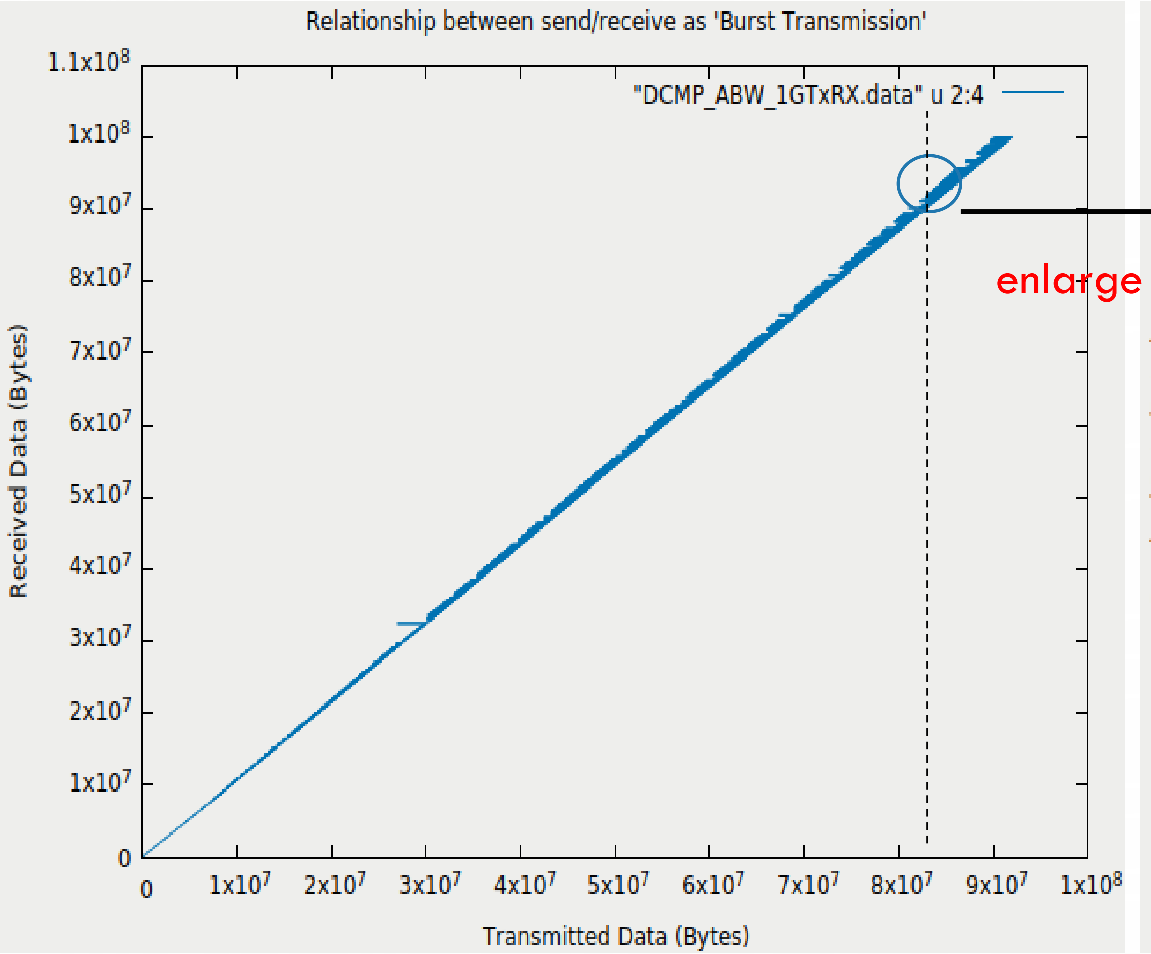
RATECA > 1 : NO CONGESTION EXPECTED → BURST TRANSMISSION

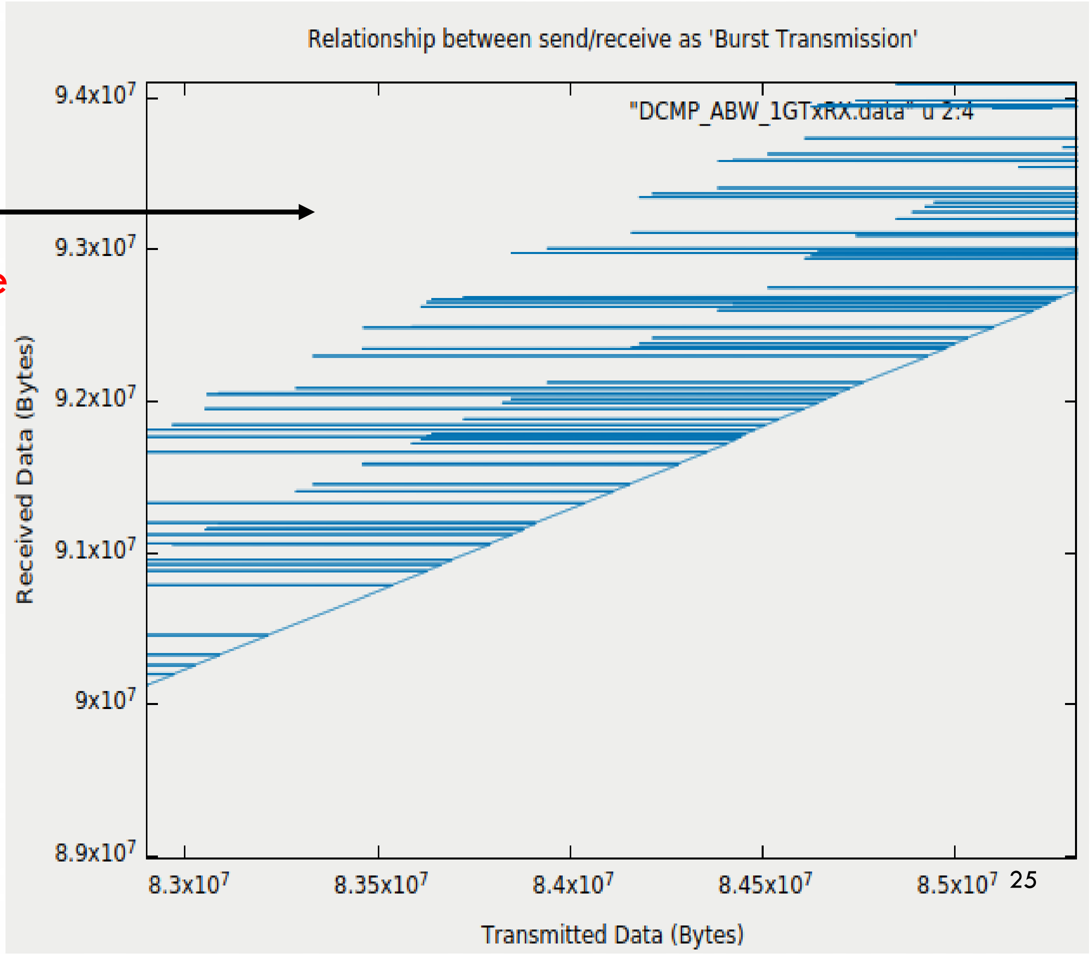
→***ADVANCING*** (→ LARGE BURSTS)

RATECA < 1 : GRADUAL INCREASE OF RTT → CONGESTION EXPECTED

→***DANGER*** (→ MINI BURSTS / CONSTANT TRANSMISSION)

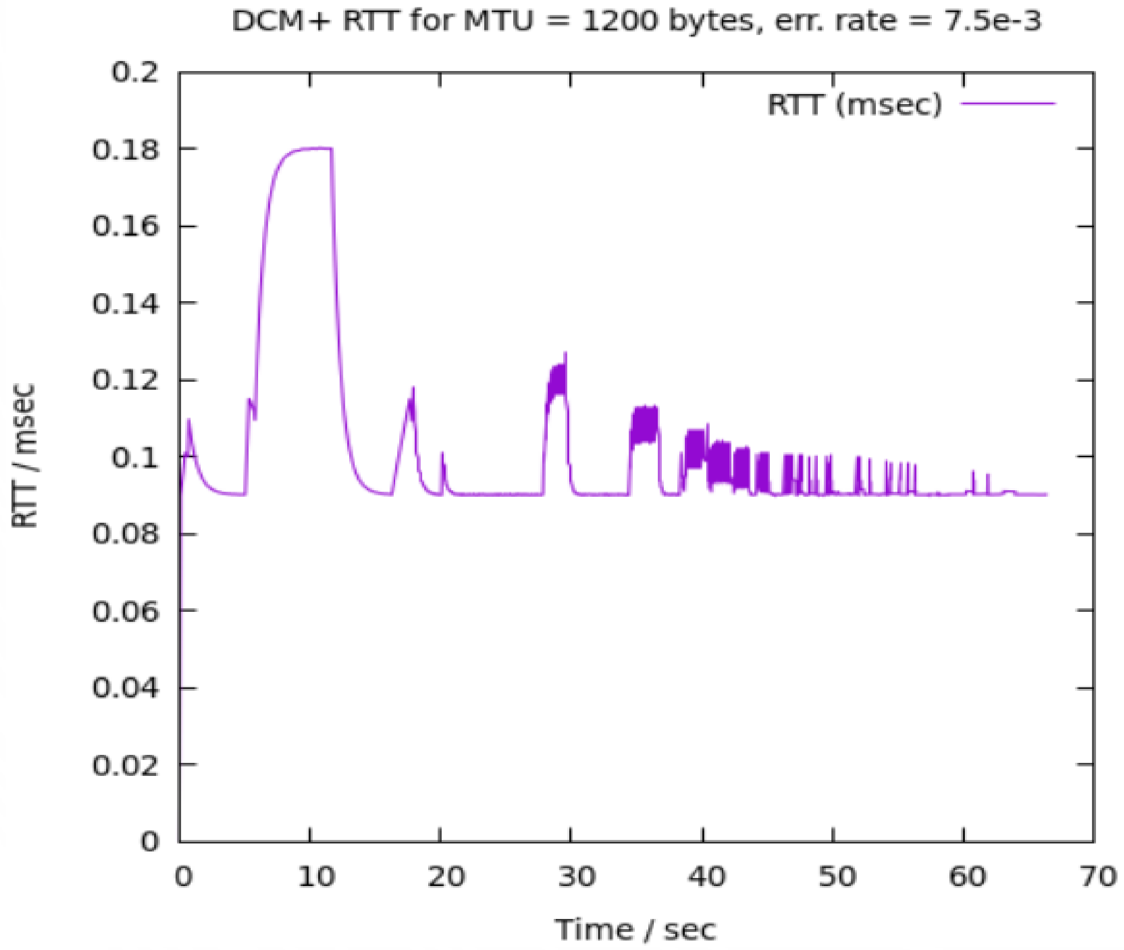
4. COMPONENTS OF TCP DCM+ (CONT.) – BURST TRANSMISSION

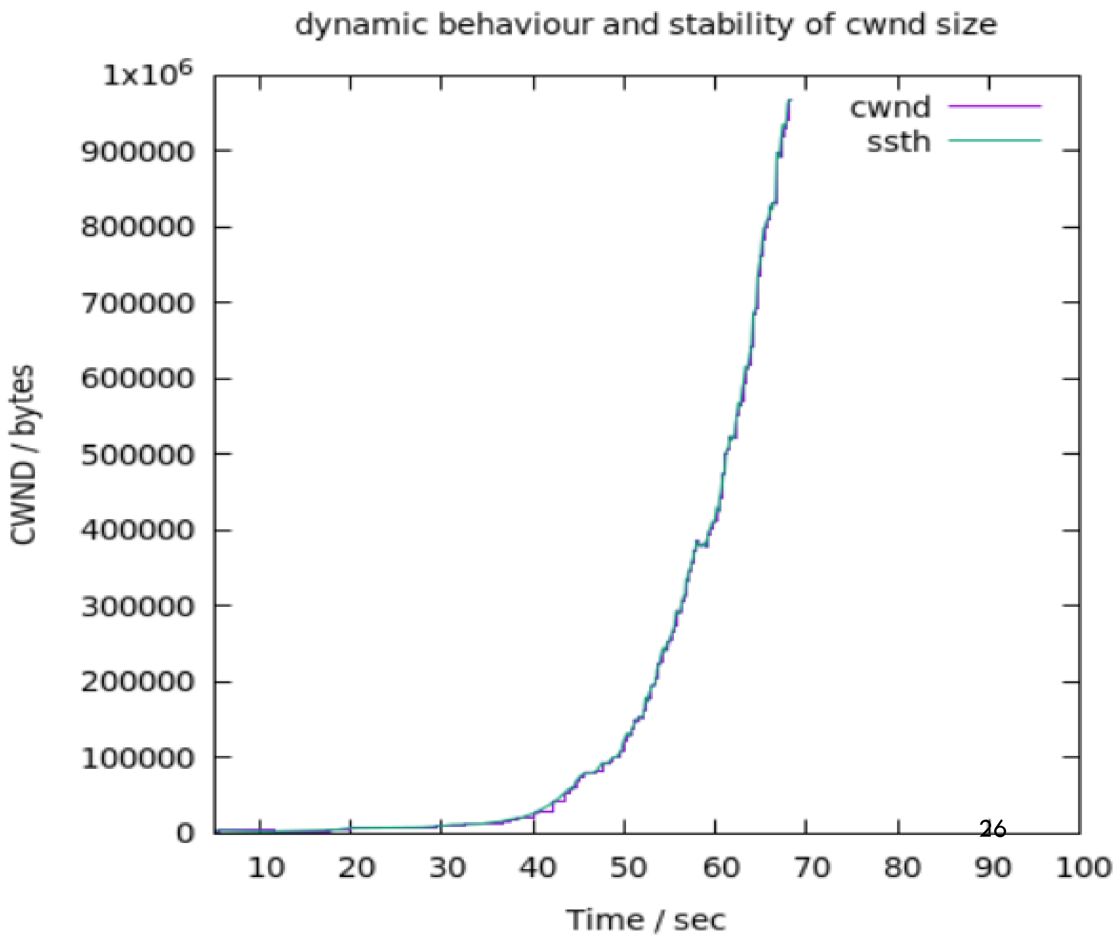




4. COMPONENTS OF TCP DCM+ (CONT.) –

DYNAMIC BEHAVIOR OF DCM+ (CWND IS TRACKING SSTHRESH)





4. COMPONENTS OF TCP DCM+ (CONT.)

2- $$RTO_{NEW} = RTO_{old} * \frac{RTT_{new}}{RTT_{old}} = \frac{RTO_{old}}{rateCA}$$

- RATECA ↑ → RTO ↓

CLEAR: INCREASING OF ***RATECA*** MEANS CONGESTIONS ARE NOT EXPECTED,

→ NO NEED TO WAIT LONGER FOR THE PACKETS.

- RATECA ↓ → RTO ↑ (BECAUSE OF DANGER OF CONGESTION → WAIT LONGER)

COMPONENTS OF TCP DCM+ (CONT.) – CA ALGORITHM

3- NEW MEMBER FUNCTION IN C++ FOR THE CONGESTION AVOIDANCE

- *VOID CONGESTIONAVOIDACE (TCP_SOCKET , ACKEDSEGMENTS)*
- *WW AND WW+ DOES NOT HAVE THIS MEMBER FUNCTION IN NS3.*
- *THIS FUNCTION OVERRIDES THE BEHAVIOR OF THE SAME FUNCTION EXISTING IN TCP NEWRENO CLASS.*
- *TCP DCM+ BEHAVIOR WITHIN THE MEMBER FUNCTION:*

```
IF NUMBER OF SEGMENTS ACKED > 0
{
        IF LAST CWND < AVAILABLE CHANNEL CAPACITY
            CWND += 2 *RATECA ;        ← ADVANCING
        ELSE
        CWND += 2/ (RATECA*CWND) ;  ← DANGER
}
```

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5. TCP DCM+ ALGORITHM

- DCM+ EQUATIONS:

1- $\text{RATECA} = \text{RTT}_{\text{OLD}}/\text{RTT}_{\text{MIN}}$

2- $$\frac{\text{RTO}_{\text{NEW}}}{\text{RTO}_{\text{OLD}}} = \frac{\text{RTT}_{\text{NEW}}}{\text{RTT}_{\text{OLD}}}$$

3- $$\text{CWND}_{\text{NEW}} = \begin{cases} \text{CWND}_{\text{OLD}} + 2 * \text{RATE}_{\text{CA}} \;; & \text{CWND} < \text{SSTHRESH} \\ \text{CWND}_{\text{OLD}} + \left(\dfrac{2}{\text{RATE}_{\text{CA}} * \text{CWND}_{\text{OLD}}}\right); & \text{CWND} \geq \text{SSTHRESH} \end{cases}$$

5. TCP DCM+ ALGORITHM (CONT.)

Measuring BURST ratio:

$$rateCA_{old} = \frac{RTT_{old}}{RTT_{min}}$$

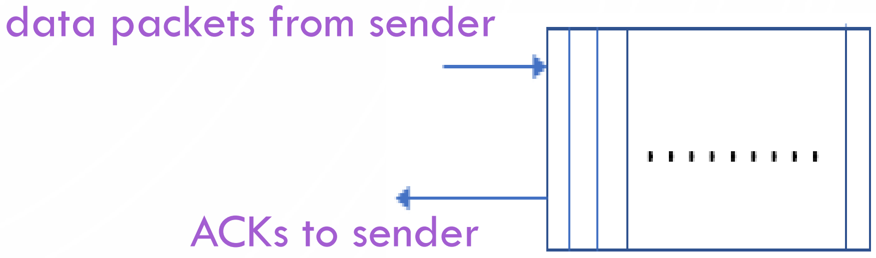
$$rateCA_{new} = \frac{RTT_{new}}{RTT_{min}}$$

Assumption : RTT_{min} remain unchanged.

space ratio on the channel $= \frac{rateCA_{old}}{rateCA_{new}}$

$$S = \frac{rateCA_{old}}{rateCA_{new}} = \frac{RTT_{old}}{\cancel{RTT}_{min}} * \frac{\cancel{RTT}_{min}}{RTT_{new}}$$

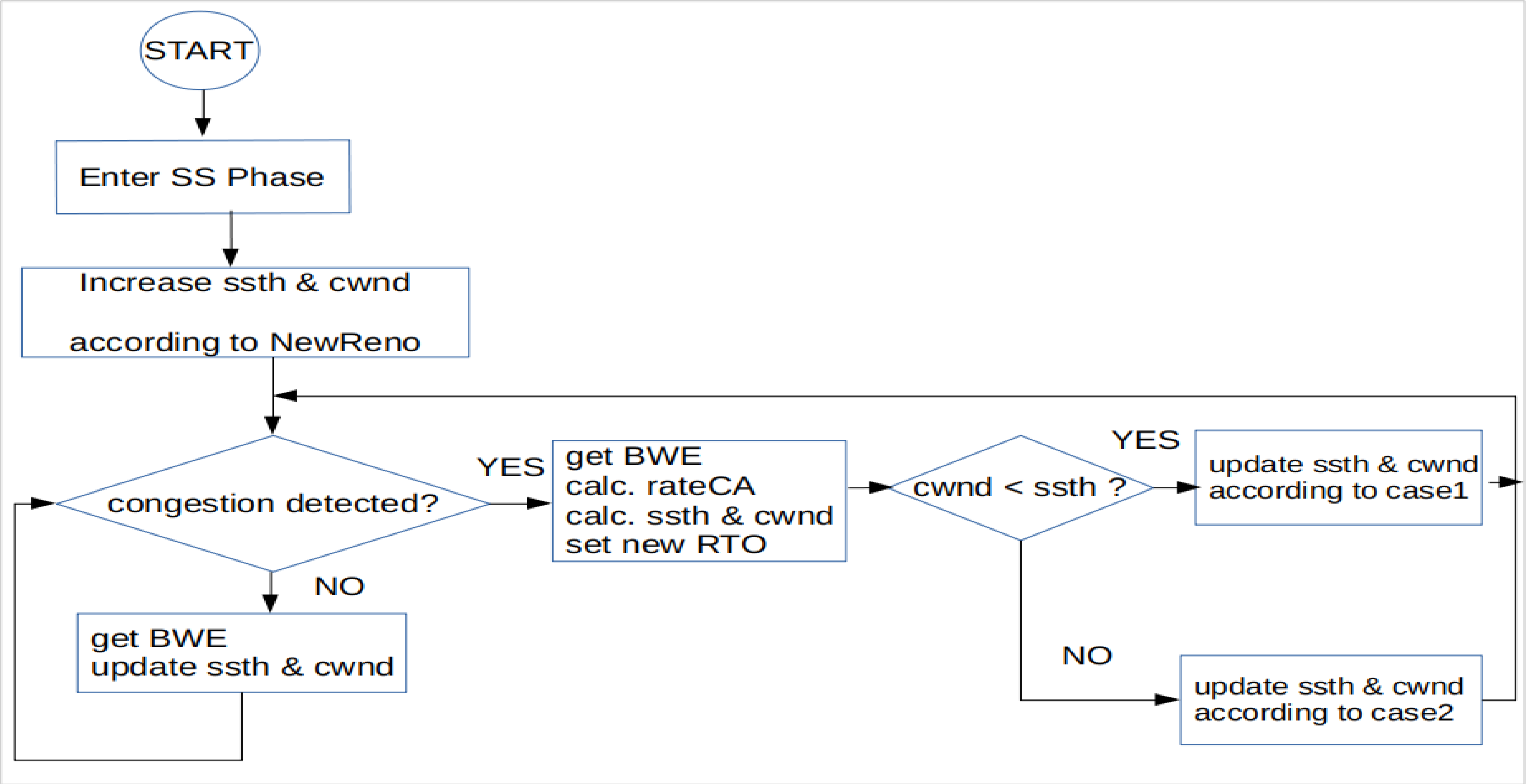
$$S = \frac{RTT_{old}}{RTT_{new}} \approx \frac{D_{q,old}}{D_{q,new}} \propto \frac{\text{old buffer capacity}}{\text{new buffer capacity}}$$



Receiver buffer

5. TCP DCM+ ALGORITHM [6]

WE SEE THE DIFFERENT PHASES IN THIS ALGORITHM: NEWRENO, WESTWOOD+ AND THE TIME PARAMETERS RTT AND RTO

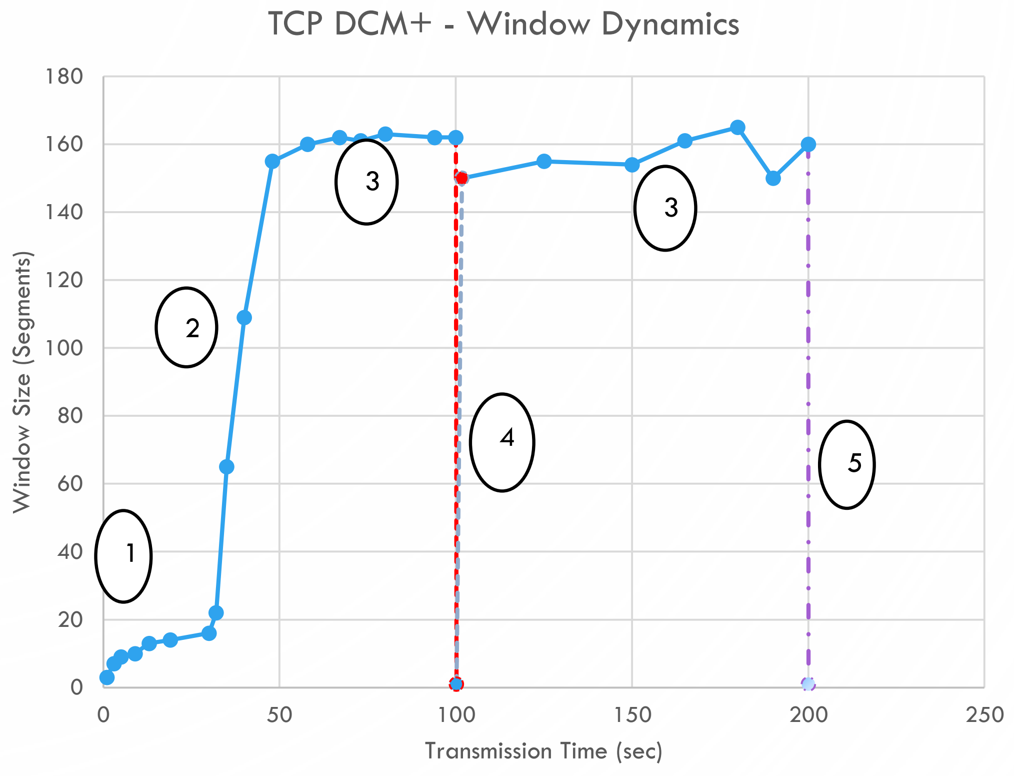


5. TCP DCM+ ALGORITHM (CONT.)

ALL THE FOLLOWING PHASES CAN APPEAR DEPENDING ON THE FOLLOWING PARAMETERS:
ERROR RATE, DATA SIZE, MTU SIZE AND TCP BUFFER SIZE.

- PHASES OF DCM+

1. *INITIALIZATION* (PROBING) PHASE (IP)
2. *ADVANCING* PHASE (AP)
3. *NEAR-CHANNEL-CAPACITY* PHASE (NCCP)
4. *LOSSES* PHASE (LP) (*OPTIONAL*)
5. *END* PHASE (EP) (*OPTIONAL*)



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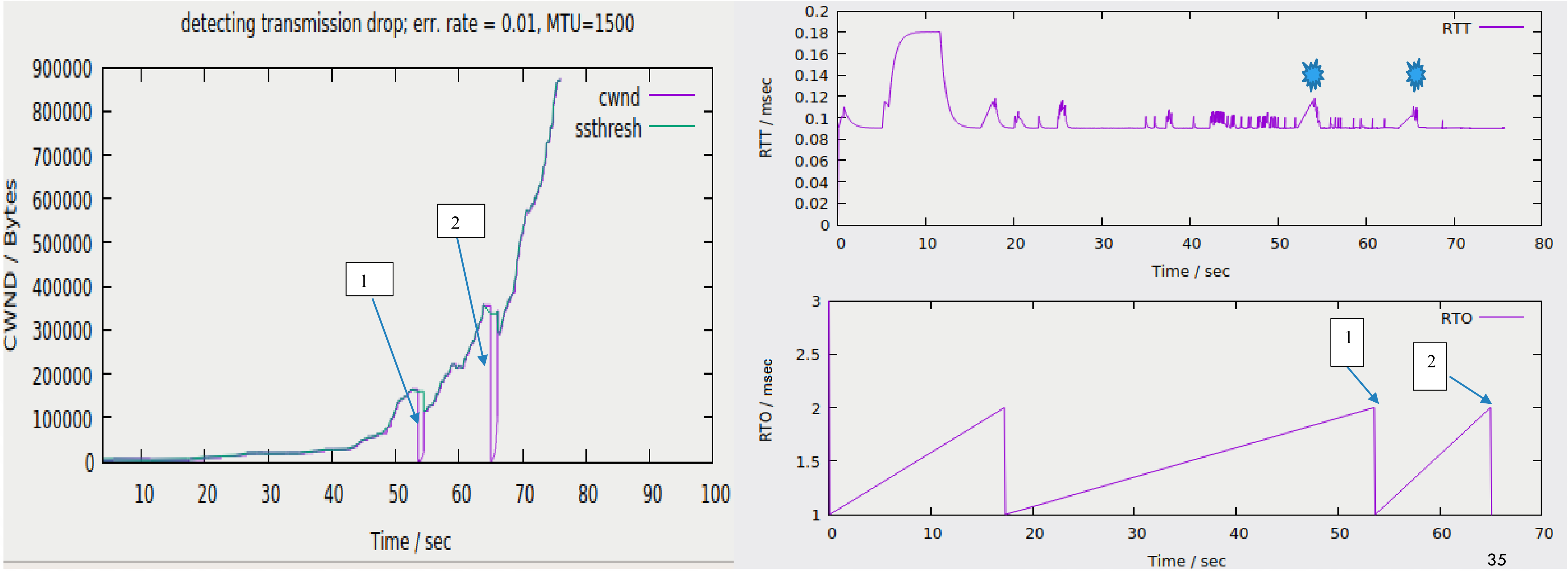
- FUTURE WORK

6. SIMULATION RESULTS –

TCP DCM+ CAN ALSO DETECT LOSSES:

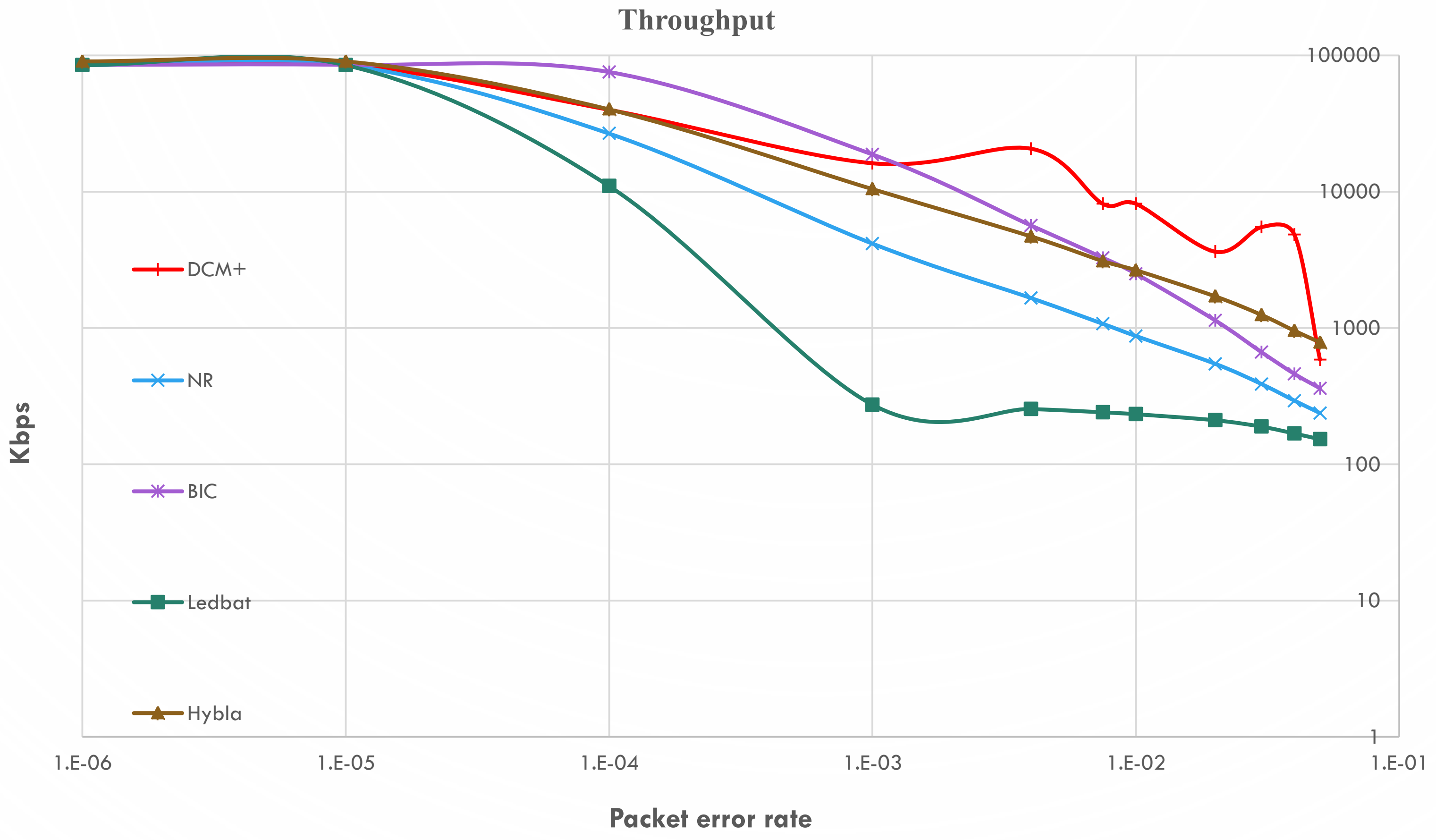
1- SPIKES IN RTT PLOT OR

2- RESETTING OF RTO VALUES.



6. SIMULATION RESULTS - THROUGHPUT

- THROUGHPUT : DCM+ SHOWS THE HIGHEST THROUGHPUT IN THE RANGE (1E-3 TO 5E-2).

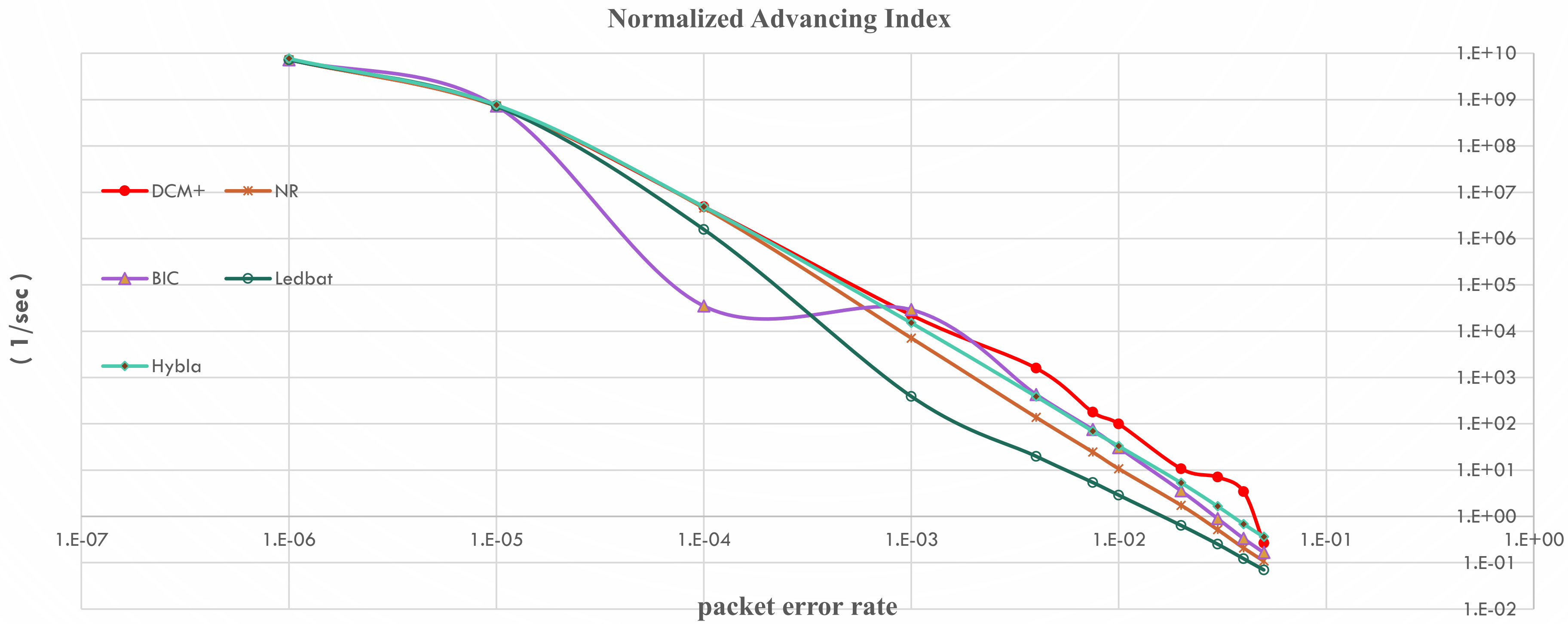


6. SIMULATION RESULTS – (NAI) ROBUSTNESS

NAI: NORMALIZED ADVANCING INDEX

NAI SHOWS THE ROBUSTNESS OF THE TRANSMISSION

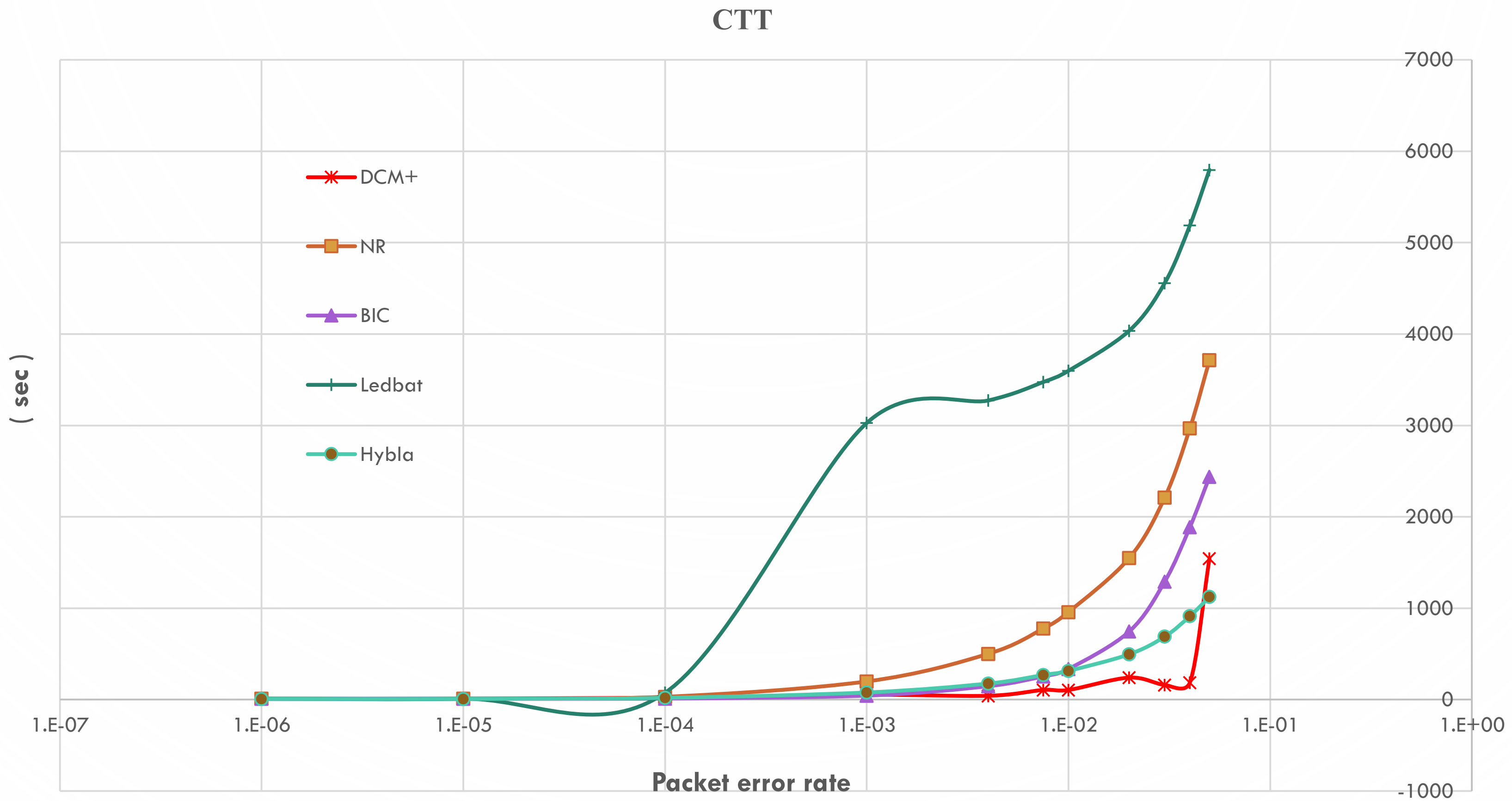
DCM+ HAS THE HIGHEST ROBUSTNESS IN THE RANGE (1E-5 TO 4E-2)



6. SIMULATION RESULTS – CTT (TRANSMISSION TIME)

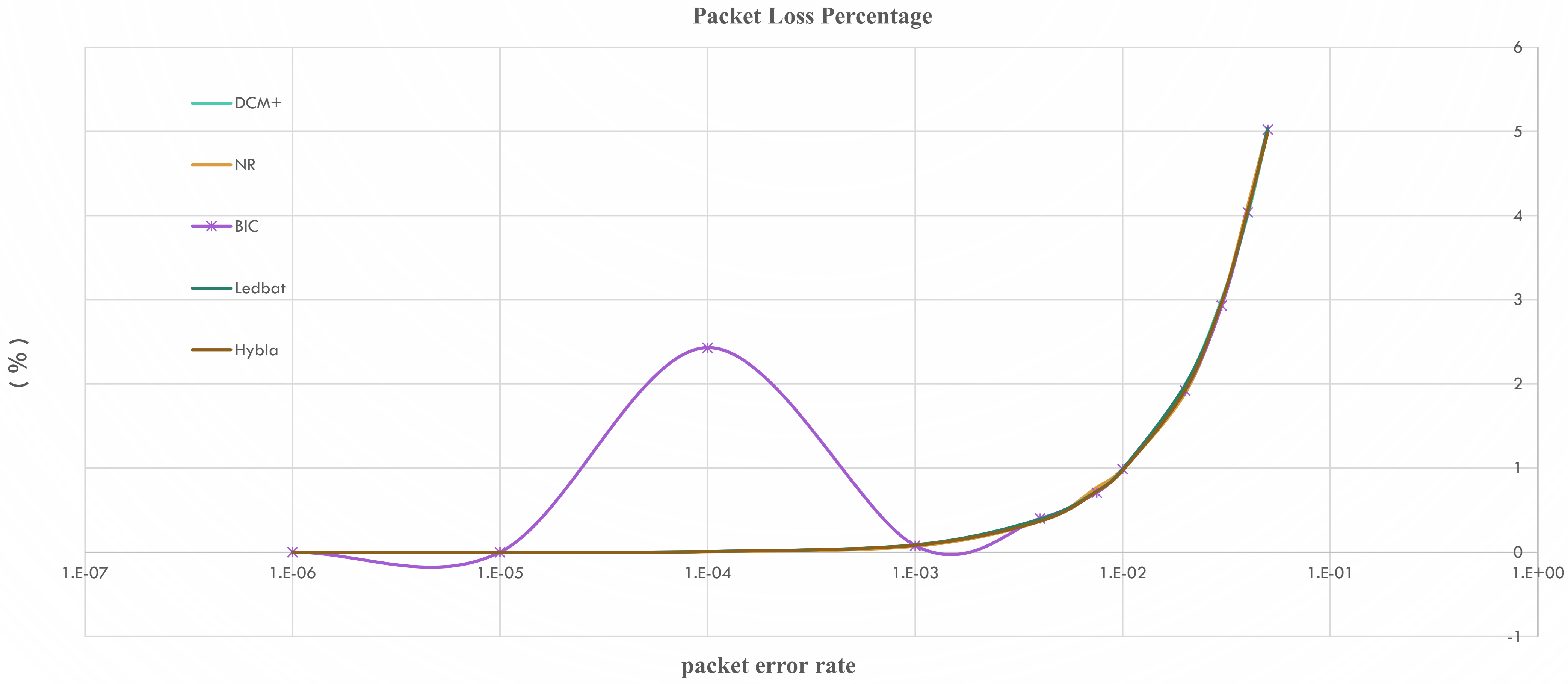
CTT: COMPLETE TRANSMISSION TIME

DCM+ SHOWS THE SHORTEST TIME NEEDED FOR THE TCP TRANSMISSION



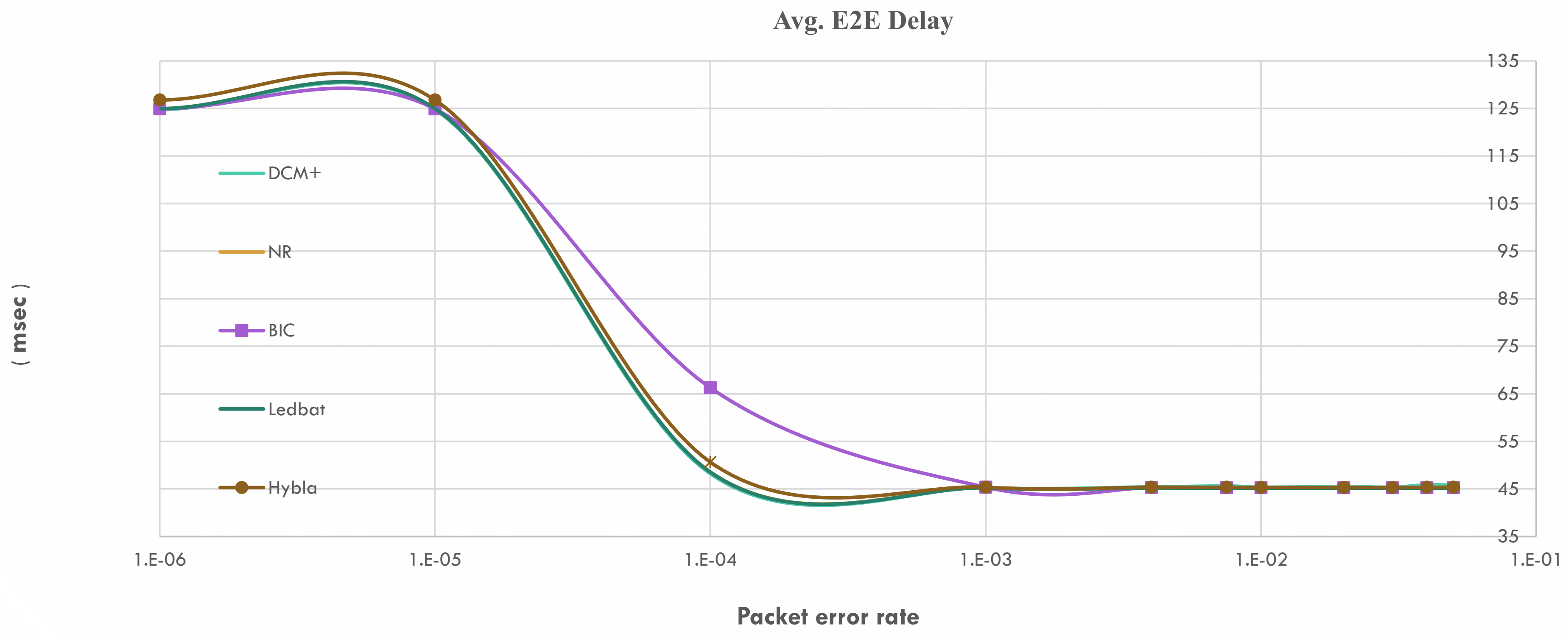
6. SIMULATION RESULTS – PACKET LOSSES

DCM+ HAS EQUAL OR LESS LOSSES THAN OTHER APPROACHES. TCP BIC SHOWS HIGHEST LOSSES IN THE RANGE (1E-5 TO 1E-3)



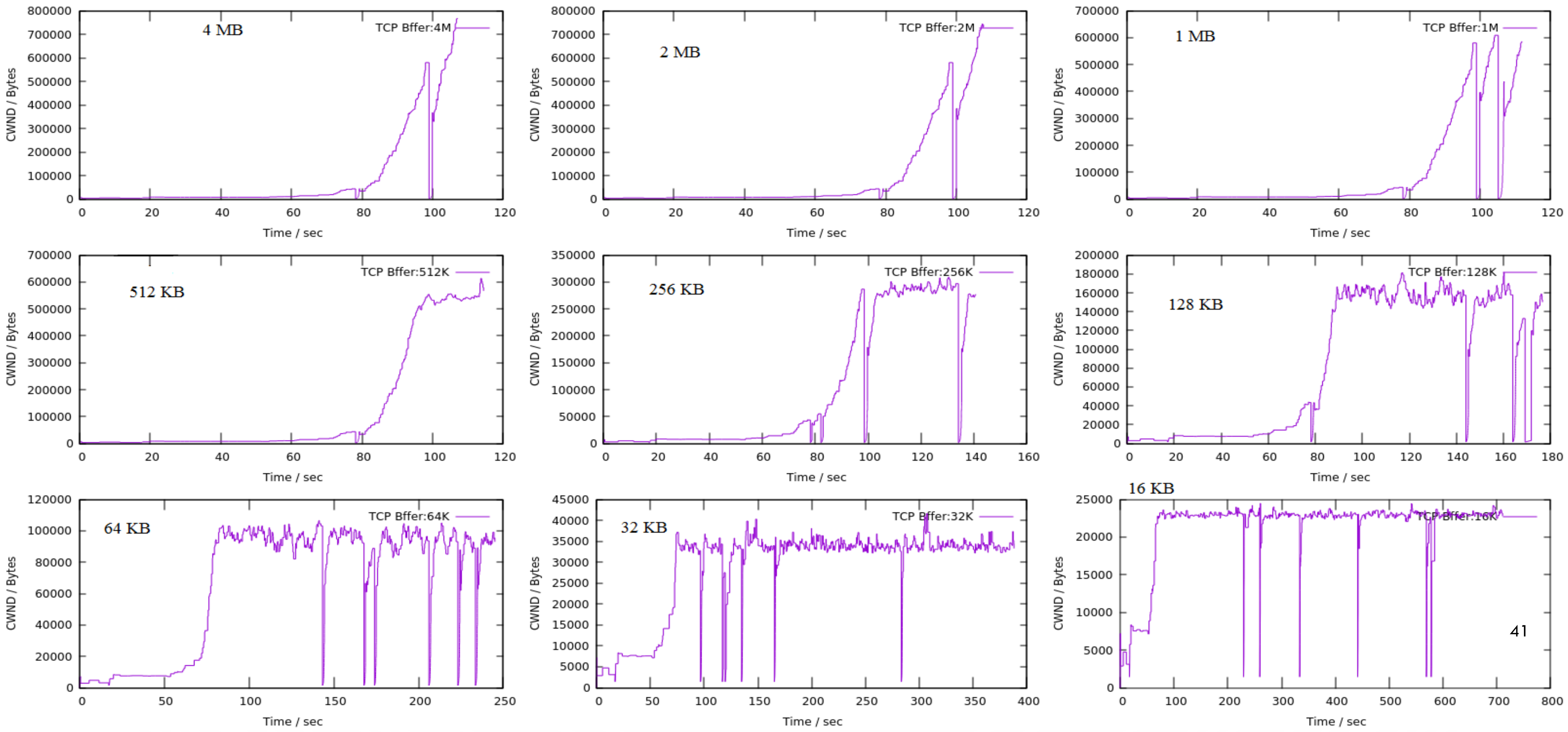
6. SIMULATION RESULTS – AVG. E2E DELAY

DCM+ SHOWS THE LOWEST DELAY, WHILE BIC SHOWS THE HIGHEST DELAY.



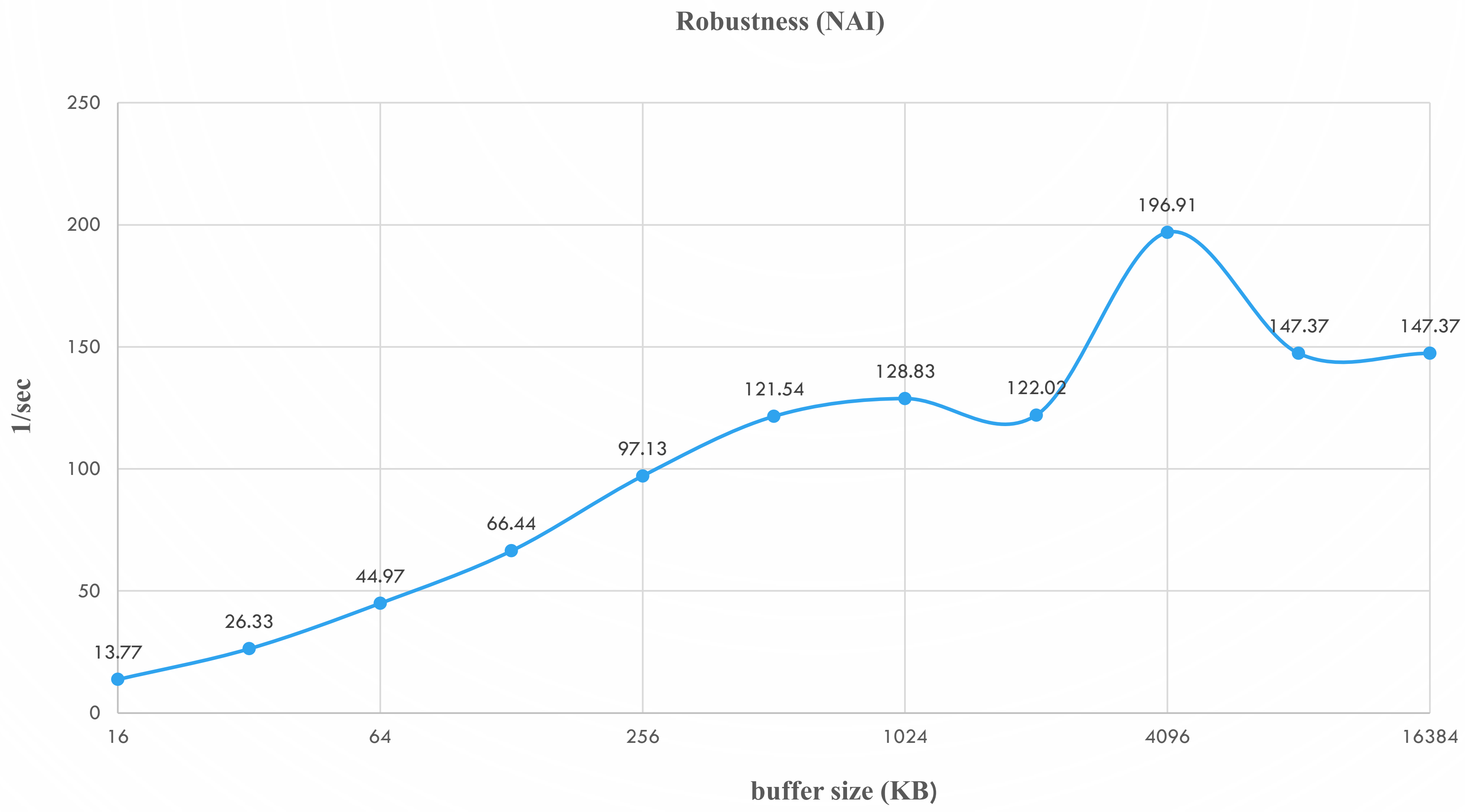
6. SIMULATION RESULTS –

THE SIZE OF RECEIVER BUFFER AFFECTS THE TRANSMISSION TIME, ROBUSTNESS AND THE DROPS OF WINDOW SIZE.



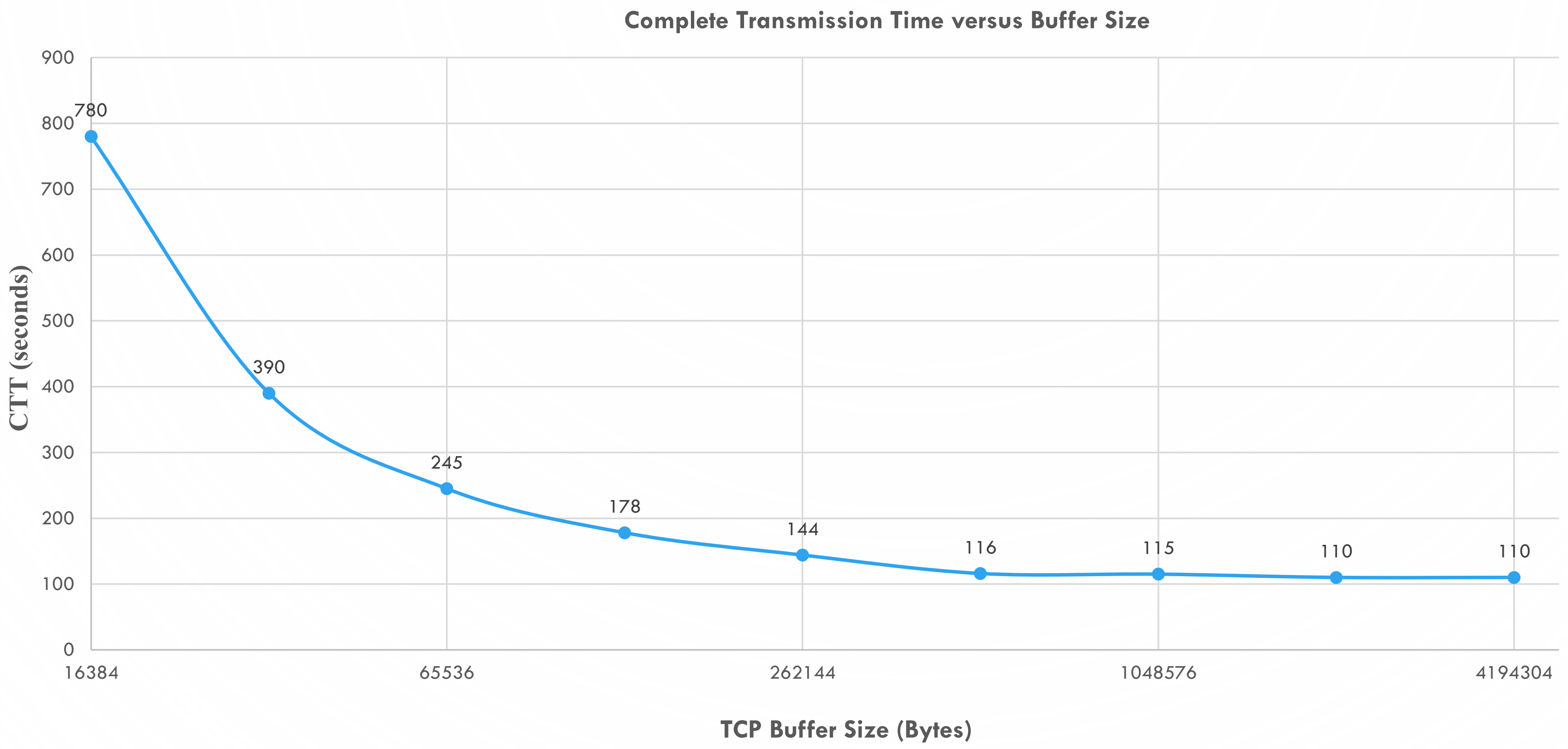
6. SIMULATION RESULTS –

TCP DCM+ TRANSMISSION ROBUSTNESS AS A FUNCTION OF RECEIVER BUFFER



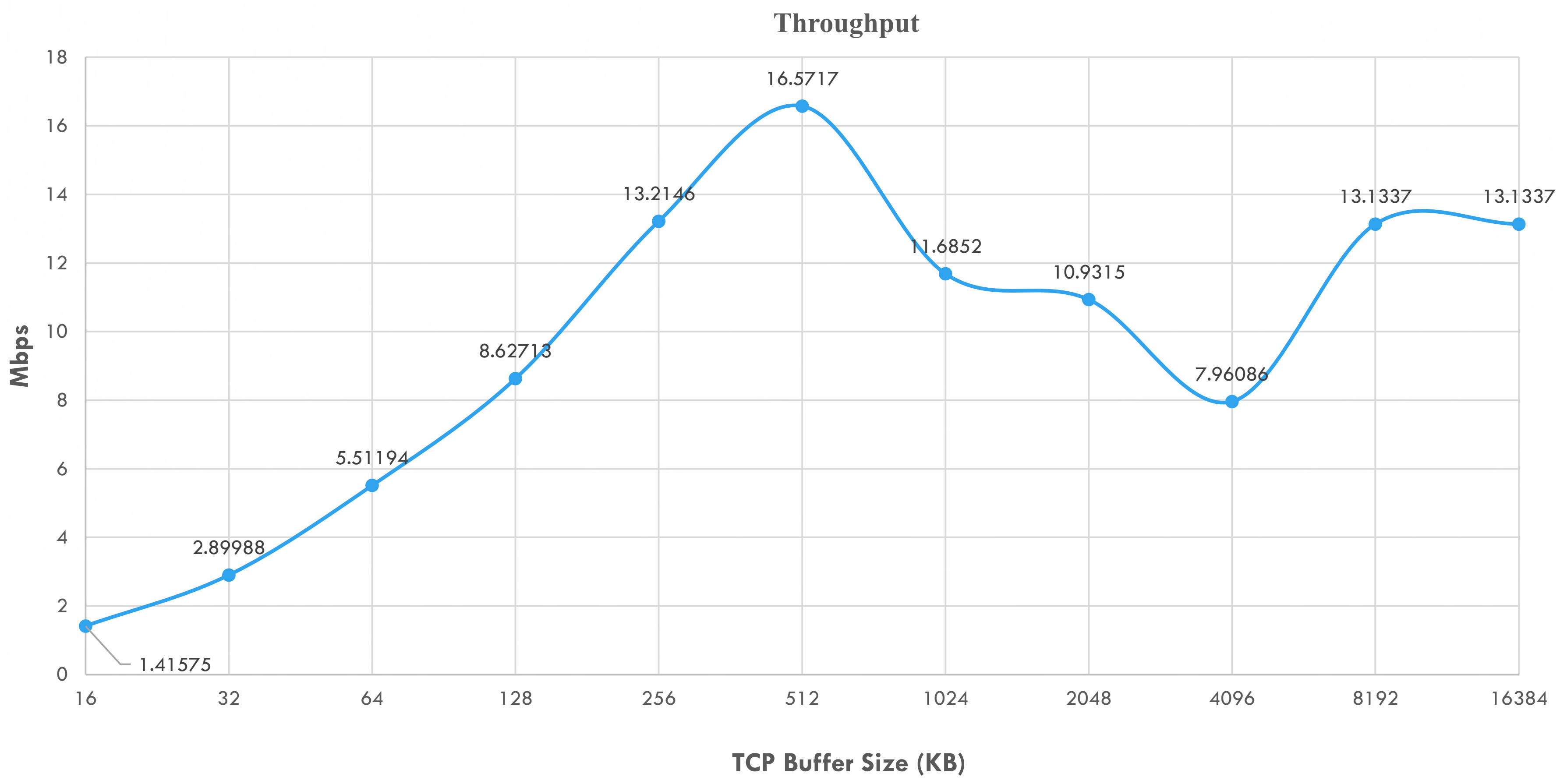
6. SIMULATION RESULTS –

TCP DCM+ WITH TCP BUFFER SIZE = 1MB REACHES ENOUGH LOW CTT.



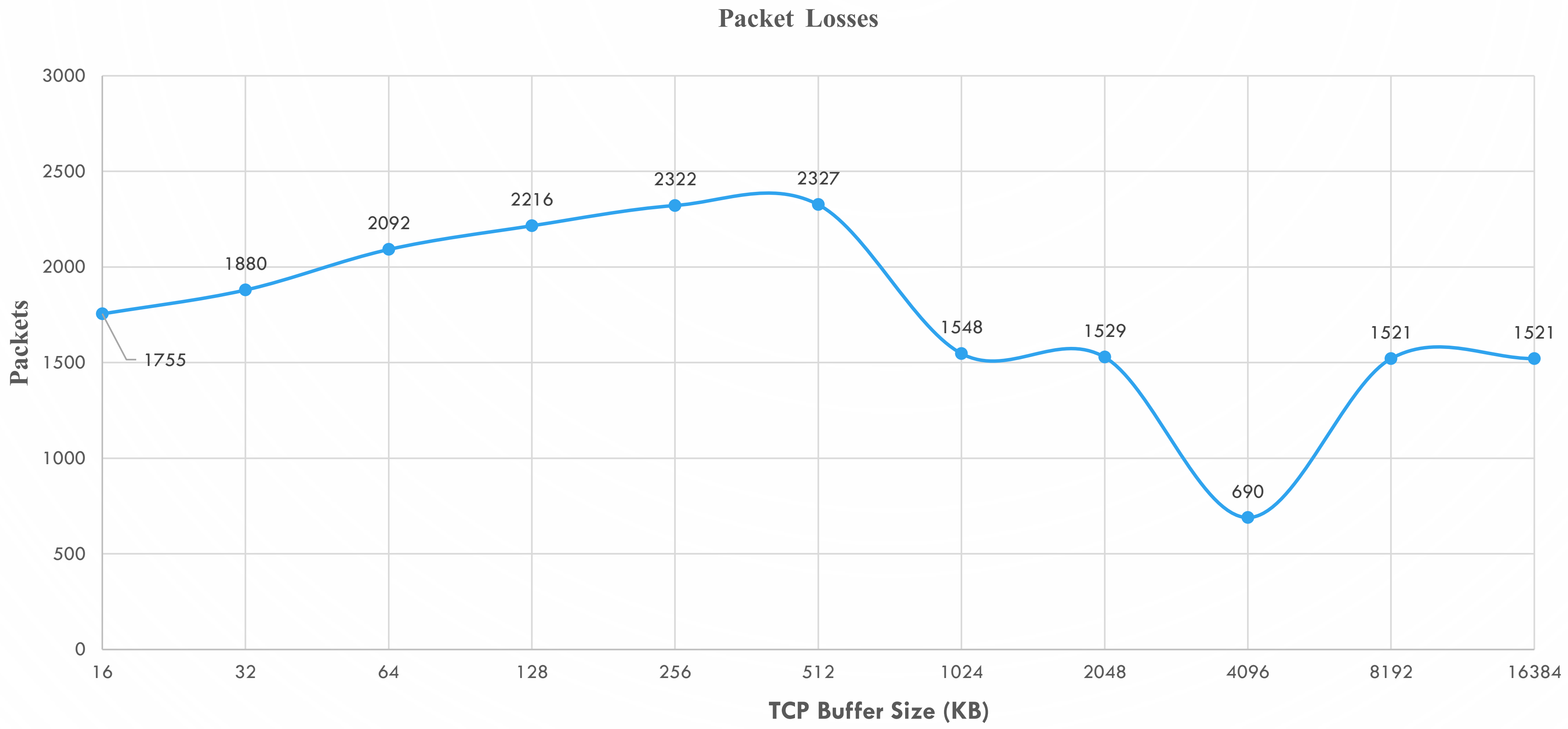
6. SIMULATION RESULTS –

DCM+ THROUGHPUT AS A FUNCTION OF RECEIVER BUFFER SIZE



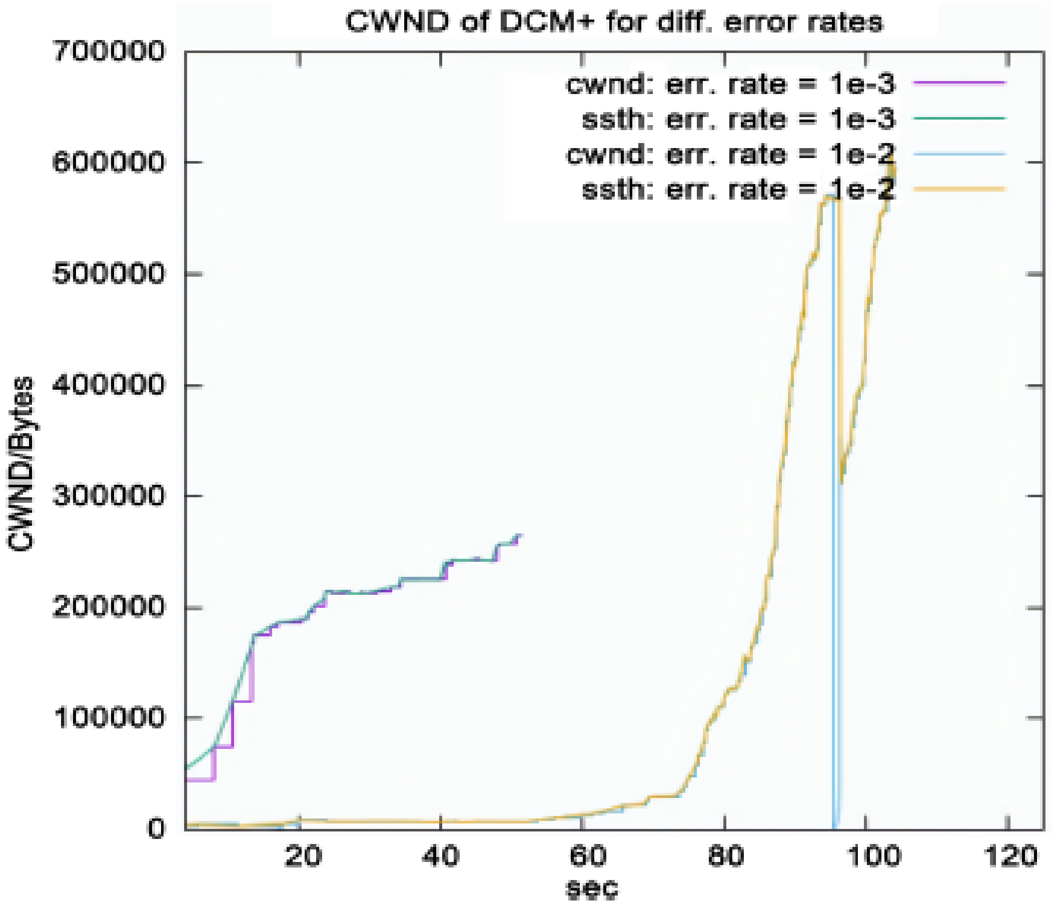
6. SIMULATION RESULTS –

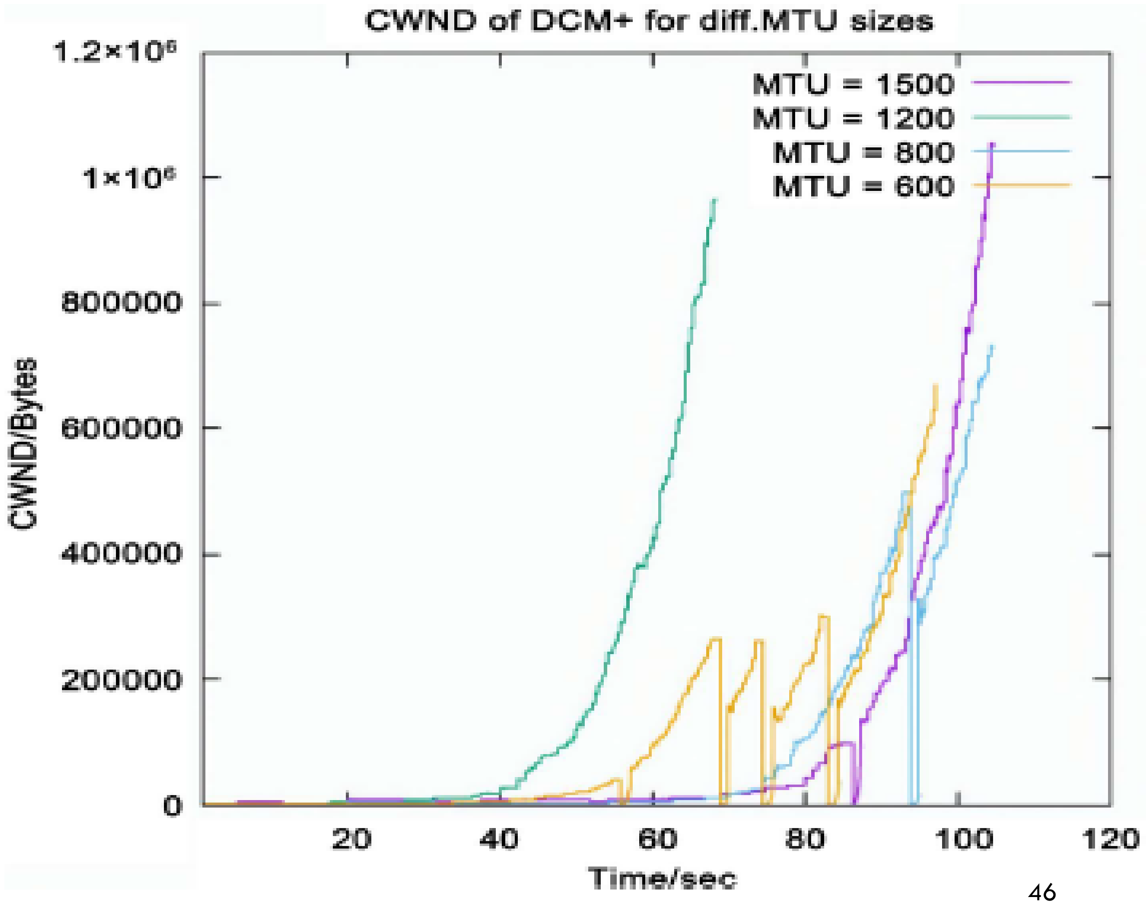
DCM+ LOSSES AS A FUNCTION OF RECEIVER BUFFER SIZE



6. SIMULATION RESULTS –

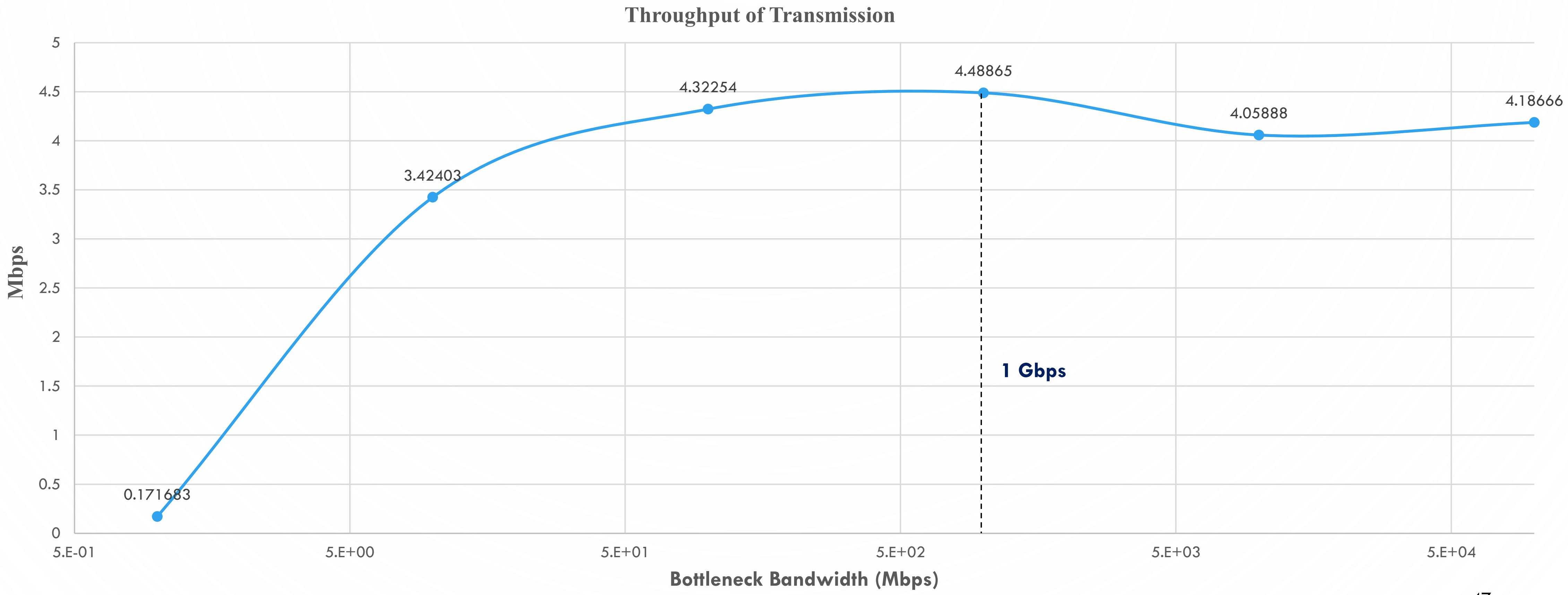
SEGMENT SIZE OPTIMIZATION BEFORE THE TRANSMISSION CAN IMPROVE THE PERFORMANCE OF TCP DCM+





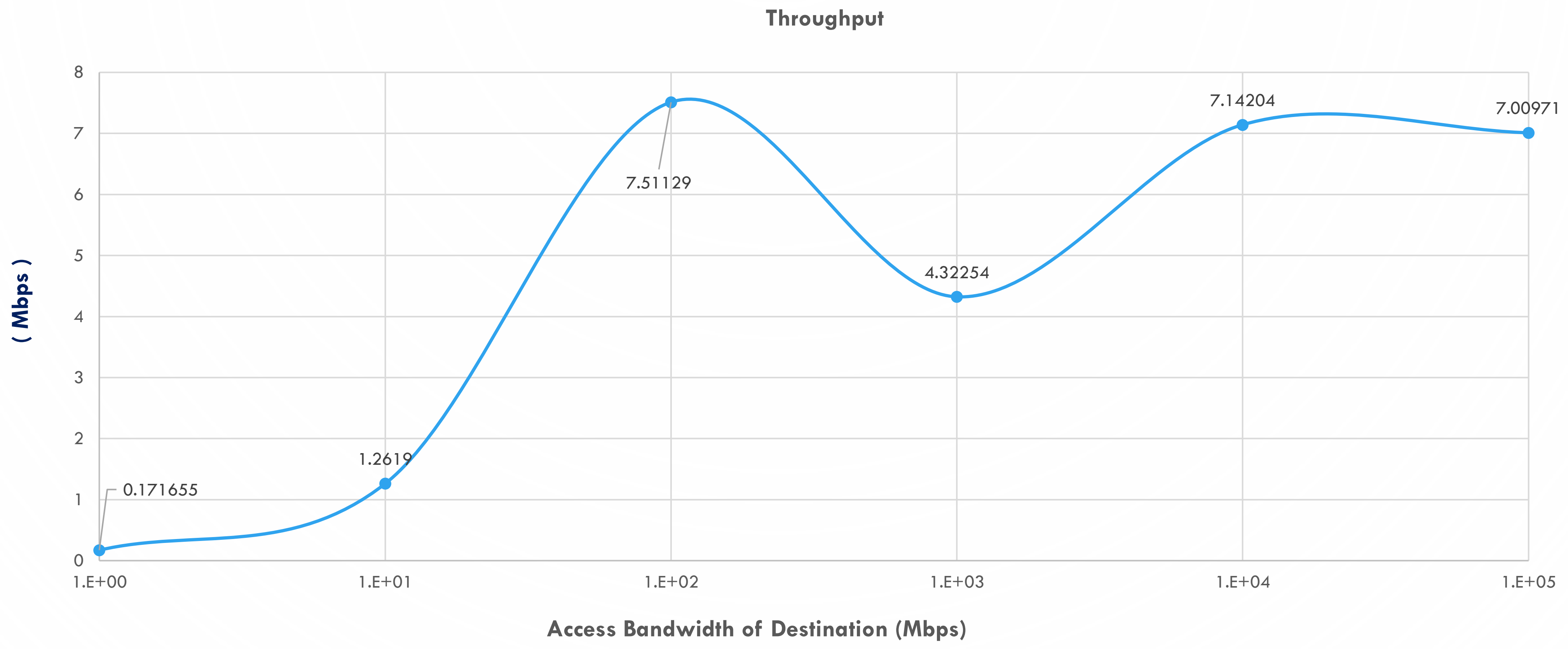
6. SIMULATION RESULTS –

MAXIMUM THROUGHPUT OF TCP DCM+ IS GUARANTEED FOR DESTINATION BW ≥ BOTTLENECK BW. (HERE: DESTINATION BW = 1 GBPS).



6. SIMULATION RESULTS –

MAXIMUM THROUGHPUT OF TCP DCM+ IS GUARANTEED FOR DESTINATION BW ≥ BOTTLENECK BW. (HERE: BOTTLENECK BW = 100 MBPS).



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