Reorder Density (RD): Metric for Degree of Reordering in Packet Sequences

http://www.ietf.org/internet-drafts/draft-jayasumana-reorder-density-00.txt

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http://www.engr.colostate.edu/ece/Research/cnrl/Reorder_Density.html

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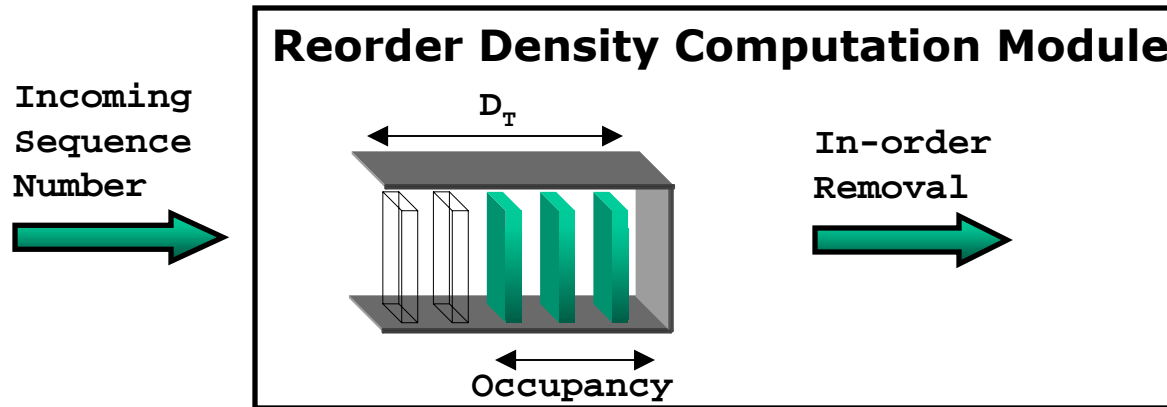
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Overview

- Concept
- Terminology
- Algorithm
- Examples
- Characteristics
- Updates in .01 Draft

Concept

Reorder Density Computation Module

Incoming Sequence Number → D_T → In-order Removal →

Occupancy

- If a packet with a sequence number higher than the currently expected packet arrives, it is buffered.
- Packets are removed from the buffer, when they become in-order or when the buffer is full.
- Occupancy of the buffer is recorded after each arrival is processed.
- Size of the buffer (D_T) determines when a packet is considered lost or useless.

Terminology

- Buffer Occupancy : Number of packets that arrived out-of-order and are stored temporarily in a hypothetical buffer.

- Buffer Occupancy Threshold (D_T) : Maximum size of the hypothetical buffer.

- Reorder Density (RD) : Density function of the buffer occupancy.

$$RD[i] = \frac{F[i]}{\sum_j F[j]}$$

where F[i] is the number of arrival instances where i buffers were occupied.

Algorithm to compute RD

- Consider an arrival instance of a packet with
  - » S : sequence number
  - » E : expected sequence number
- We consider three cases for the computation of F[i], i.e. the number of arrival instances at which i buffers were occupied.
  - » Case 1 : Duplicate packet arrival (S already received)
  - » Case 2 : Expected packet arrival (S = E)
  - » Case 3 : Out-of-sequence packet arrival (S > E)

Algorithm to compute RD

Case 1 (Duplicate packet arrival) :

      Ignore the packet.

Algorithm to compute RD

Case 2 (Expected packet arrival) :

i.   Update the expected sequence number.

ii. Remove the arrived packet and any other (previously received) in-sequence packets from the buffer.

iii. Update the frequency of the current buffer occupancy.

Algorithm to compute RD

Case 3 (Out-of-sequence packet arrival) :

i. If buffer is not full, store the packet in the buffer.

ii. Otherwise,

 a. Increase the expected sequence number treating the packet expected before increment as lost.

 b. Remove any (previously received) in-sequence packets from the buffer.

 c. Update the frequency of the current buffer occupancy.
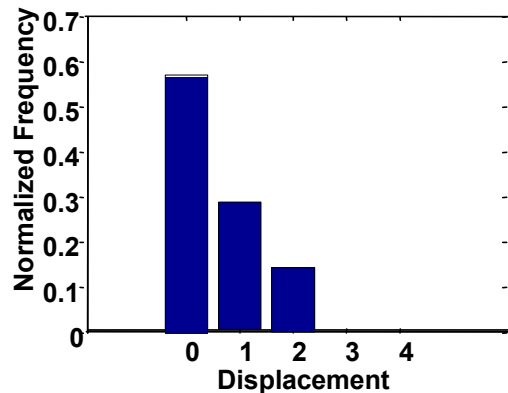
Examples of RD Computation

Case of no packet loss : [1,2,4,5,3,7,6].

RD Computation Steps:

E	1	2	3	3	3	6	6
S	1	2	4	5	3	7	6
D	0	0	1	2	0	1	0
F[D]	1	2	1	1	3	2	4

RD:

Displacement (D)	0	1	2	3
Frequency F[D]	4	2	1	0
Normalized Frequency RD[D]	4/7	2/7	1/7	0

Case of packet loss : [1,2,4,6,5,7,8] with D_T=3.

RD Computation Steps:

E	1	2	3	3	3	3	8
S	1	2	4	6	5	7	8
D	0	0	1	2	3	0	0
F[D]	1	2	1	1	1	3	4

RD:

Displacement (D)	0	1	2	3
Frequency F[D]	4	1	1	1
Normalized Frequency RD[D]	4/7	1/7	1/7	1/7
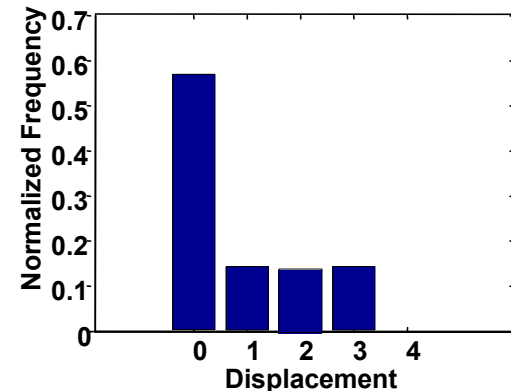
Characteristics

- Shape of RD is related to the nature of reordering.
- 90th percentile, mean and standard deviation of RD can be used when a simpler metric is required.
- On-the-fly computation possible.
- Computation complexity bounded by D_T.
- A packet is considered lost if it does not arrive within D_T.
- Effect on reordering due to a packet is captured immediately on arrival, hence, allowing application to take appropriate action on-the-fly. (For example, a TCP receiver may hold on ACKs to avoid false fast-retransmits caused by reordering.)

Reorder density plots of Internet data sets
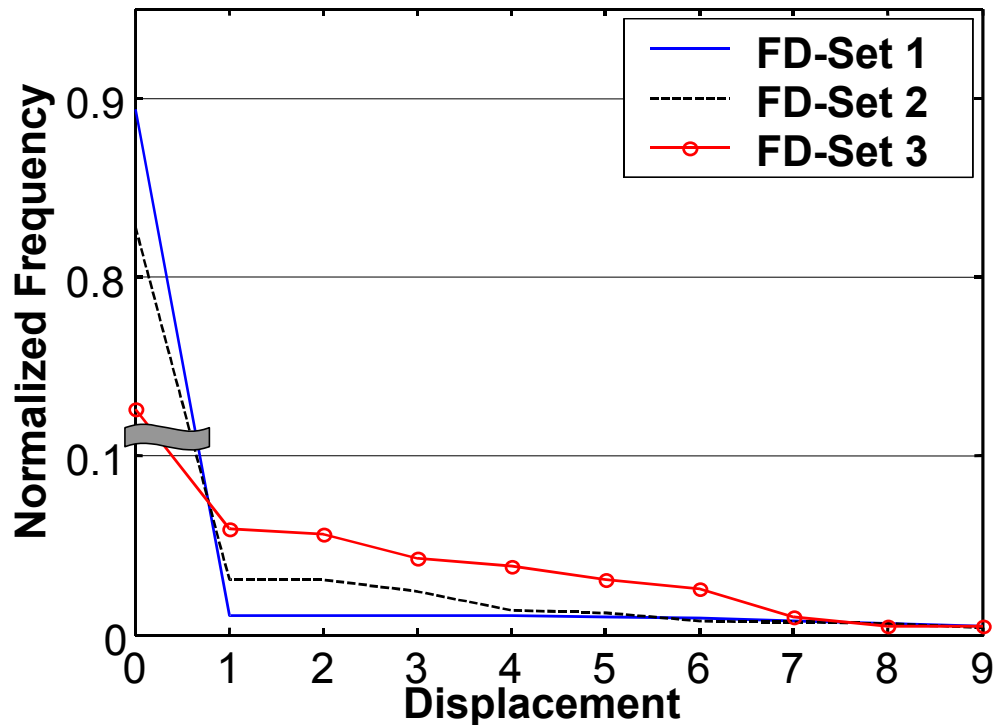
Data collected by downloading files over Internet

- FD-Set 1 and 2
  - » Download from http://www.drdo.org
- FD-Set 3
  - » Download from http://www.kalkitech.com

Changes in upcoming (01) version

- Comparison of RD with other metrics with examples
- Modification to the RD algorithm
  - » Previously duplicate packets were not considered reordered, but still counted for. Now, the algorithm does not count the duplicate packets.
- Editorial/Terminology changes as suggested by RFC reviewers.

Thank You

Questions or Feedback for the Authors?