Uplink Data Compression For Futuristic Wireless Networks

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Problem Statement

- Uplink (UL) data sent in mobile network has repetitive data blocks/strings (Fig.1.).
- Till Rel14, LTE used only RoHC (Robust Header Compression) for compression of only data header (TCP, IP header etc.)
- Uplink Data Compression (UDC) is introduced in 3GPP Rel15, to enhance uplink transmission and to help network scheduler (eNB) to enhance the UL bandwidth usage/capacity.
- UDC uses Deflate algorithm (RFC 1951), which uses LZ77 and Huffmann coding for compression .

Fig.1. Repetitive data block [1]

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Problem Statement

- To ensure higher compression efficiency deflate updates the compression buffer every single data block compression.
- Strict-in-sequence delivery and compression buffer synchronization between transmitter and receiver node is required.
- UDC is configured in RLC-AM (Acknowledged Mode) and is deployed at PDCP (Packet Data Convergence Protocol).
- Strict-in-sequence delivery requirement of current system leads to packet loss issue when buffer synchronization is lost and has also lead to some apprehensions on further extending existing UDC as data compression scheme.

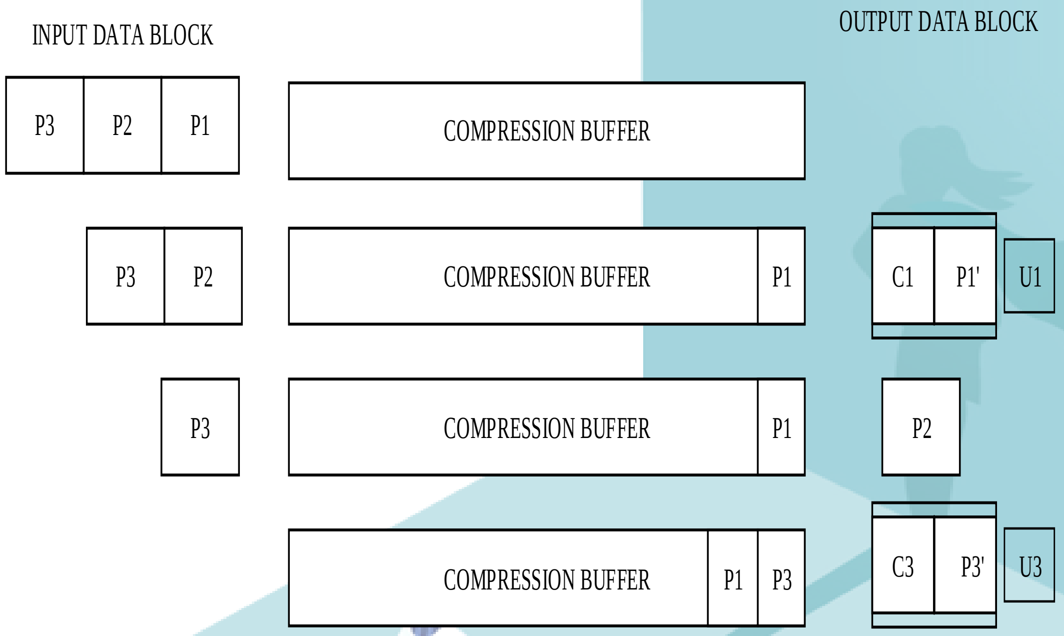

Fig.2. Uplink Data Compression

Problem Statement

- **Packet loss Issue:**
- Checksum failure is used to indicate UE about the lost buffer synchronisation
- On encountering checksum failure, receiving entity drops all subsequent compressed data PDUs, until it receives freshly compressed PDUs (indicated by PDCP header).
- The magnitude of dropped PDUs is proportional to delay incurred in UDC packet transmission, processing at the receiver and/or transmitter and amount of uplink resource allocation
- RTT (delay incurred) = t2 - t1

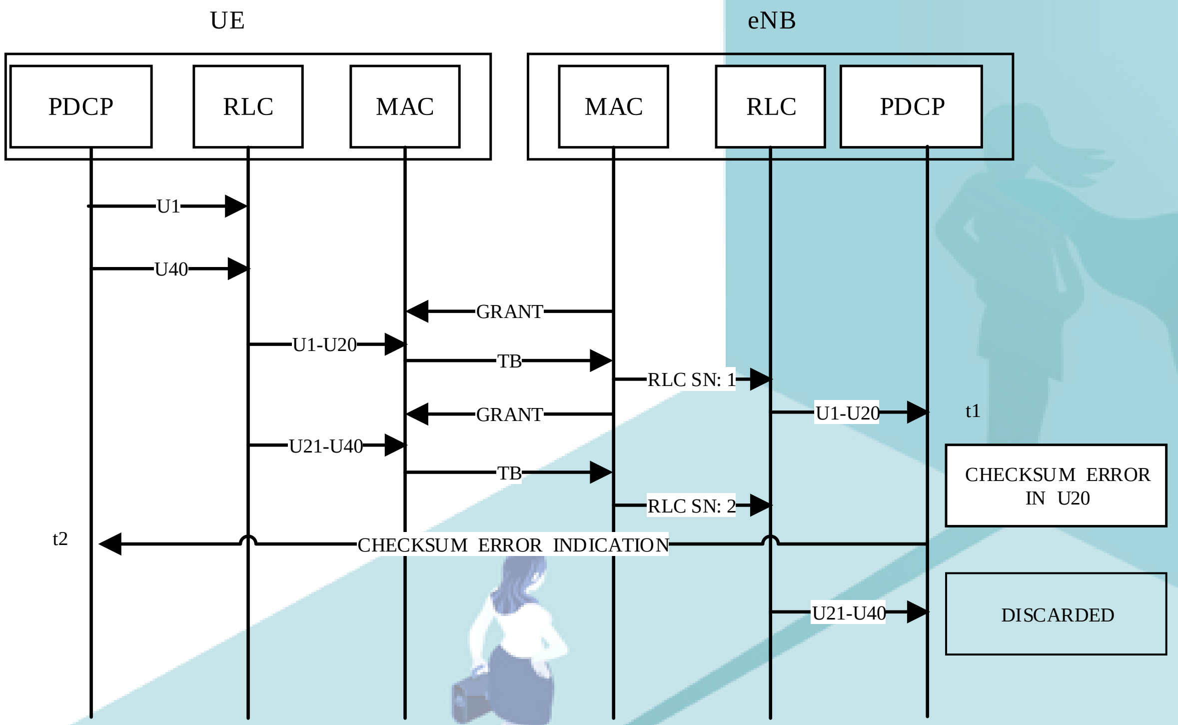

Fig.3. Packet Loss Issue

Problem Statement

- **Limited UDC Application:**
- 3GPP LTE Rel-15 introduced other features like Split bearer, PDCP Duplication, RLC out-of-order delivery.
- These features target higher throughput while achieving balanced data processing load
- Applying existing UDC, would either results in
  - Imbalance in packet processing by ensuring in sequence data processing, or;
  - Frequent checksum failure due to out of sequence data processing

  Either way, system performance will be degraded.
- Excluding UDC from new feature limits the compression scope to very small traffic scenarios.

Problem Statement

- **Problem Severity:**
- Packet Loss Issue:
  - UDC Checksum failure can fail due to:
    - Packet drop due to PDCP discard timer expiry at UE side
    - PDCP buffer issue at eNB side
  - In scenarios where channel conditions are not very good or when load on eNB side is very high these problems are very common

- Limited UDC application:
  - The new features seem to have done injustice for traffic mapped on UDC or vice-versa as they cannot be configured simultaneously and therefore lead to limited application or curb network scheduling flexibility.

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Solution

- Methods for decreasing the amount of packet loss due to checksum failure:
  - Preventive Method
  - Recovery Method

- Preventive Method:
  - Control the number of compressed PDUs available for transmission
  - Define a packet formation rate (PFR)
  - PFR decides amount of PDUs to be compressed at PDCP in a given time
  - Factors governing PFR:
    - Grant rate : UL grant received from network per TTI
    - Prioritized bit rate : Bit rate allocated by network for logical channel prioritization
    - Uplink error rate

Solution

- Recovery method:
  - New ‘T2’ timer introduced
  - Maintain the successfully acknowledged RLC data PDU for additional T2 time
  - On receiving UDC checksum failure before T2 timer expiry:
    - PDCP allocates successive new Sequence Number (SN), starting from first not transmitted SN, and
    - Re-transmit all T2 alive PDCP PDUs for which application layer ACK (eg: TCP Ack) has not been received.
  - Factors governing T2
    - Block Error Rate
    - Signal to Noise Interference ratio (SINR)
    - RTT

Solution

- Method for interworking UDC with NR/New features:
  - Synchronize the compression buffer periodically every T time and/or every N data block.
  - During this duration, same compression buffer (B1) is used for (de)compression.
  - In parallel, a running compression buffer (B2) is also maintained locally which is updated every data block.
  - B1 is updated with content of B2 once B2 is synched between transmitter and receiver.

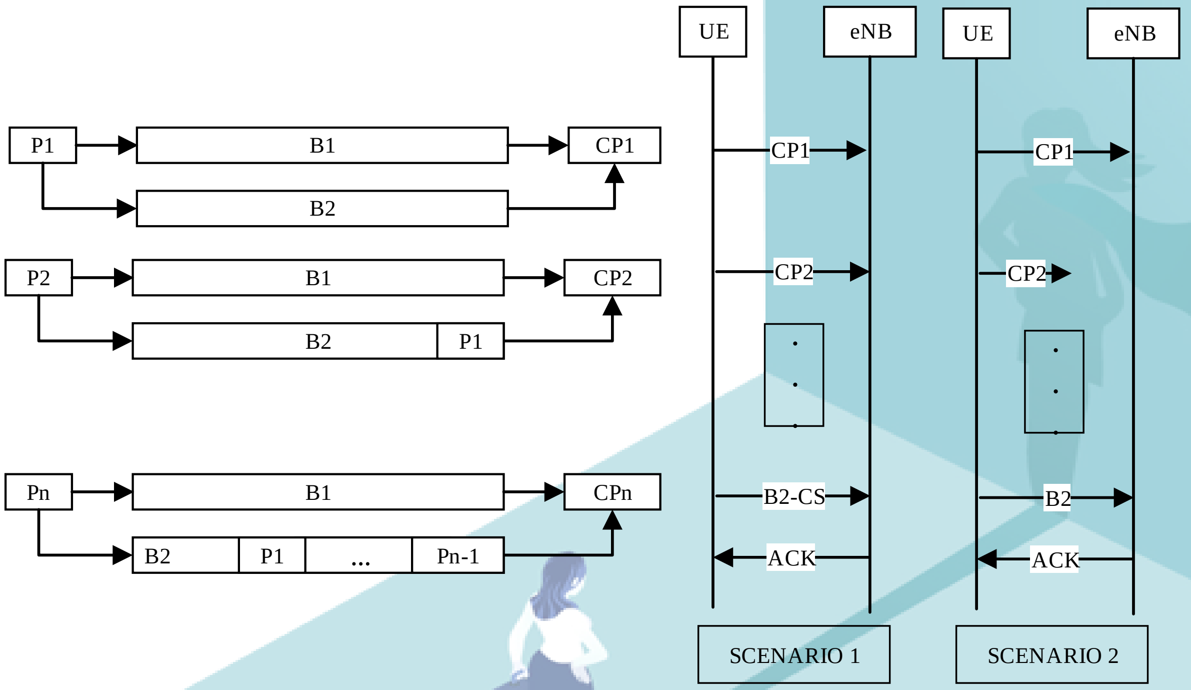

Fig.4. UDC Interworking With New Features

Simulation Environment

- LTE L2 behaviors were modelled based on 3GPP standard for UE specifications
  - with and without proposed solution

- Next Generation NodeB (gNB)/eNB PDCP, RLC and MAC behaviors were modelled with below simulation parameters

Poll re-transmit time (msec)	40
Poll PDU	5
Status Prohibit time (msec)	30
Compressed packet size (byte)	300
Input data buffer size (byte)	20000

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Simulation Environment

- Network simulation involved
  - Modelling processing of received UL PDU
  - Generating checksum failure randomly despite acknowledging the UL PDU at RLC level.

- Checksum failure indication was modeled for different values of RTT, i.e. 6, 7 and 9msec respectively.

Experimental Results

- Recovery method to decrease packet loss
  - With current system higher packet loss was observed with increasing value for grant size and RTT delay (captured in Fig.5.)
  - With recovery method applied, high packet recovery was observed with minor re-transmission overhead of correctly decompressed UDC packets (captured in Fig.6. with RTT = 6msec)

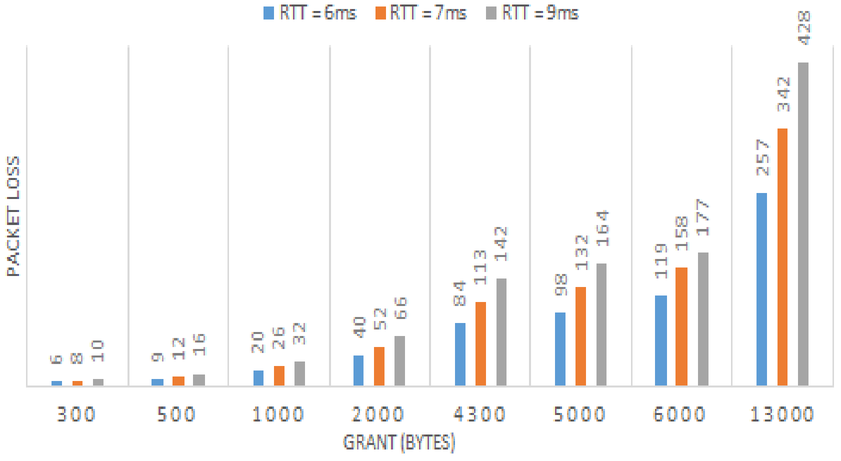

Fig.5. UDC Packet Loss

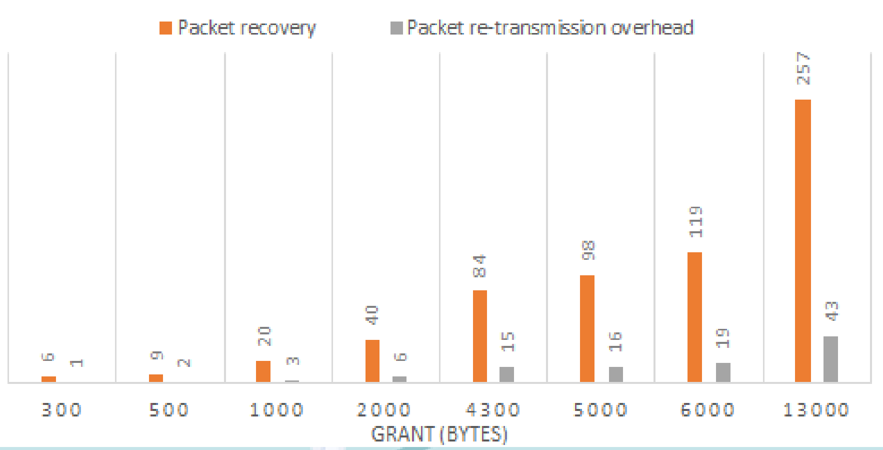

Fig.6. Packet Recovery Results

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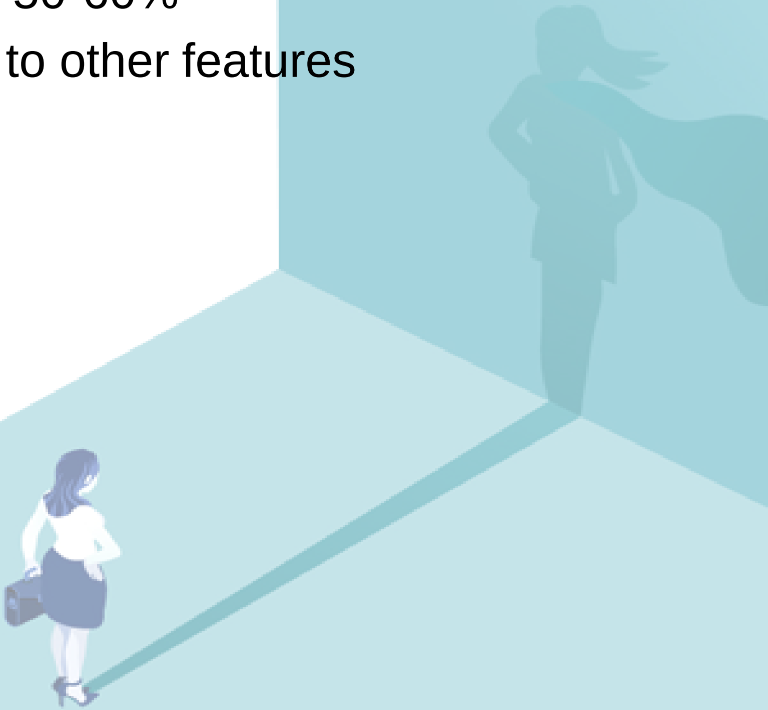
Experimental Results

- Method for interworking UDC with NR/New features
  - Compression efficiency achieved from traditional UDC = 80-85%
  - Compression efficiency achieved from proposed solution = 50-60%
  - 50-60% of UL resource saved while extending UDC scope to other features



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Conclusions

- Using T2 timer and PDCP level re-transmission, shows high packet recovery at protocol level itself.
- Using a combination of semi-static and dynamic buffers, removes the dependency of in sequence data reception with little effect on compression efficiency.

References

[1] 3GPP, TR 36.754 - Study on Uplink (UL) data compression in LTE

[2] https://www.w3.org/Graphics/PNG/RFC-1951

[3] 3GPP, TS 36.323 - Packet Data Convergence Protocol (PDCP) protocol specification

[4] 3GPP, R2-1901806 - Comparing RoHC and UDC Header Compression for TSN

[5] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[6] 3GPP, TS 36.321 - Medium Access Control (MAC) protocol specification

[7] 3GPP, TS 36.322 - Radio Link Control (RLC) protocol specification