3GPP TSG RAN Rel-18 workshop
Electronic Meeting, June 28 – July 2,2021

RWS-210484

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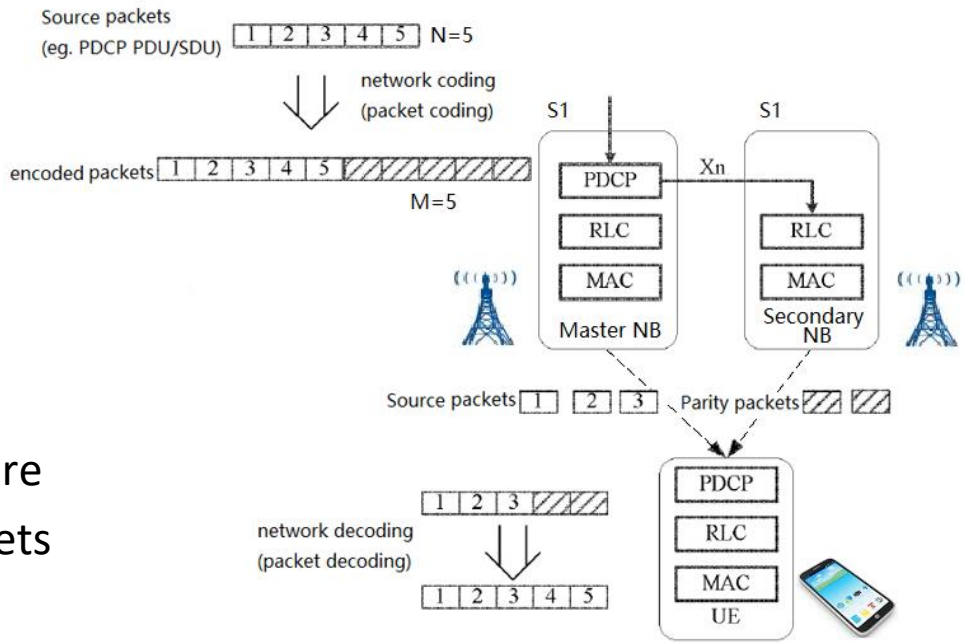
Tomorrow never waits

Source: ZTE, Sanechips
Agenda: 4.3

Discussion on Network coding for 5G Advanced

Scenarios and Motivations

- Packet Duplication over multiple connections have been supported in NR Rel-16 for URLLC. However, only simple duplication is supported.
- For Rel-18, simple duplication can be substituted by network/packet coding duplication depicted by the following figure for XR and URLLC, wherein all parity packets can be sent in the second link.



- **Motivation:** Network/packet coding can be used to further increase the reliability or data transmission efficiency for multiple connections. This has potential benefit especially for XR and IIOT scenarios where there are massive IIOT users.

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Erasure codes for Network/packet coding(NC)

- Network/packet coding can be implemented by erasure codes with BEC channel, such as Reed-Solomon codes, Raptor codes, Low density generator matrix codes and so on.
- For erasure codes, there are the optimal erasure codes. For the optimal erasure codes, in the encoding stage, erasure codes encode N data elements to generate additional M parity elements via arithmetics over Galois finite field. These N + M elements that are encoded together collectively constitute a codeword, promising that any N out of the N+M elements within a codeword suffice to reproduce the original N data elements. In other words, erasure codes can tolerate any M element failures within each codeword.
- Reed-Solomon codes are the optimal erasure codes. When N is large, Raptor codes have near optimal erasure code performance.

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Initial evaluation for Network/packet coding(NC)

- Evaluation is conducted to compare the reliability performance comparison between simple duplication and NC based duplication, which is the failure rate of one PDCP PDU/SDU at a given pair of the packet loss rate of the first link (Pe1) and the packet loss rate of the second link (Pe2).
- Simulation assumption:
  - N is the number of source packets which will be transmitted in the first link, eg N=5 in the figure;
  - M is the number of parity packets which will be transmitted in the second link, eg M=5 in the figure;
  - Pe1 is the packet loss rate of the first link, eg Pe1=3/5=0.6 in the figure;
  - Pe2 is the packet loss rate of the second link, eg Pe2=2/5=0.4 in the figure;
  - Failure rate is defined as the decoding error rate of one PDCP PDU/SDU;
  - Optimal erasure codes are assumed and link simulation based on BEC channel are used;
  - As a simulation assumption, each packet in the first link has its independency but the same packet loss rate Pe1, that is to say, whether each packet is received wrongly is simulated and decided by a independent random variable with even distribution, and N packets have N independent variables; meanwhile, each packet in the second link has its independent but the same packet loss rate Pe2.

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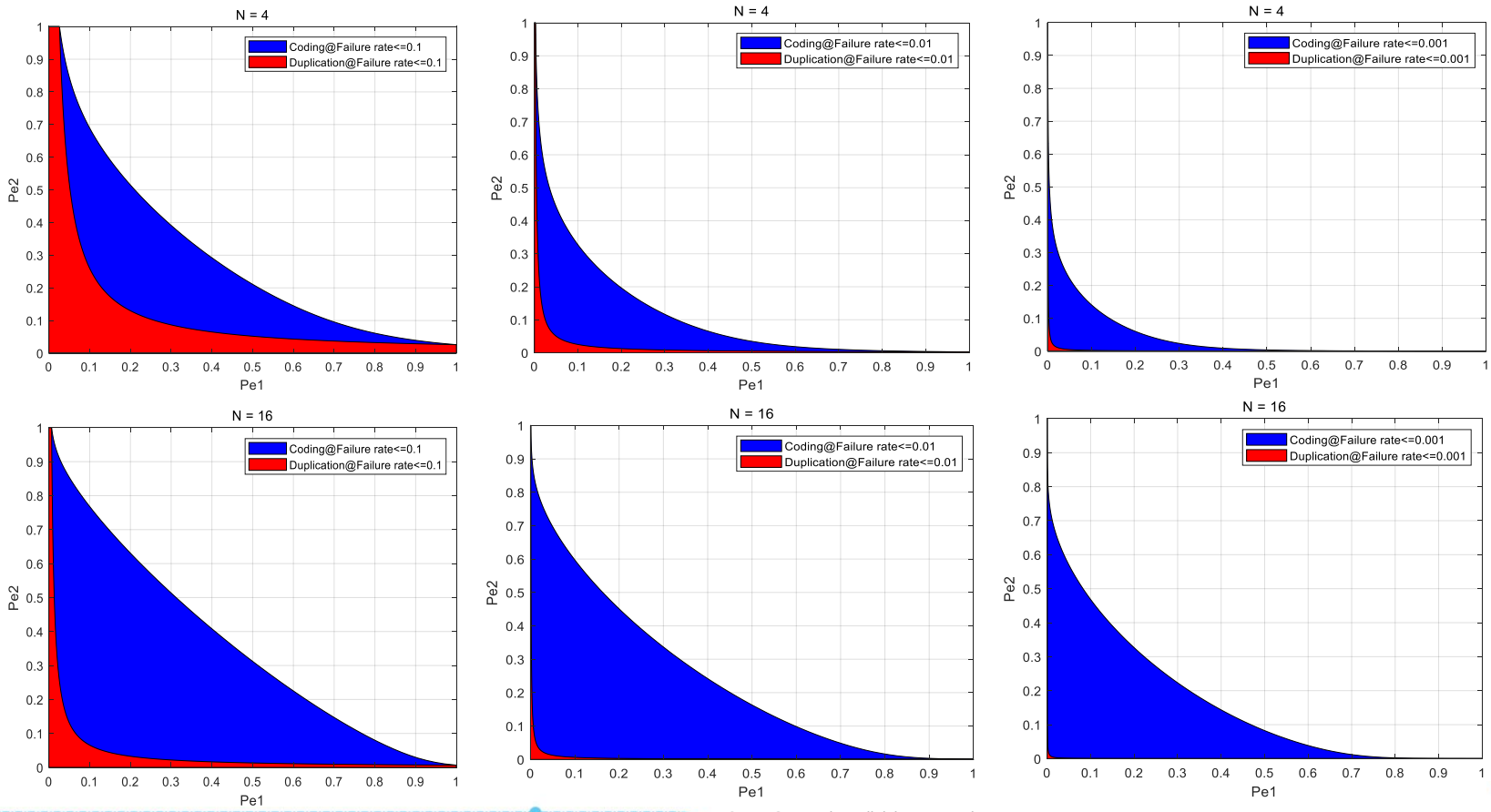
Reliability Comparison – Simple Duplication vs NC based Duplication



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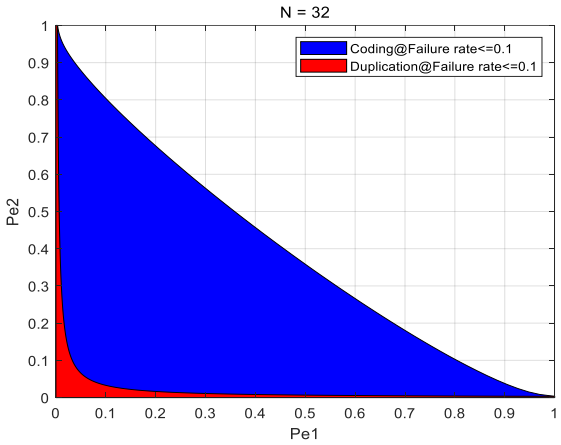

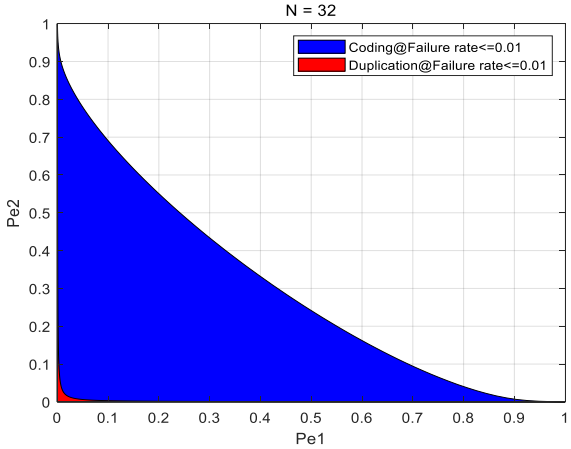

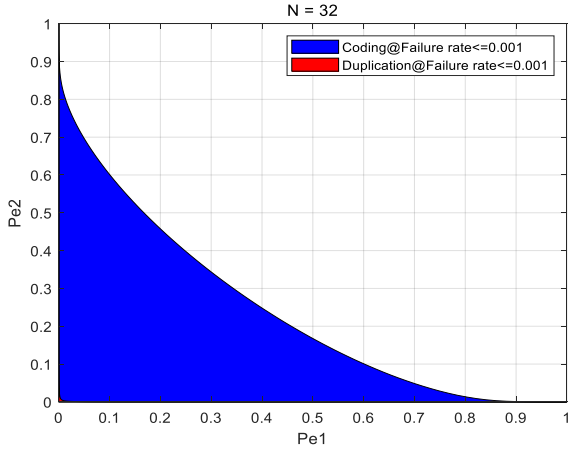

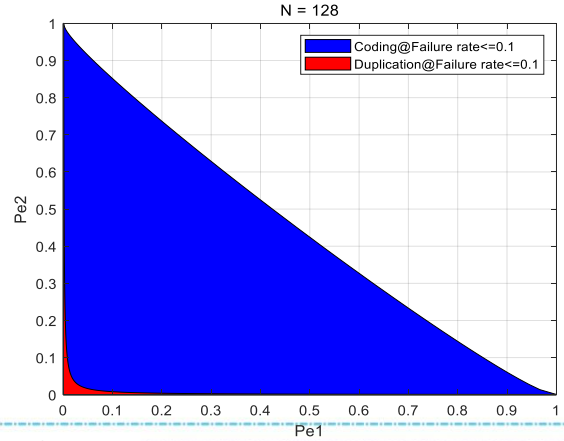

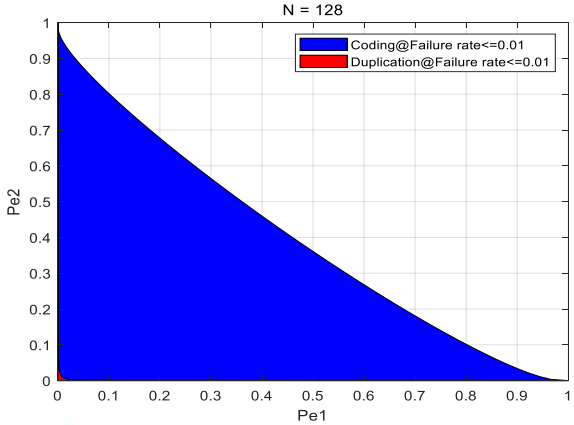

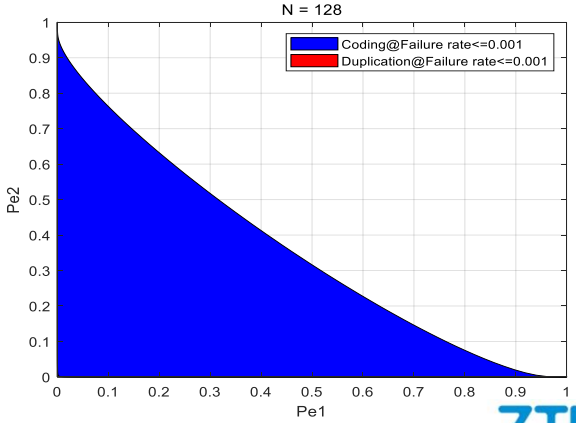

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Evaluation Results Overview

- The observations from simulation are summarized as follows:

Observation 1: *According to the failure rate at a given pair of Pe1 and Pe2, NC based duplication has much better reliability performance than simple duplication over dual connections due to FEC coding gain.*

Observation 2: *The performance gap between simple duplication and NC based duplication has become larger when N increases, which means that NC based duplication is very useful for large packet traffic e.g. XR traffic with high date rate requirement.*

Observation 3: *The performance gap between simple duplication and NC based duplication has become larger when target Failure Rate increases, which means that NC based duplication is very useful for high reliability scenarios with requirements of very low PER with a limited PDB.*

Notes 1: The packet loss rates of the first/second links(Pe1/Pe2) are decided not only by channel capacity of links but also the network traffic control within a certain time window e.g. PDB.

Notes 2: In industrial scenarios, network/packet coding has been applied in the multiple connections, e.g. the aggregation of multiple TCP links, which can improve the reliability, throughput and coverage.

Proposal: *Network coding based PDCP duplication can be introduced in Rel-18.*

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Potential Scope

- **Use cases**
  - Identify scenarios and use cases (e.g. DC, IAB, mTRP, etc.), as well as the corresponding evaluation methodology and simulation assumptions for performance evaluation.
- **Study mechanism of network coding based PDCP duplication to exploit link diversity. (RAN2)**
  - The packets segment/concatenation with equal size
  - The ordering of packets
  - Flexible redundancy ratio for different reliability requirements
  - Flexible split for different paths
- **Study erasure code schemes for network coding (RAN1)**
  - Study the potential erasure codes eg Reed-Solomon codes, Raptor codes, LDGM codes for network coding based duplication over multiple links, and strive to derive a solution of the optimal erasure codes.

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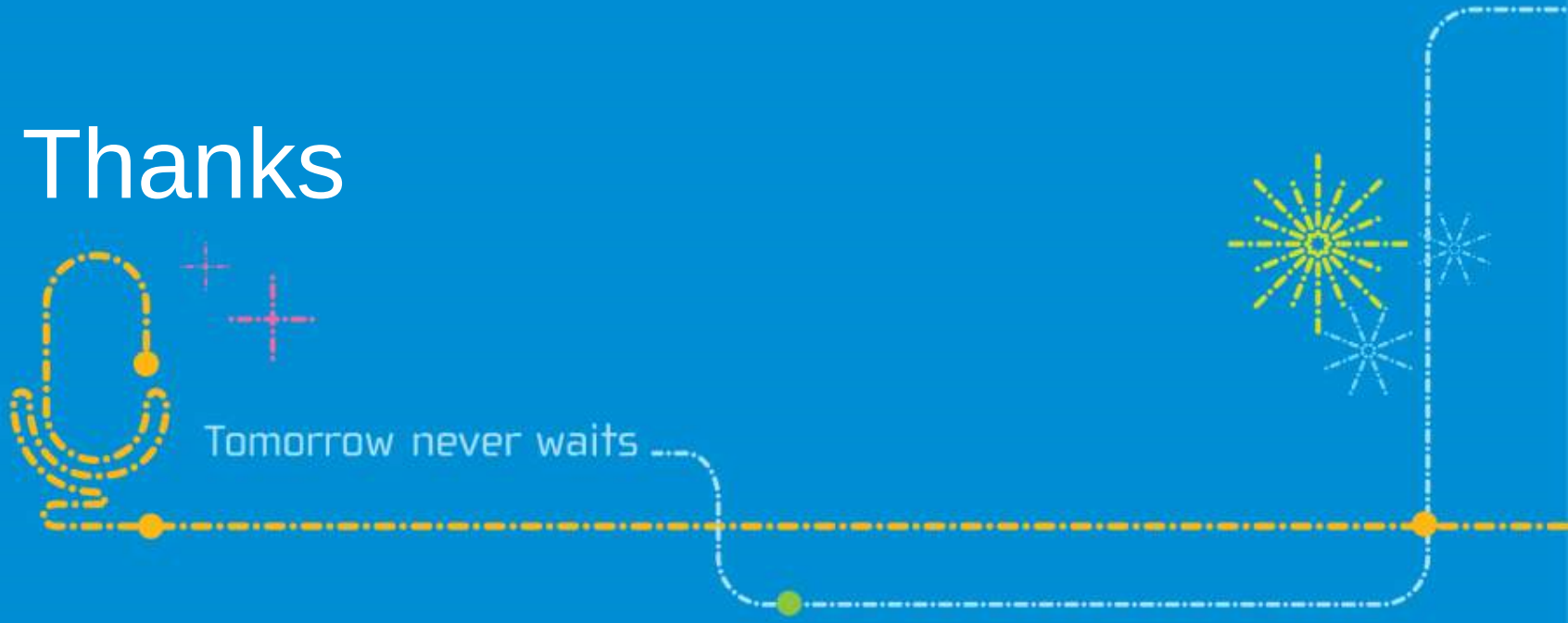
Thanks