Higher layer protocol enhancements
Fully exploit NR data rates in FR1 and FR2

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Background

- TCP
  - Pre-eminent internet transport protocol
  - Known performance bottlenecks
- QUIC has been considered as a replacement for TCP
  - Study in CT (CP-182345, TR 29.893) found it was not ready for 3GPP use yet
- Opportunity to provide a 3GPP-based solution to facilitate implementation and fully unleash NR data rates

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Motivation 1: ACK prioritization

- Scenario: UEs with bidirectional TCP data flows
  - UL TCP segments carrying “piggybacked” TCP ACKs are interspersed with TCP segments that carry only data
  - The resulting head-of-line blocking can delay TCP ACKs resulting in slower TCP connections
- Potential solutions
  - “Marking” of TCP segments carrying ACKs
  - Splitting TCP ACKs onto RLC UM bearers
  - Using PDCP control PDUs to carry TCP ACKs

- Simulation assumptions
  - TCP NewReno, 1Gbps DL, 500Mbps UL, no mobility, AM bearer, IPv4, Fast ReTx

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Motivation 2: Tackle excessive ACK Generation

- Scenario: High data rate DL TCP flow
  - High TCP ACK data rate to support high DL TCP data rate
  - TCP ACKs are cumulative: not all TCP ACKs are essential
  - TCP is clocked by ACKs: ACK suppression to be done carefully
- Potential solution
  - Careful TCP ACK suppression
  - TCP Delayed Ack (sending ack after 2, 3 or more DL TCP PDU receptions

- Simulation assumptions
  - TCP NewReno, 5Gbps DL, no UL data, no mobility, AM bearer, IPv4

DL Simulation Tests		UL ACK data rate
1	Normal TCP ACK	62.2Mbps
2	Suppressing TCP ACK (FIFO)	33Mbps

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Motivation 3: Tackle blocking at high frequencies

- Scenario: TCP in mmWave spectrum
  - High sensitivity to blockage by buildings, vehicles, and human movement
  - Frequent and unpredictable blockage harms TCP performance
  - TCP performance is very sensitive to the duration of interruption
- Potential solutions
  - UE-based autonomous switching to minimize packet loss
- Simulation assumptions
  - TCP Cubic, 38 GHz carrier freq., 8Tx and 4Rx antennas, minimum RTO = 200ms

Blockage model	TCP Throughput	TCP Degradation
No blocking	807Mbps	0%
0.1s blocking every 5s	712Mbps	12%
0.2s blocking every 5s	371Mbps	54%
1s blocking every 5s	229Mbps	72%

NOTE: TCP performance ~holds with blockage shorter than 100ms.
Longer interruptions lead to severe degradation (TCP congestion control algorithms e.g. RTO timeout or congestion avoidance)

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Motivation 4: TCP Path Selection over Dual Connectivity

- Dual-Connectivity (DC) – two links of DC usually do not offer the same latency performance.
- Three modes of bearer operations on top of DC:
  - (1) bearer aggregation, (2) bearer switching, and (3) bearer duplication, with bearer anchoring and PDCP reordering in one of the two DC links
- Bearer aggregation increases aggregated bandwidth, but TCP performance still suffers from reordering delay imposed by the slower link.
- Problem is aggravated in slow-start phase, as the growth of TCP-window in slow-start is dominated by RTT
- Need to exploit the best (faster) link to unleash the full potential of TCP over 5G

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Motivation 5 inter-RAT handover – NR > LTE

- 5G NR UEs expected to have multi-mode capability to support inter-RAT handover between NR and LTE (4G)
- Significant difference of data rates between 4G and 5G during 5G>4G HO will result in a large amount of buffered data and sudden increase in transmission delay
- Current TCP implementation designed and optimized for stable networks
  - Does not adapt well upon sudden bandwidth changes.
- Without a chance to adapt its retransmission timer and TCP window to such a large bandwidth decrement, TCP will assume packet loss and trigger un-necessary congestion control and TCP retransmissions.
- One possible solution: Indicate the underlying RAT information to the TCP layer or provide some built-in support

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Proposal: Study

- Proposed components
  - Study enhancements to NR for increased data rate and reduced latency in the context of TCP data
  - Study RAN-based mechanisms to improve TCP performance over NR
    - Identify a common system model, scenarios of interest, and metrics to evaluate TCP performance
    - Quantitative evaluation of RAN enhancements for TCP (incl. combinations of proposals) and down-selection of candidates
    - Identify impact on RAN2 specs including user plane and control plane aspects for promising mechanisms
- Lead: RAN2
  - Study followed by feature

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