Transport protocol performance over cellular access: adaptability issues and future steps

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Motivation of the work

Testing environment

Technical analysis of results

Confirmation of findings over different testbeds

Conclusions and future work
Motivation of the work (I)

• Mobile Internet growth
  • 4000-fold in ten years
  • 70% in the last year

• Research focus
  • Infrastructure evol.: 5G, SDN, NFV, IoT, M2M, Cloud...
  • Transport protocols performance

• Variability in terms of BW and delay
  (Resource sharing and Self-inflicted effects)
Motivation of the work (II)

• Transport protocols (mostly TCP) have been thoroughly modelled
  • Based on rounds
  • Markov chain
• But hard due to ...
  • Continuous evolution of TCP features
  • Variable/unpredictable circumstances of mobile networks
• Need for ...
  • Up-to-date TCP/IP stack
  • Deployments so as to run real traffic
Testing environment (I)

- Simulated/emulated framework
  - Simulated/emulated framework
  - DCE capabilities
- Selected TCP flavors
  - Loss-based
    - NewReno
    - CUBIC
  - Delay-based
    - CAIA delay gradient (CDG)
  - Hybrid
    - Westwood+
    - Illinois
Testing environment (II)

- Variable modulation
- Movement impact (propagation + fading)
- 2 different movement inertia
- Good quality
- Resource sharing
- Cross-traffic delay

Diagram:
- UE1 to UE10
- eNodeB
- S1-U
- Forward & Backward
- UE
- SGW/PGW
- Server
Technical analysis of results (I)

• Start-up performance analysis
  • Standard Slow-Start
    • $cwnd + 1$ for each ACK until:
      • it reaches ssthresh value
      • losses a packet
  • Hybrid Slow-Start
    • Behaves as standard Slow-Start with two additional exit conditions
      • Detection of Packet-train lengthen
      • Delay increment (establishing boundaries)
Technical analysis of results (II)

- **Start-up performance (II)**

![Graph showing slow-start phase convergence with an immense gap between each other]
Technical analysis of results (III)

- **Start-up performance (III)**

In-flight packets during a standard Slow-Start phase duration

- Elbow-Pace change
- Constrained injection
- and therefore achieved speed

![Graph showing in-flight packets during a standard Slow-Start phase duration with annotations for Elbow-Pace change, Constrained injection, and Delay detection.](image-url)
Technical analysis of results (IV)

- Mobility impact (I)
  - Speed selection
    - 60 km/h -> common limitation in rural roads (*)
    - 200 km/h -> max. speed in high-speed trains (*)
  - Movement inertia
    - Forward movement
      - UE moves away from the eNodeB (constantly)
      - Obtained SINR -> tendency to worse conditions
      - Mean MCS tendency -> lower values (more robust)
    - Backward movement
      - The other way around
      - Starting the communication in poor channel cond.
  - CWND adaptability
Technical analysis of results (V)

• **Metrics**

**Distribution of MCS during forward movement (60km/h)**

Wasted TxOp/s in each MCS section
Technical analysis of results (VI)

- Mobility impact (II)

Wasted TxOps/s while moving forward (NewReno)

Queue draining zone

Bufferbloat area

Slow-Start phase
Technical analysis of results (VII)

• Mobility impact (III)

Wasted TxOps/s while moving forward (Comparison of CCAs)

Queue draining zone

Wasted TxOps per second

Bufferbloat area

Slow-Start phase

MCS value

Avg

CUBIC-60kmph
CUBIC-200kmph
NewReno-60kmph
NewReno-200kmph
Westwood+60kmph
Westwood+200kmph
Illinois-60kmph
Illinois-200kmph
CDG-60kmph
CDG-200kmph
Technical analysis of results (VIII)

• Mobility impact (IV)

Wasted TxOps/s while moving backward (NewReno)

Ramp-up phase

Bufferbloat area

![Graph showing Wasted TxOps/s while moving backward](image-url)
Technical analysis of results (IX)

- Mobility impact (V)

![Graph showing UE moving backward at 60 km/h](image_url)

- Line graphs comparing NewReno-CWND and NewReno-Tx on Buffer (#packets) vs. CUBIC-CWND and CUBIC-Tx on Buffer (#packets).
- Cumsum (Goodput (#packets/s)) for NewReno and CUBIC over time.
Technical analysis of results (X)

• Mobility impact (VI)

UE moving backward at 200km/h
Technical analysis of results (XI)

• Mobility impact (VII)

Wasted TxOps/s while moving backward (Comparison of CCAs)
Confirmation of findings over different deployments (I)

Aeroflex

iMinds-w.ilab-t
Confirmation of findings over different deployments (II)

- Hybrid Slow-Start in Aeroflex
Confirmation of findings over different deployments (IV)

- CCA comparison in w.ilab-t

CCA comparison (Pattern 1)

CCA comparison (Pattern 2)

CCA comparison (Pattern 3)
Conclusions

- Impact of Hybrid Slow-Start mechanism under some delay variability circumstances
- Forward vs backward
  - Inertia, tendencies and phases
- CUBIC -> mobile network capabilities underutilisation during Hybrid Slow-Start phase
- CDG -> the delay boundaries of the protocol may well be adapted to cellular networks’ constraints
- Westwood+ -> estimation of the available bandwidth not suitable for mobile networks as is
- NewReno and Illinois
  - Delay-awareness to make the most in terms of transmission opportunity usage
Future work

- Complete the work with the analysis over
  - Large-scale and real-world
- Signaling proposal and mobile edge computing management
- Hybrid Slow-Start
  - Adaptation of Initial Window
  - Adaptation of Slow-Start mechanism
  - Congestion-Avoidance phase
- Feasibility/suitability check among testbeds/deployments
• Spanish Ministerio de Economía y Competitividad (MINECO) under grant TEC2013-46766-R: QoEverage.
• Cost Action IC1304 through the STSM entitled ”Evaluation of QoE-optimized transport protocols on cellular access” (2015).
• Cost Action IC1304 through the STSM entitled ”Evaluation of modern transport protocols over iMinds LTE facilities” (2016).
Confirmation of findings over different deployments (III)

- Poor performance due to delay skip (RTT burst)

Mechanisms of CUBIC

- Backward - Packet train mechanism
- Forward - Packet train mechanism
- Backward - Delay mechanism
- Forward - Delay mechanism
- Backward - Both mechanisms
- Forward - Both mechanisms