04830241 – Computer Network Practicum

Cross layer analysis on High-speed Rails Networking

LAB 1: TCP-LTE performance analysis on High-speed Rails

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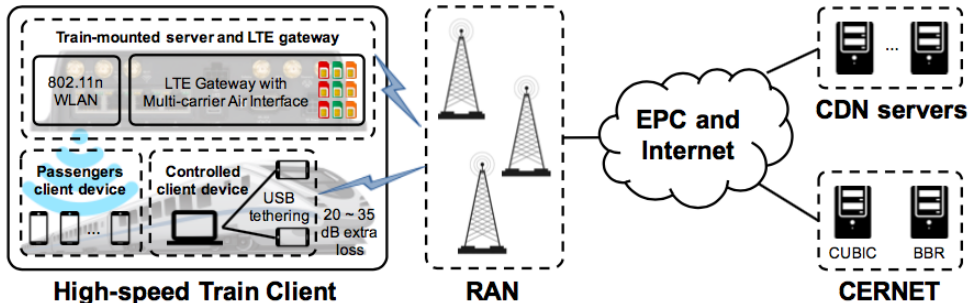
Goal

- **Why do we choose the scenario of High-speed Rails?**
  - High-speed rail (HSR) systems potentially provide a more efficient way of door-to-door transportation than airplane.
  - HSR poses unprecedented challenges in delivering seamless Internet service for on-board passengers from the trackside broadband radio.
- **What will you need to do in this lab?**
  - Learn to use free network protocol analyzer *wireshark* and runtime network information from operational cellular networks analytic tool *mobileinsight.*
  - Analyze TCP-LTE cross layer performance on High-speed Rails over LTE networks.
- **What will you learn from this lab?**
  - Learn how to use common tools to analyze network traces.
  - Learn TCP metrics used to analyze performance.
  - Learn different congestion control algorithm and LTE knowledge.

Lab Overview

- Part I (10pt) – TCP layer analysis
  - Different CCA (congestion control algorithm) in HSR
  - Control experiment data
- Part II (15pt) – Cross layer analysis
  - Analyze impact of LTE
  - Control experiment data
- Part III (optional & 3pt bonus) – Real user data in HSR analysis
  - User traffic pattern
  - Web/Video profile
  - Crowd-sourcing experiment data
- Part IV (optional & 7pt bonus) – Analysis tool chain
  - Take pcap and mobileinsight as input
  - Control experiment data



- Control experiment
  - Run two experiments simultaneously on the two phones
    - Tether two Android phones (Xiaomi 5s) to one laptop via USB 3.0
    - The phones are equipped with SIM cards of same carrier in China
  - Fixed duration of 150 seconds
  - Run tshark on both client and server to collect packet-level TCP traces.
  - Using MobileInsight to collect LTE information including PHY rate and handover events
- Crowd-sourcing experiment
  - Collect TCP flows from on-board passengers, in order to study the passengers' network usage and their flow characteristics "in the wild"
  - Providing free WiFi service via an on-board LTE gateway
  - "Fuxing Hao" trains for the Beijing-Shanghai HSR route
  - At the speed up to 350 km/h

Submission

- **Due: 10/29 23:59**
- **Submit:**
  - **Send report and code (Part III and IV) to jing.wang@pku.edu.cn**
  - **Title: LAB1_Name_StudentID**
- **Grading points:**
  - **Report quality is more important than length**
  - **You are encouraged to analyze from you own perspective, please contact us if you have any thoughts beyond the material in this document**
  - **Interesting and fresh finding is preferred**
  - **Bonus points will not exceed 10pt**
- **Feel free to contact us via wechat**

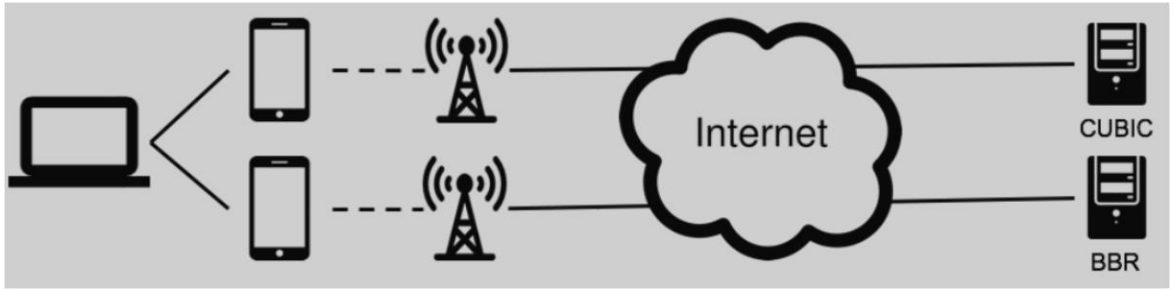
TCP variants premier

- CUBIC – loss-based window control
  - CIMD: More aggressive than Reno, less aggressive than BIC
    - Optimized for high BDP connection
    - Window expanded based on elapsed time from last congestion NOT reception of ACK
  - Back up when "congestion" detection
    - Can be misguided by in-network delay or (local random) packet loss
    - One of the source causing bufferbloat
  - Default TCP for Linux, arguably largest worldwide deployment

- BBR – congestion/model-based rate control
  - BDP modeling: pace the BtlBw rate and control the bytes-in-flight at *RTprop* × *BtlBw*
    - Some algorithm details:
      - *RTprop*: minimum RTT in last 10 seconds
      - *BtlBw*: maximum throughput in last 10 *RTprop*
      - Sending rate in each *RTprop*: *BtlBw* × *cycling pacing_gain (i.e., 1,1,1,1,1,1, 5/4, 3/4 …)*
    - Avoid bufferbloat and ignore local (random) loss
    - Can suffer from a long disconnection
      - E.g., 10 *RTprop* or longer
  - Developed by Google and deployed for Youtube, achieve 4~14% improvement over CUBIC in WAN

Part I – TCP layer analysis

- Data: TCP trace of BBR and CUBIC
  - 150 seconds flow starting at the same time in same LTE network environment
  - Client side: pcap captured by tshark
  - Server side: RTT, throughput, bytes in flight, out of order delay data per seconds; retransmission
- Tool: wireshark
  - A free and open source packet analyzer
  - Used for analysis pcap data
  - https://www.wireshark.org/
- Analysis guide
  - Difference between the two congestion algorithm
  - Special property of TCP on HSR
  - Other interesting discovery



Experiment and Analyze

- Investigate how TCP congestion control (CC) affects the TCP performance and demonstrate your findings. Plot and compare the metrics of CUBIC and BBR. The metrics you analyze could include but not limited to:
  - Throughput, Round trip time, Bytes in flight, Retransmission rate from server side
  - Goodput, Out-of-order Delay from client side
- Figure out what other TCP metrics change when packet loss happens at server side. Does BBR and CUBIC have the same behavior? Why?
- Find special property of TCP on HSR. Compare the Wireshark traces collected in HSR at both static and high speed and find the influence caused by high-speed for BBR and CUBIC respectively. Find the difference with above metrics.

Part II - Cross layer analysis

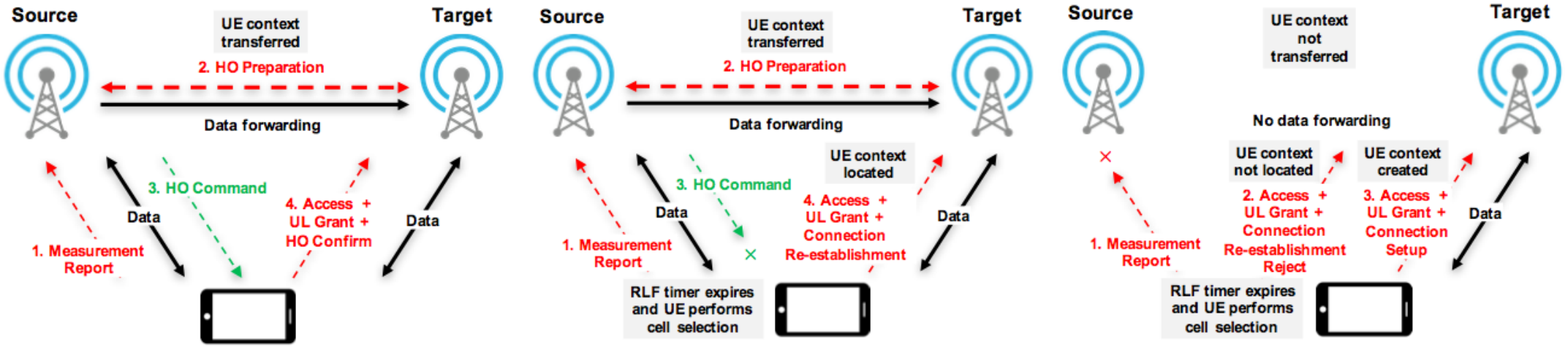
- Additional data: LTE information collected by mobileinsight
- Mobileinsight: offers full-stack, fine-grained, runtime 4G/3G network data
  - Message in xml format
  - Support many cellular message types, see http://www.mobileinsight.net/msg_type.html
  - See http://www.mobileinsight.net for more information
  - Paper – Mobileinsight: extracting and analyzing cellular network information on smartphones https://dl.acm.org/citation.cfm?id=2973751
- Analysis guide:
  - Analyze TCP behavior when important LTE events happen (e.g. handover)
  - Analyze TCP performance in different LTE condition (e.g. signal strength, MCS)
  - Bonus: Discover and analyze the extra penalty caused by LTE

Experiment and Analyze

- Analyze the handover behavior from the mobileinsight trace and how handover impacts TCP performance. Compare the different of BBR and CUBIC. The metrics include but not limited to:
  - Disruption time (no data are transferred and no resource blocks are allocated) caused by handover.
  - TCP throughput degrade percentage caused by handover.
  - RTT variation caused by handover.
- Classify the network condition using signal strength and MCS and analyze TCP performance in different cluster.
  - Classify the network by different MCS (16QAM, 64QAM, QPSK) and see the relationship between signal strength and MCS
  - Classify the network condition by signal strength into good signal (RSRP < 85 dB), just so so signal (85 dB < RSRP < 95 dB), bad signal network (RSRP > 95 dB). Then analyze the TCP performance in different network condition.
- Other findings can be found in:
  - Supporting Mobile VR in LTE Networks: How Close Are We? https://dl.acm.org/citation.cfm?id=3179411
  - Accelerating Mobile Web Loading Using Cellular Link Information https://dl.acm.org/citation.cfm?id=3081367

Some important messages in mobileinsight

- LTE_RLC_DL_AM_All_PDU: RLC layer received packets
- LTE_RLC_UL_AM_All_PDU: RLC layer sending packets and ACK downlink packets
- LTE_PHY_PDSCH_Stat_Indication: mac layer ack/nack and HARQ information
- LTE_PHY_Serv_Cell_Measurement: signal strength(RSRP, RSRQ, RSSI)
- LTE_PHY_PDSCH_Packet: MSC, TBS allocation
- LTE_RRC_OTA_Packet: handover information for different type



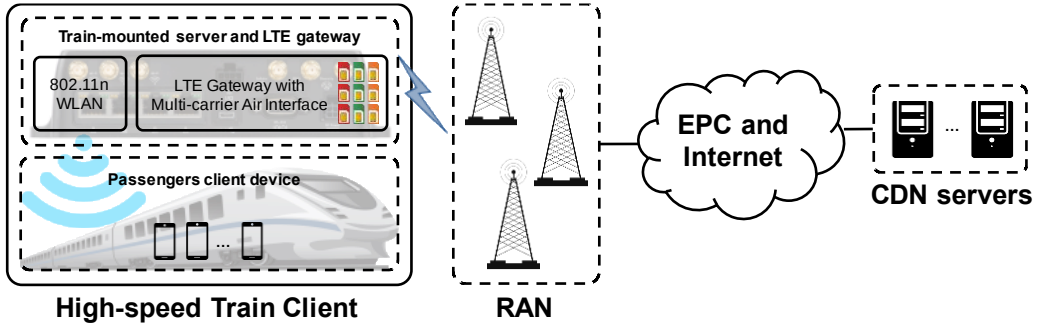
(a) Successful (Type I)

(b) RLF (Type II)

(c) NAS Recovery (Type III)

Part III (optional) - Real user data analysis

- Data: Real user data
  - Pcap collected from HSR LTE gateway using tcpdump
- Analysis Guide:
  - Web content profile:
    - Content-type percentage (overall flow size/ number of flow)
    - Object size distribution of different content-type
    - Object data rate for different content-type
  - HTTP QoE Characterization:
    - Cluster the object by size (0-1KB, 1KB-1MB, 1MB-10MB, >10MB) and analyze object download time distribution
    - Completion Percentage for different cluster of object
    - Time to first byte: the duration from the user or client making an HTTP request to the first byte of the page being received by the client's browser.
  - User Traffic Pattern
    - Device/User Concurrency in week day or weekend: active WiFi users according to different IP addresses per second/minute
    - Flow Concurrency: simultaneously flow according to different IP/port tuple
    - Diurnal Pattern: active flow number at different time in one day (10:30 – 23:00)
  - DNS information: most popular website users visit



Part IV (optional) – Analysis tool chain

- Input: TCP and LTE raw data
- Output: analysis result
- Guide:
  - Combine the analysis experience of previous parts
  - Align the LTE packet with TCP/IP packet
    - Using the packet size as the main information
  - Segment the latency caused by different LTE events
- Reference
  - https://conferences2.sigcomm.org/co-next/2015/img/papers/conext15-final51.pdf