Nash Technologies GmbH

HSDPA Scheduler – Support of QoS

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Agenda

1. Basics on QoS Scheduling
   - Throughput Constraint Function

2. Support of Streaming Traffic
   - System Simulation Tool LUPUS

3. Service Differentiation for I/B Traffic

4. Summary

HSDPA Resource Allocation Problem

- Available Resources in HSDPA
  - Time, Transmit Power, Channelisation Codes

Scheduling Tasks: User Ranking and TFRC Selection

- To which Users Data shall be transmitted in the next TTI of 2ms?
- What Transport Format Resource Combination (TFRC) shall be chosen for the Users of the Ranking List in the next TTI, i.e. what Transport Block Size, Modulation and how many Codes?

- Available Information
  - Channel Quality Information (CQI) for each active UE
  - ACK/NACK feedback for each active UE
  - Queue dynamics (buffer occupancy, buffer flow)
  - QoS parameters (allowed delay & jitter, required data rates)
- Scheduling Requirements
  - Maintenance of QoS and Fairness Constraints
  - Maximization of Network Throughput

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Support of QoS – User Ranking Criterion

- HSDPA scheduler supports QoS by applying specific user/ priority queue ranking:

$$rank \sim \max\{PW \cdot SM\}$$

- Scheduling metric SM can be according any of the well-known rules:
  - E.G. proportional fair metric

$$SM \sim CR(u_i)/thr(u_i)$$

  - $CR(u_i)$ – channel rate of user u_i: impact of RF channel
  - $thr(u_i)$ – average throughput of user u_i: history of data transmission

- Priority weight PW provides throughput constraint function:
  - Increase priority, when $thr < R_{min}$
  - Decrease priority, when $thr \geq R_{max}$
  - Does not affect ranking, when $R_{max} > thr \geq R_{min}$
  - R_{min}, R_{max} – rate bounds

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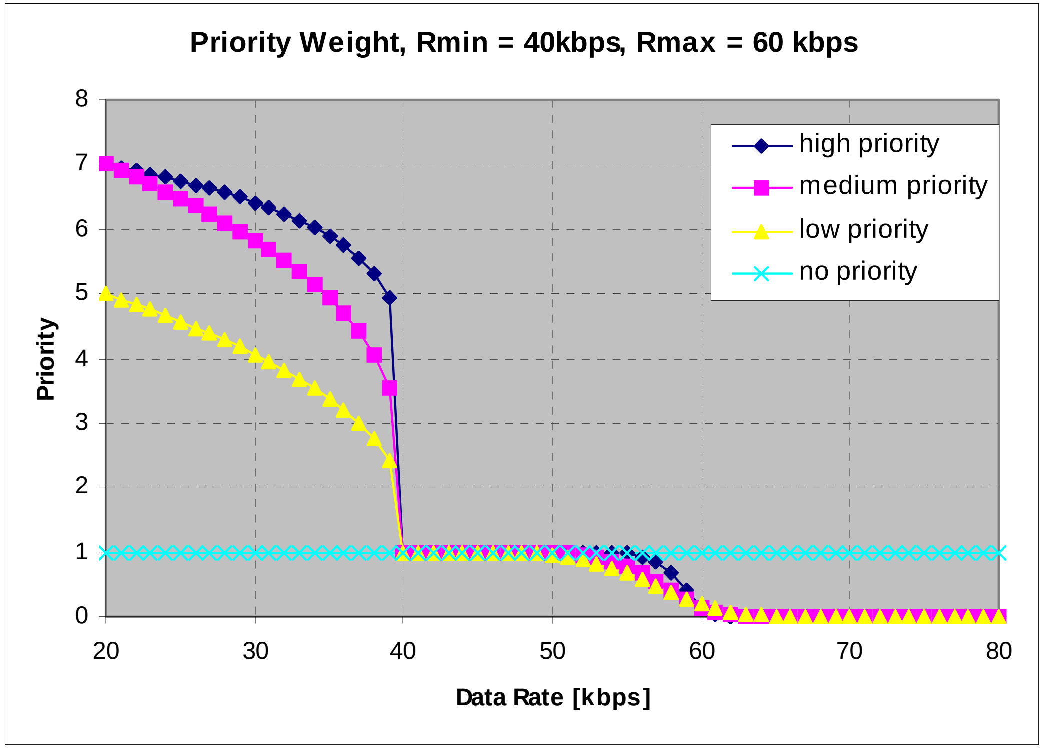
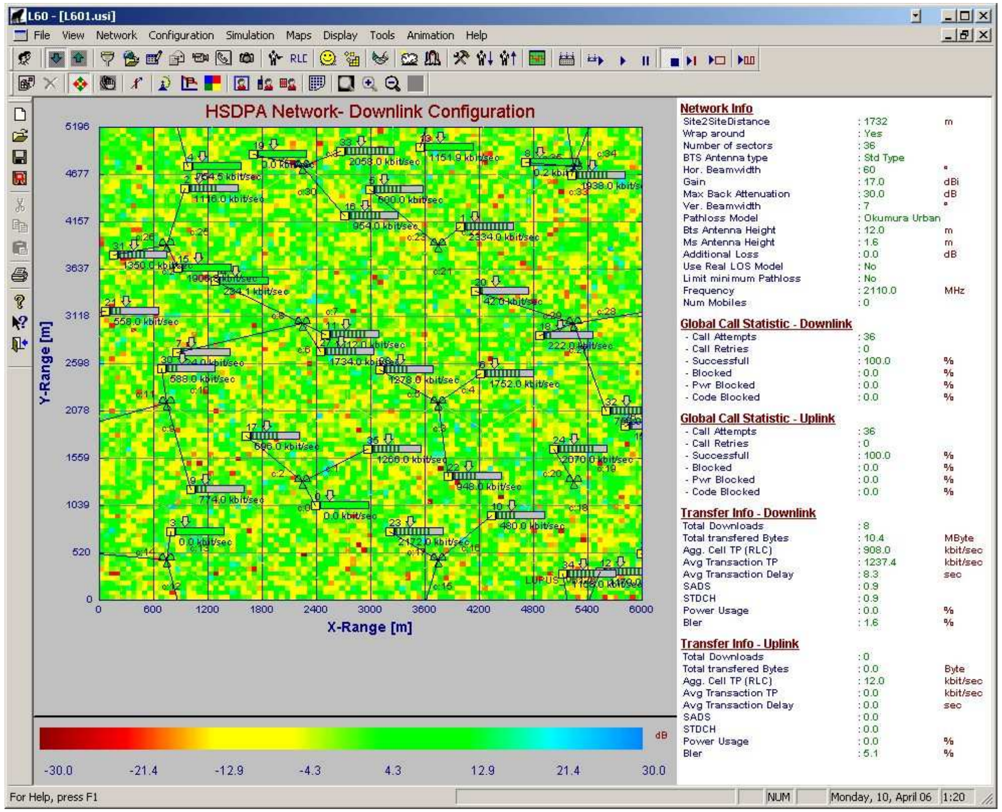
Illustration of User Priority Weighting



- The figures illustrates the weighting of the priority for different shaping settings
- Shaping increases or decreases the priority of a user depending on its measured data rate
  - The priority becomes the higher the more the data rate R falls below R_{min}
  - The priority becomes the smaller the more the data rate R exceeds R_{max}
  - With higher priority setting priority shoots up as soon as $R < R_{min}$

System Level Simulation Tool

- LUPUS ≡ **Lu**cent **P**acket **U**MTS **S**imulator
- System level simulator for UMTS uplink and downlink [2]
  - R99 PS/ CS, HSDPA, HSUPA
  - Protocol stack includes physical layer, MAC-hs, MAC-e/es, MAC-d, RLC, and TCP/UDP/IP
  - Traffic Models for FTP, HTTP, email, video streaming, voice call, video call



- Written in C++
- Runs under Windows (GUI) and Linux/Unix (grid engines)
- Based on SL2 (System Level Simulation Library, developed within Alcatel-Lucent)

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Simulation Assumptions

Network

- 12 sites, 36 cells, cloverleaf, site-to-site distance 1732 m (cell radius 1000m)
- Path loss model: Okumura Urban
- Shadow fading:
  - Standard deviation: 7 dB
  - Correlation length: 50 m
  - Correlation between cells: 0.5
- Channel model: Composite
  - 26% AWGN, 39% PedA3, 18% PedA30, 17% VehA30
- Downlink background noise: -100 dBm
- Power settings: 40W total power, 23% reserved for common channels
  - HS-SCCH power allocation: CQI-based
- Number of HSDPA codes: 4 HS-SCCH/ 12 HS-PDSCH
- Users are randomly placed and move according to their channel model with random direction

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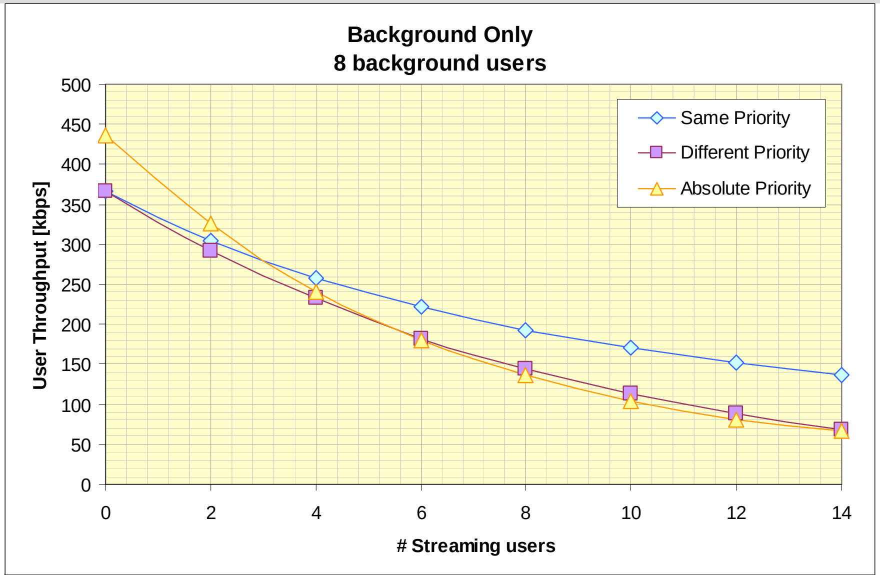
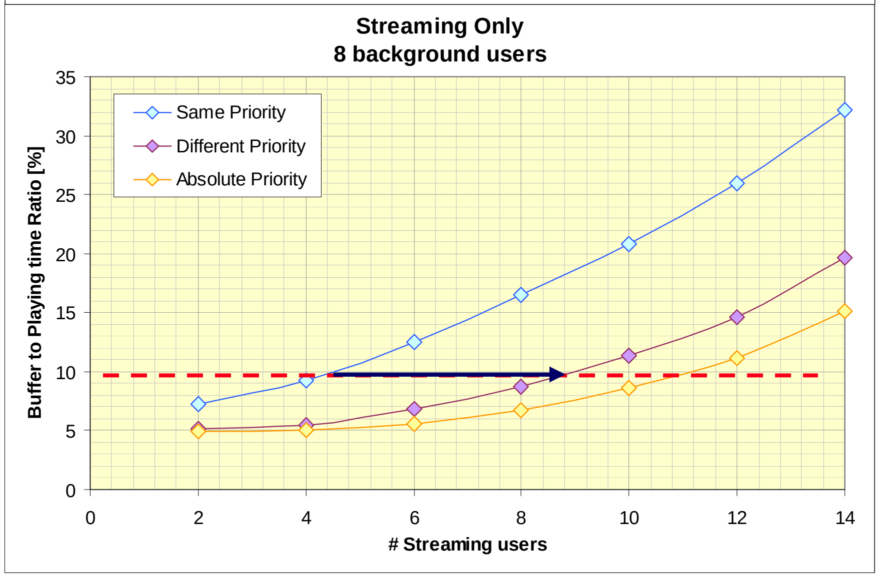
Simulation Scenario – Support of Streaming Service

- Network parameters as before
- Two groups of service
  - High priority streaming service with call duration of 60 sec, thinking time = 30 sec
    - UDP data rate ~110 kbps
  - Background FTP download with average filesize of 2 MBytes, thinking time = 30 sec
- Three different priority schemes have been investigated
  - Same priority: both services get R_{min} = 10 kbps, R_{max} = 400 kbps, medium priority
  - Different priority:
    - streaming service gets R_{min} = 128 kbps, R_{max} = 160 kbps, high priority
    - background service gets R_{min} = 10 kbps, R_{max} = 400 kbps, medium priority
  - Absolute priority: streaming service is always served first
- Streaming traffic has varied from 2 users/cell to 14 users/cell
  - Two scenarios with 4 and 8 background users, respectively

Results – User Perceived quality





- Throughput constraint function provides priority to the streaming user
  - Priority schemes reduce the background user throughput
  - Resources are given to the streaming users, hence improve their performance
- Different priority scheme provides ~100% capacity gain
  - Performance trade-off can be tuned by varying b and k factors
  - Performance is close to the (ideal) absolute priority scheme

Note: cell throughput will be impacted when providing QoS !

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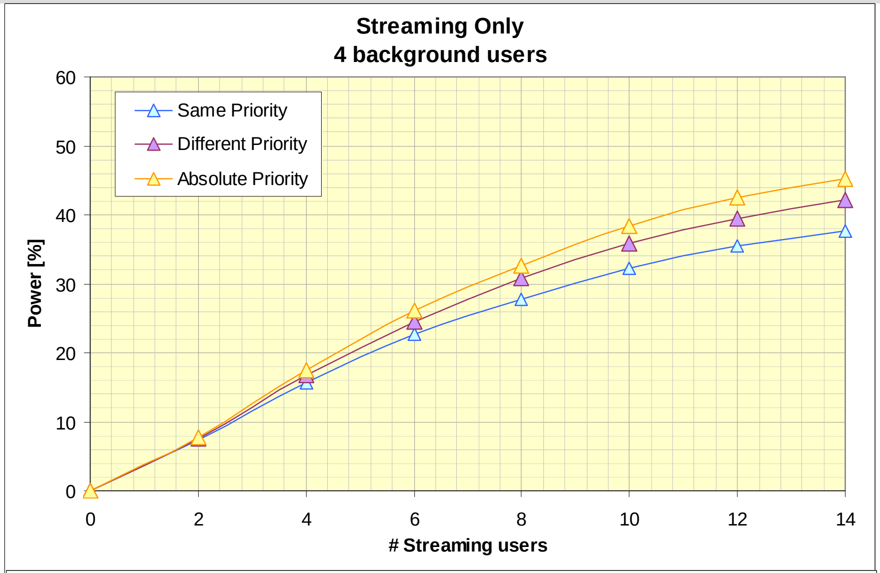
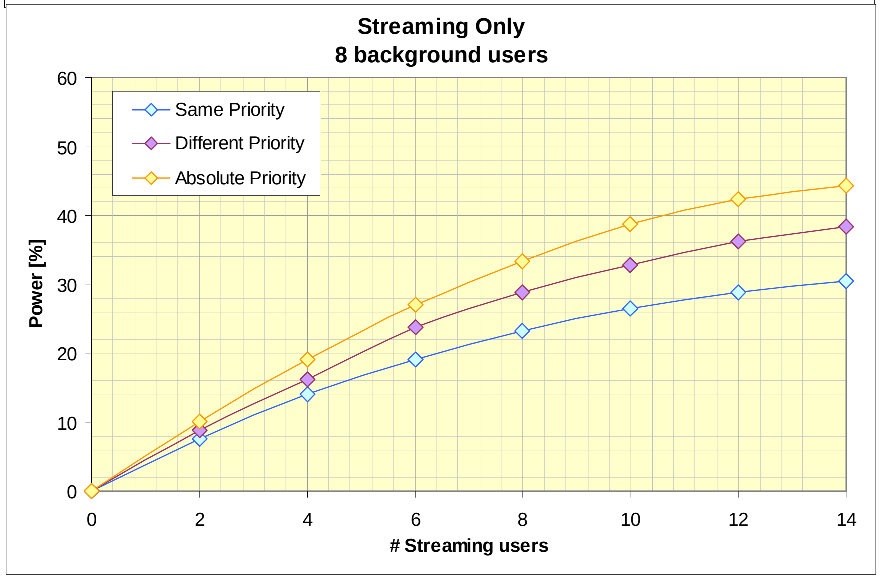
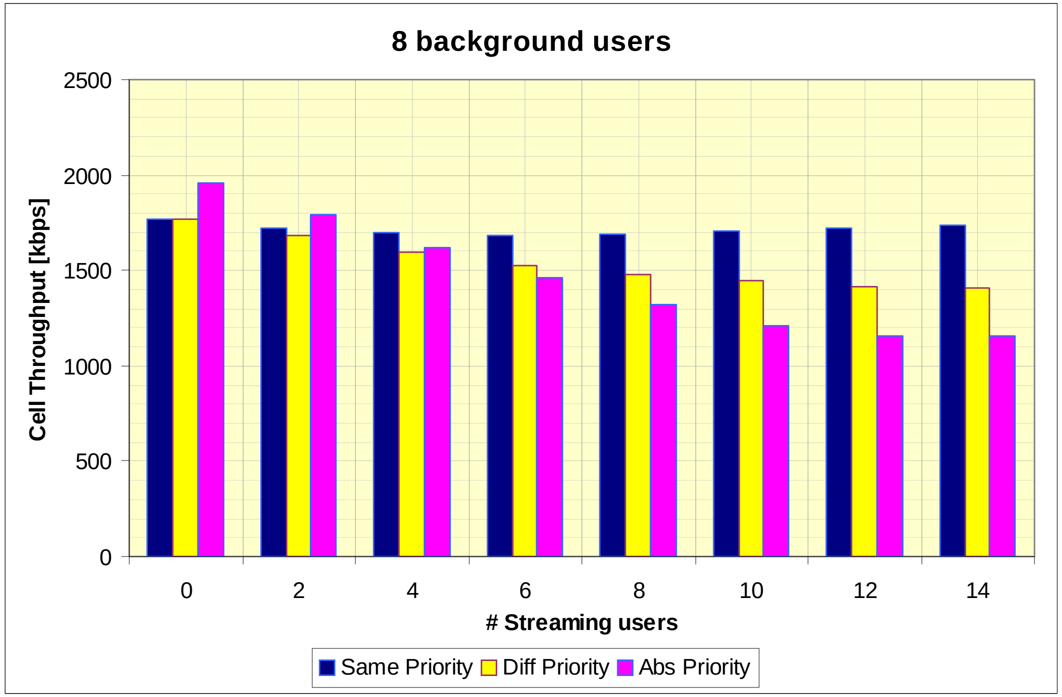
Results – Resource Assignment





- Priority schemes will give more average power resources to the streaming users
  - Users are scheduled more often.
- Depending on the priority scheme impact from background traffic is reduced
  - Power consumption of streaming users becomes more like R.99
  - Admission control can be based on the consumed streaming power

Results – Cell Throughput



- Providing QoS will deviate the ranking from optimal throughput
- Cell throughput will be lower for the priority schemes providing QoS esp. when larger traffic.
  - Different priority scheme provides trade-off between QoS and cell throughput

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Simulation Scenario – Support of Service Differentiation

- Network parameters as before
- Two groups of FTP download services with average filesize of 2 MBytes, thinking time = 30 sec
- Three different priority schemes have been investigated
  - Same priority: both groups get R_{min} = 10 kbps, R_{max} = 400 kbps, medium priority
  - Different priority:
    - High priority service gets R_{min} = 100 kbps, R_{max} = 600 kbps, high priority
    - Background service gets R_{min} = 10 kbps, R_{max} = 400 kbps, medium priority
  - Hard priority: high priority service is scheduled first, when thr < R_{min} = 100 kbps
- High priority traffic has varied from 2 users/cell to 14 users/cell
  - Two scenarios with 4 and 8 background users, respectively

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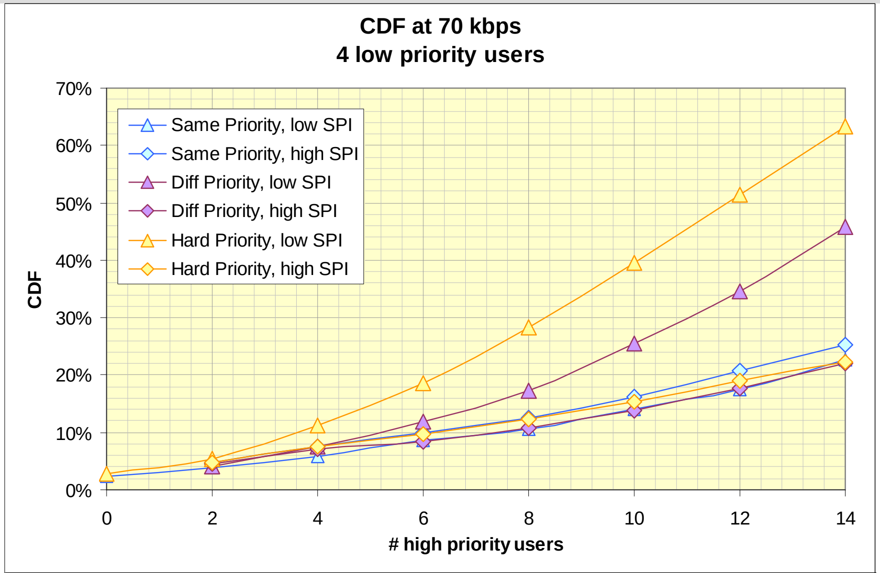
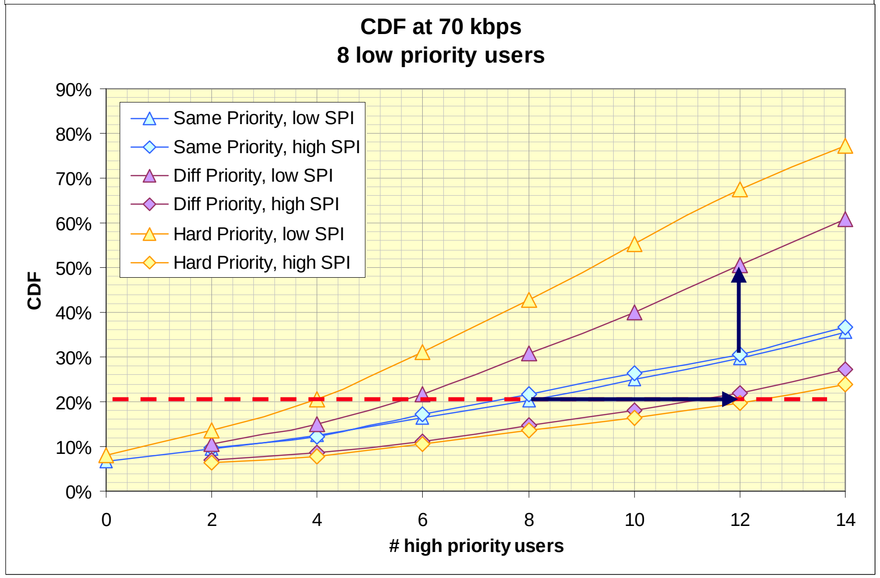
Results – User Throughput





- Constraint function will provide more resources to the high priority service when thr < R_{min}
  - This reduces the amount of high priority users with low throughput.
  - Throughput of low priority users is reduced.
- Different priority scheme serves ~50% more high priority users
  - Performance is close to the (ideal) hard priority scheme
- Depending on the priority scheme impact from background traffic is reduced

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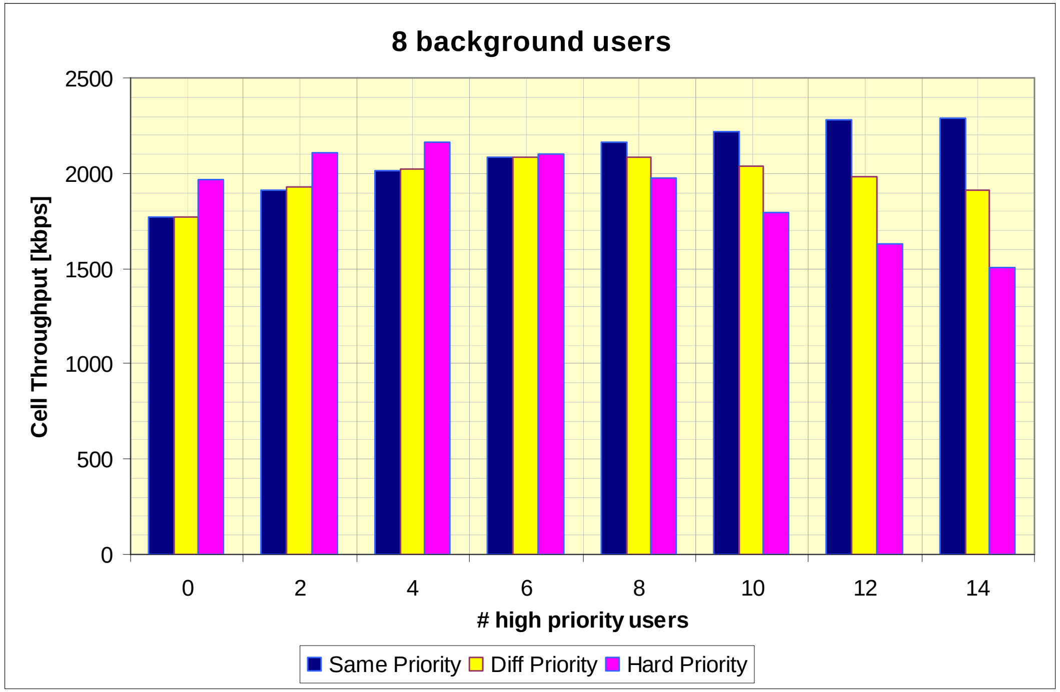
Results – Cell Throughput



- Providing priority will deviate the ranking from optimal throughput
- Cell throughput will be lower for the priority schemes providing R_{min} esp. when larger traffic.
  - Different priority scheme provides trade-off between service differentiation and cell throughput

Summary

- Throughput constraint function can be efficiently applied on the user ranking function for high volume traffic such as streaming, FTP or HTTP
  - With special parameter settings the scheduler can be adjusted to different scheduling modes.
  - With dedicated parameter set, the scheduler can keep the user perceived quality for the streaming service or can provide priority for interactive/ background service.
  - User perceived performance is close to the (ideal) absolute/ hard priority scheme.
- Providing service differentiation with R_{min} will always reduce the cell throughput
  - Constraint function will deviate user ranking from throughput optimal metric
  - Different priority scheme provides adjustable trade-off between differentiation and cell throughput.
- Constraint function becomes inefficient for low volume traffic such as VoIP
  - Here, absolute priority with simple FIFO scheme looks promising [6]

References

[1] A. Das, N. Gopalakrishnan, T. Hu, F. Khan, A. Rudrapatna, A. Sampath, H.-J. Su, S. Tatesh, and W. Zhang: "Evolution of UMTS Toward High-Speed Downlink Packet Access," Bell Labs Technical Journal, vol. 7, no. 3, 2003, pp. 47–68

[2] S. Brueck, E. Jugl, H. Kettschau, M. Link, J. Mueckenheim, and A. Zaporozhets: "Radio Resource Management in HSDPA and HSUPA," Bell Labs Technical Journal, vol. 11, no. 4, 2007, pp. 151–167

[3] M. Andrews, K. Kumaran, K. Ramanan, A. Stolyar, P. Whiting: "Providing Quality of Service over a Shared Wireless Link," IEEE Communications Magazine, Feb. 2001, pp. 150–154

[4] M. Lundevall, B. Olin, J. Olsson, N. Wiberg, S. Wänstedt, J. Eriksson, and F. Eng: "Streaming Applications over HSDPA in Mixed Service Scenarios," Proc. IEEE VTC 2004 Fall, Sep. 2004, pp. 841–845

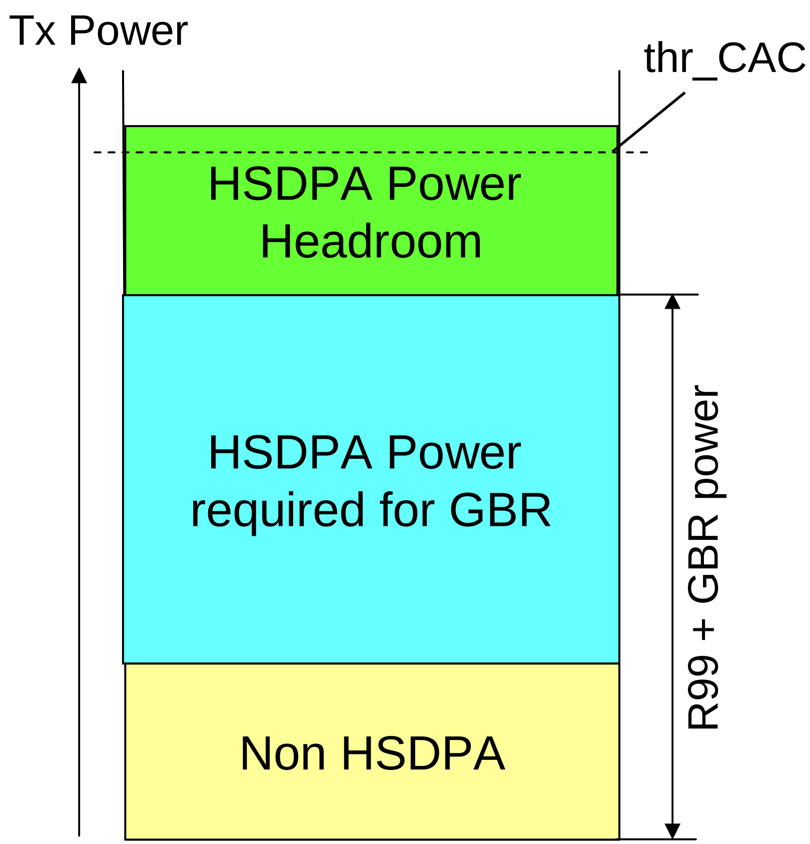
[5] J. Mueckenheim, M. Casado-Fernandez, E. Jugl: "On the Support of Uplink Streaming Service over E-DCH," Proc. ITG Mobilfunktagung, May 2008, pp. 7–12

[6] Q. Bi, P.-C. Chen, S. Vitebsky, Y. Yang, Q. Zhang: "Performance of 1x EV-do revision a systems with best effort data and voice over IP," Bell Labs Technical Journal, vol. 11, no. 4, 2007, pp. 217–235

[7] J. Mueckenheim, S. Brueck, M. Schacht: "A Model for HSDPA Cell Load and its Applications," Proc. IEE 3G2005, Nov. 2005, pp. 401-405

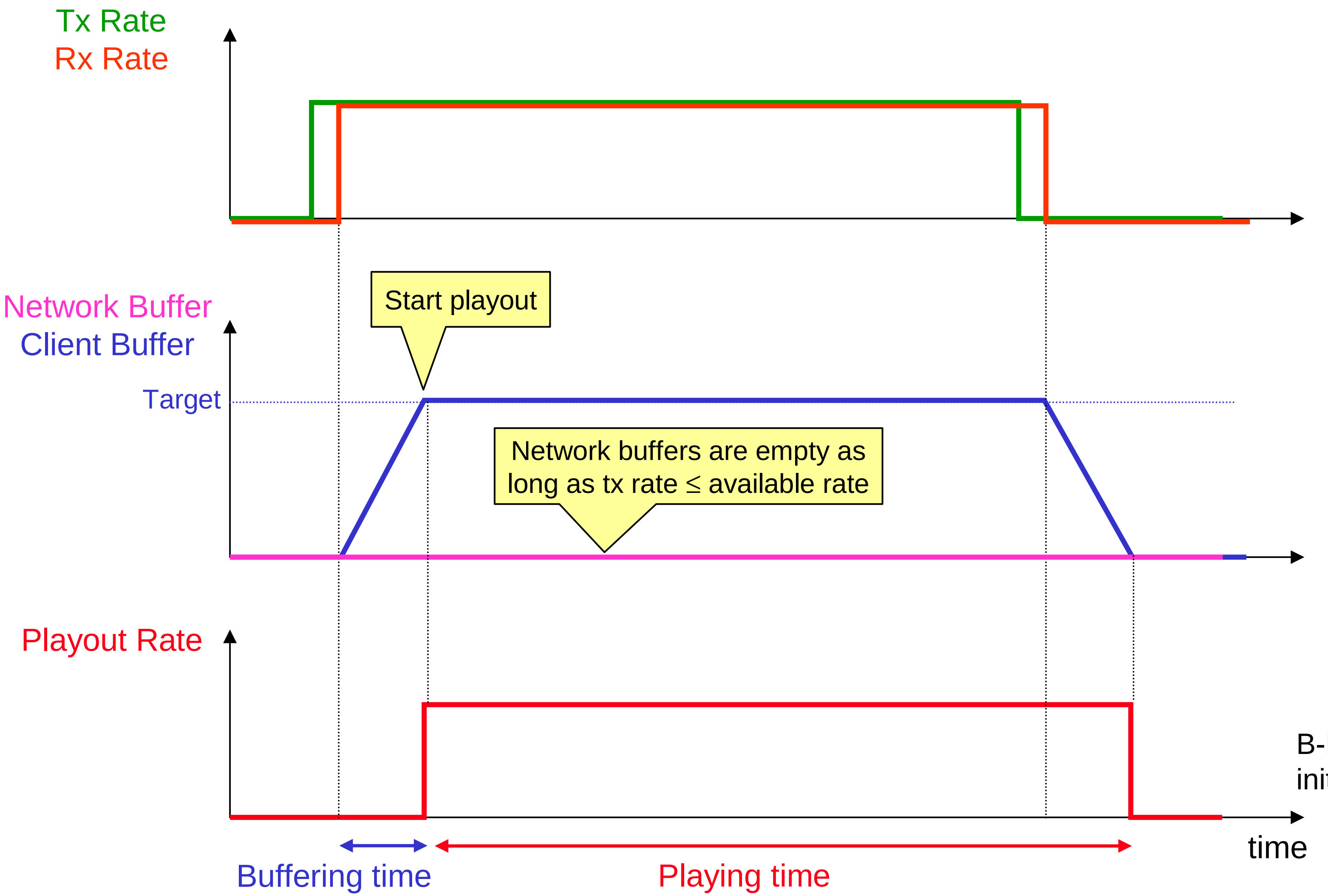
Backup Slides

Admission Control for GBR Streaming Services [7]



- HSDPA scheduler measures the HSDPA power required to support GBR traffic in the past
- NodeB reports this power to RNC
  - "*HS-DSCH Required Power*" measurement report
- RNC performs admission control as for DCH (e.g. GBR = 64k):
  - If R99 + GBR power < thr_CAC, then admit request for new GBR service
  - If R99 + GBR power ≥ thr_CAC, then deny request for new GBR service
- thr_CAC to provide some power headroom
  - Overload protection
  - For I/B service over HSDPA

Streaming App – Perfect Transfer [5]



B-P ratio > 0 due to initial buffering !

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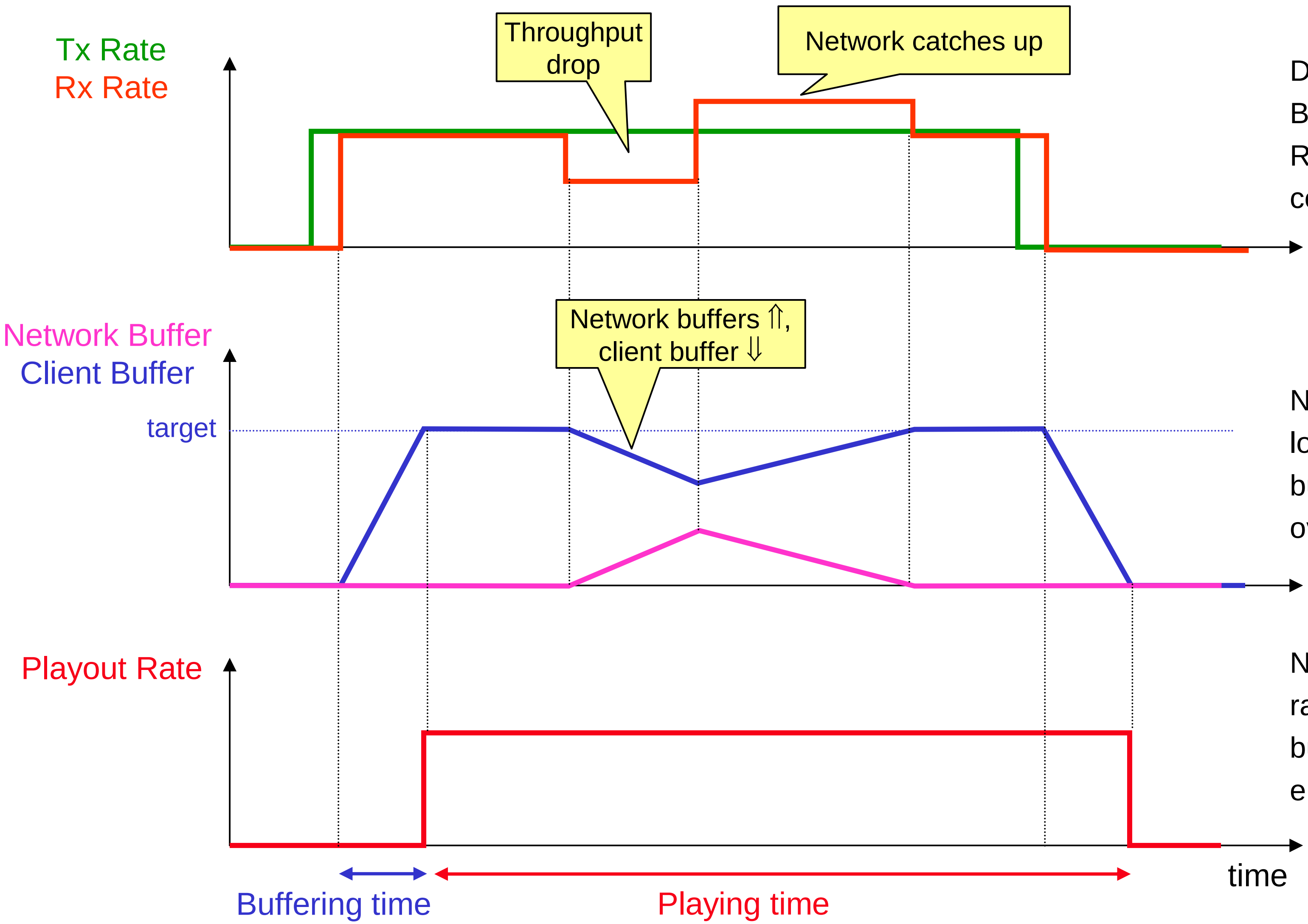
Streaming App – Short Throughput Drop



Drop e.g. due to high BLER, cell change, RF or load conditions etc.

No packet loss as long as network buffers do not overflow.

No impact on B-P ratio as long as client buffer does not run empty.

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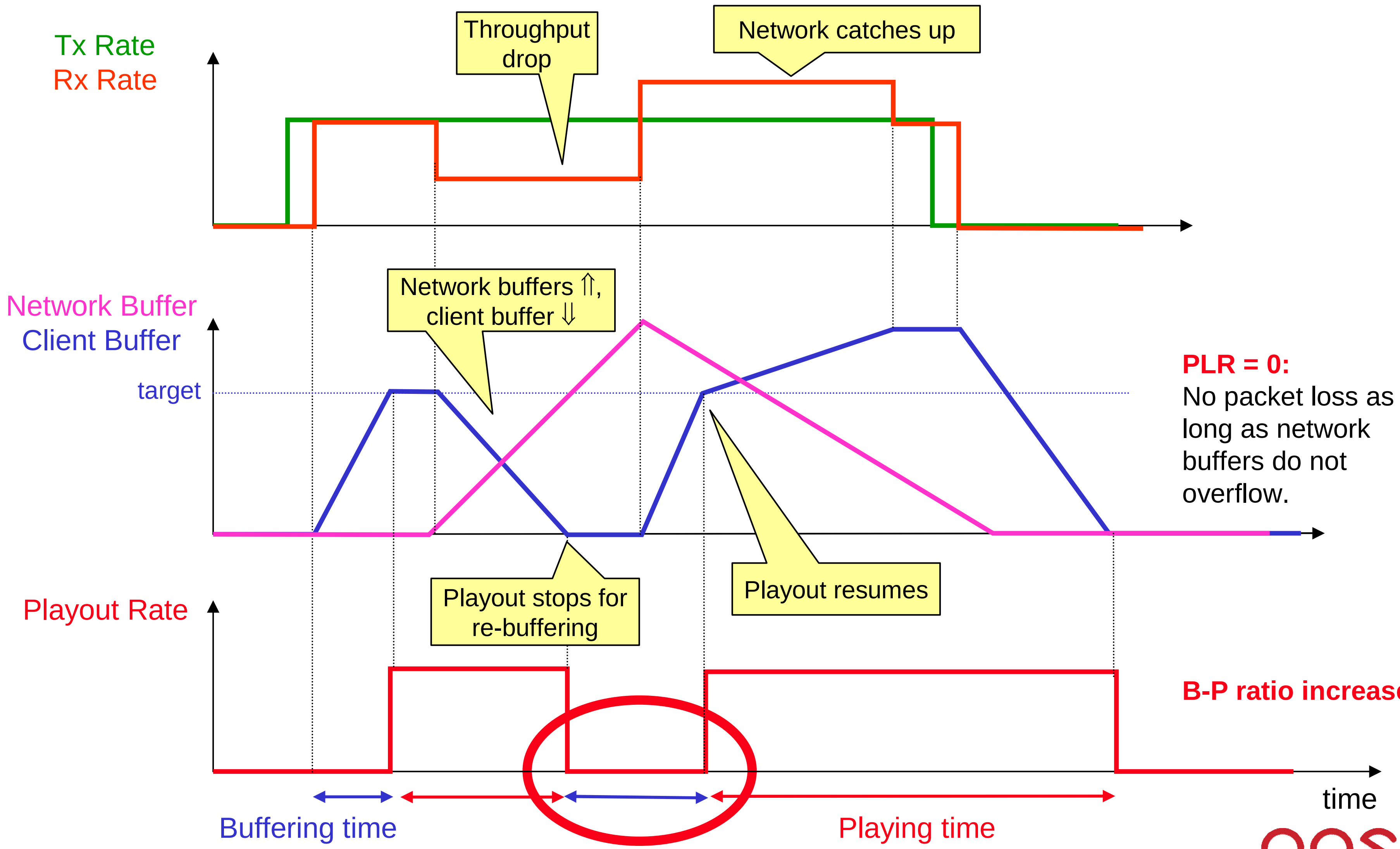
Streaming App – Sustained TP Drop



PLR = 0:
No packet loss as long as network buffers do not overflow.

B-P ratio increased

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