QoS-driven and Fair Downlink Scheduling for Video Streaming over LTE Networks with Deadline and Hard Hand-off

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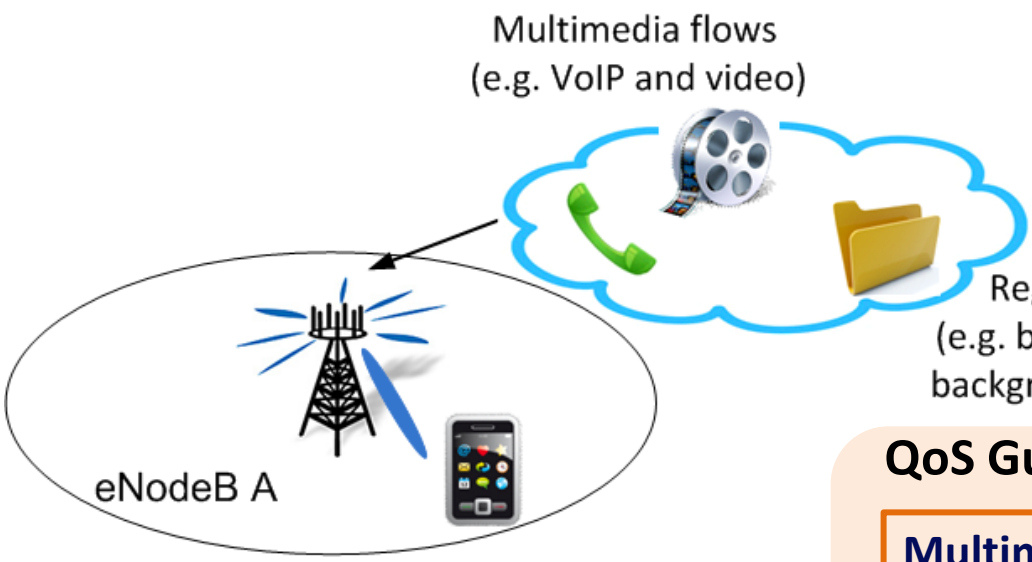
Outline

- Background
  - LTE and New Technical Barriers to Overcome
  - Challenges in LTE Downlink Scheduling Design
- Proposed Downlink Scheduling Scheme
  - Major Contributions – Innovative Designs for Hybrid Traffics and Highly Mobile Users
  - Transmission Deadline Control (TDC) Module
  - Hand-off Control (HOC) Module
  - Simulation Results and Analysis
- Conclusions

❑ LTE and New Technical Barriers to Overcome



LTE

- Fully IP and packet-based
- Support hybrid traffic
- Support high speed users

High Mobility Support

- Minimize service interruption for mobile users in handoff

QoS Guarantee for Multimedia Flows

- Multimedia flows is bandwidth hungry
- Delay sensitive multimedia flows

Fairness for Regular Flows

- Guarantee the normal service to regular data flows

❑ Challenges in LTE Downlink Scheduling Design

LTE

- Fully IP and packet-based
- High Mobility Support

⟷

Wireless LAN

- Fully IP and packet-based
- Low Mobility Support

↓

Packet scheduler need to assure satisfactory service when a mobile user is crossing the "border" with high moving speed.

↓

Soft HO

The radio link to the source cell is broken after a reliable connection to the target cell has been established.

Hard HO (LTE)

The radio link to the source cell is broken before a reliable connection to the target cell has been established.

↓

Interruption Time

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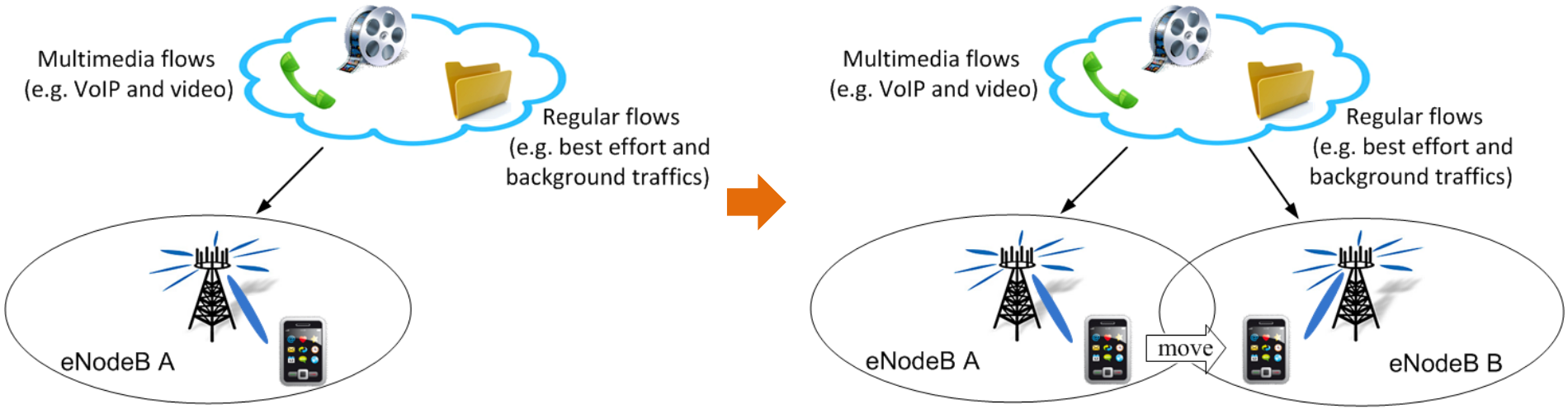
- **Regular Flows → Non-delay-sensitive → Not affected**
- **Multimedia Flows → delay-sensitive → Service degradation**

❑ Challenges in LTE Downlink Scheduling Design



Single cell

Multiple cells

QoS to Multimedia Flows

Delay constraints of multimedia flows

QoS to Multimedia Flows

Delay constraints of multimedia flows

+

Service Interruption caused by hard HO

❑ Challenges in LTE Downlink Scheduling Design

LTE

*** Support hybrid traffic with service guarantee**

*** Handle hard HO with minimized interruption**

Requirements for LTE Downlink Scheduler

QoS to Multimedia Flows

1. Satisfy delay constraints for multimedia flows

2. Reduce service degradation caused by hard HO

Fairness to Regular Flows

Guarantee the normal service to regular flows

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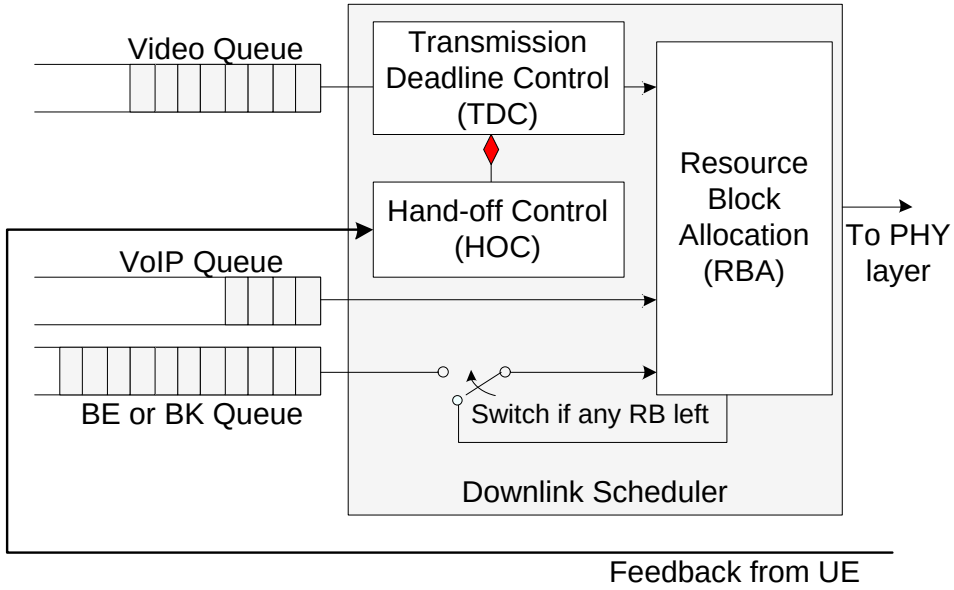
Proposed Downlink Scheduling Scheme

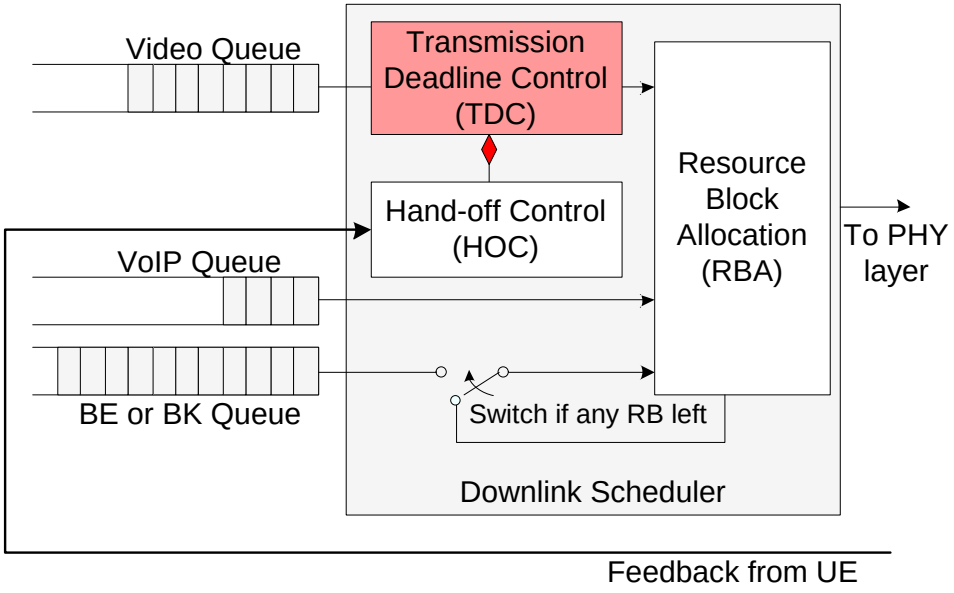


The Major Contributions

The innovative design of the scheduler through two QoS driven operational control modules:

TDC module and HOC module.

TDC Module



QoS (video flow) ⟷ Trade-off ⟷ Fairness (regular flow)

Sort out the mess

Innovation in TDC Module

Design a composite QoS metrics considering both video deadlines and fairness

Design Implementation

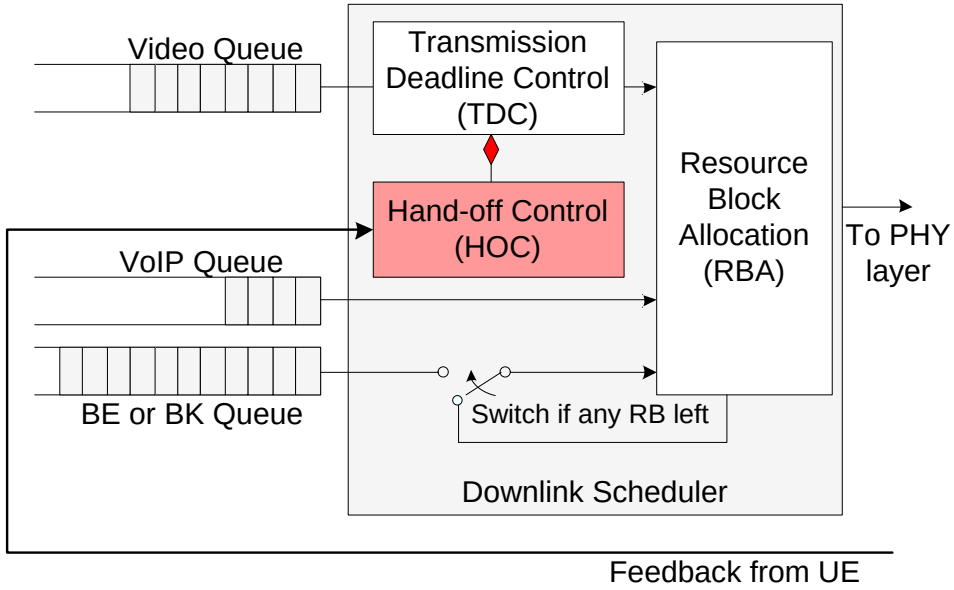
- **A video packet is scheduled only if there is pressing need for transmission (i.e., if not transmitted, the packet will miss the deadline).**
- **When there is no pressing need for multimedia transmission, regular flows are scheduled.**

Satisfy delay constraints of multimedia flows

Guarantee the normal service to regular flows

HOC Module

We propose the *novel* concept of the *alert zone.*



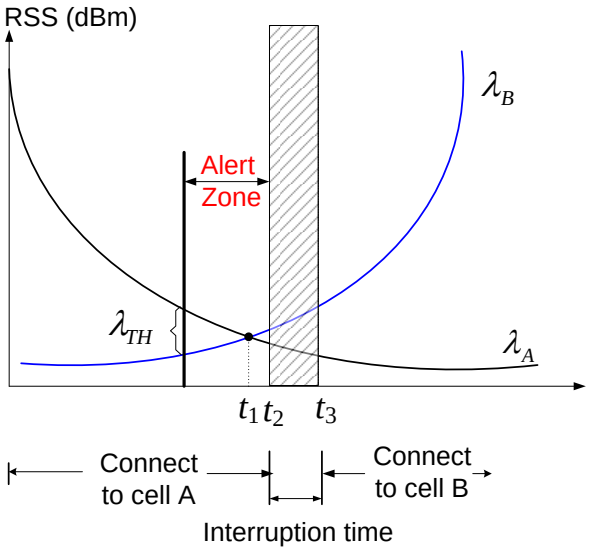


Fig.2. HO decision making.

Design Implementation

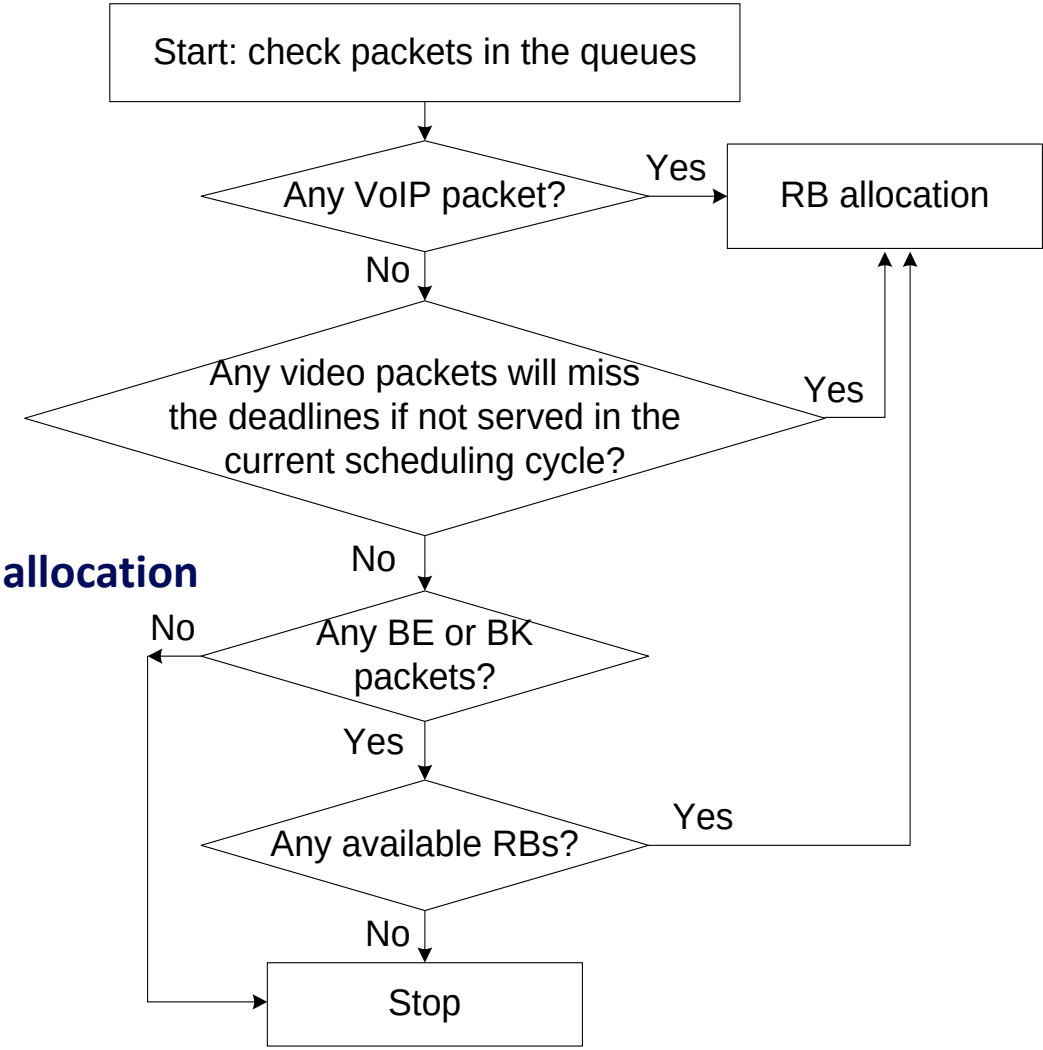
1. **HOC detects whether there is any video consumer who is in the alert zone;**
2. **If so, then HOC triggers TDC to continually update the transmission deadlines of video packets to make sure their transmissions.**

The video consumer in the alert zone is continually served by the eNodeB before HO, thus he may buffer enough data resulting in a small probability of playback buffer underflow.

Reduce service degradation caused by hard HO

Procedures for the Proposed Algorithm

- **In the beginning of each scheduling cycle, the scheduler first checks the packets in the queues;**
- **Discover VoIP packet → RB allocation**
- **Discover video packet**
  - **Check transmission deadline;**
  - **If the packet will expire if not served in the current scheduling cycle → RB allocation**
- **Discover BE or BK packet**
  - **Check the availability of RB;**
  - **Available → RB allocation**



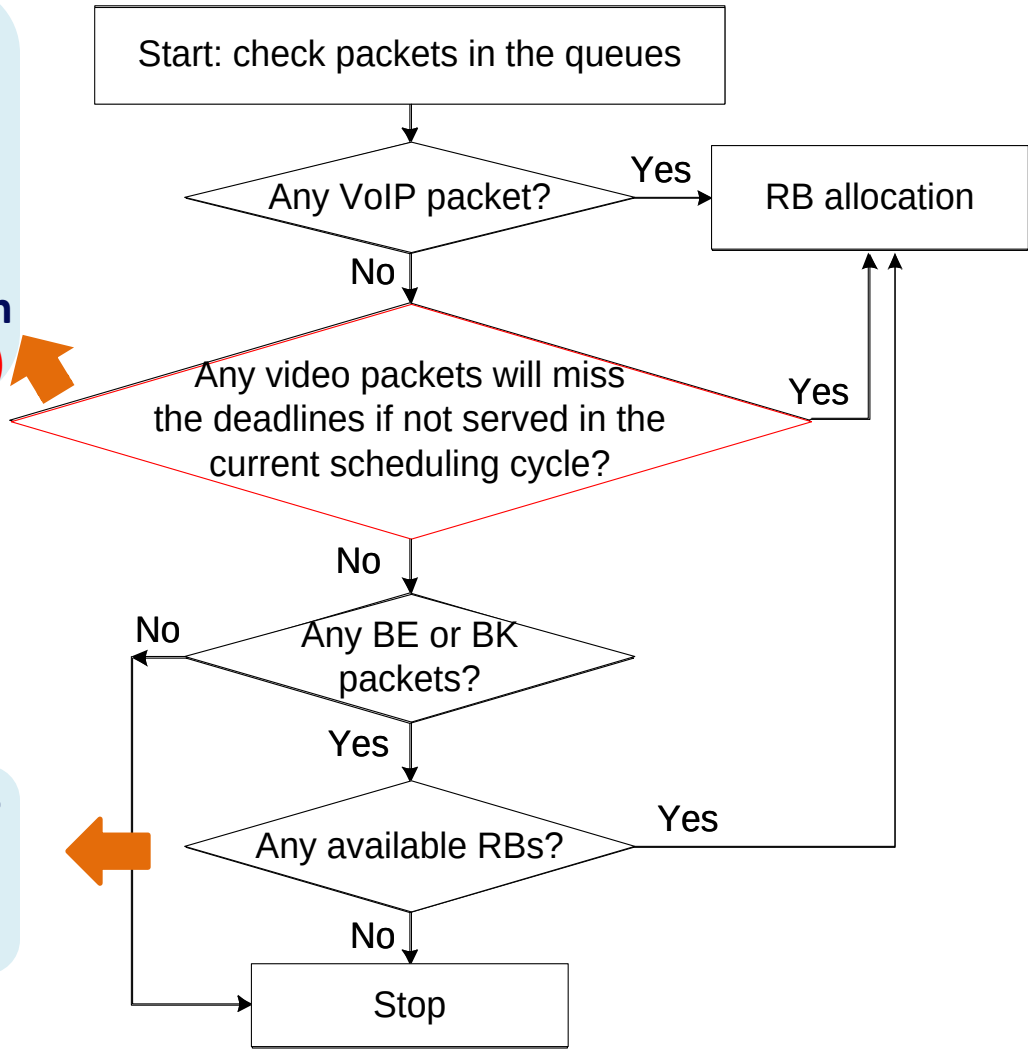
❑ Procedures for the Proposed Algorithm

Controlled by TDC and HOC Modules

TDC: - Compute the transmission deadlines (QoS) according to the delay constraints;
- Update the transmission deadlines.

HOC: Trigger TDC to update the transmission deadline.(Reduce service interruption)

When there is no pressing need for multimedia transmission, regular flows are scheduled. (Fairness)



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❑ Simulation Results

- **Comparison Schedulers**

➢ Proportional Fair (PF) [1]: aiming to maximize the total throughput, as well as to guarantee fairness among different types of users.

No consideration on delay constraints of multimedia flows

➢ Exponential Proportional Fair(EXP-PF) [2]: introducing a priority parameter to the PF scheduler.

Only offering an average packet delivery delay, rather than any strict guarantees on packet delay

- **Simulator — LTE-Sim** [3]

❑ Simulation Results

- Percentage of Expired Video Packets

Percentage	10 users, 30km/h	20 users, 30km/h	10 users, 120km/h	20 users, 120km/h
PF	0.89%	30.46%	0.606%	40.52%
EXP-PF	0.069%	11.48%	0.074%	33.54%
Proposed	0.021%	2.81%	0.035%	10.34%

- Average Percentage of Service for Regular Flows

PF	EXP-PF	Proposed
58.28%	57.88%	55.09%

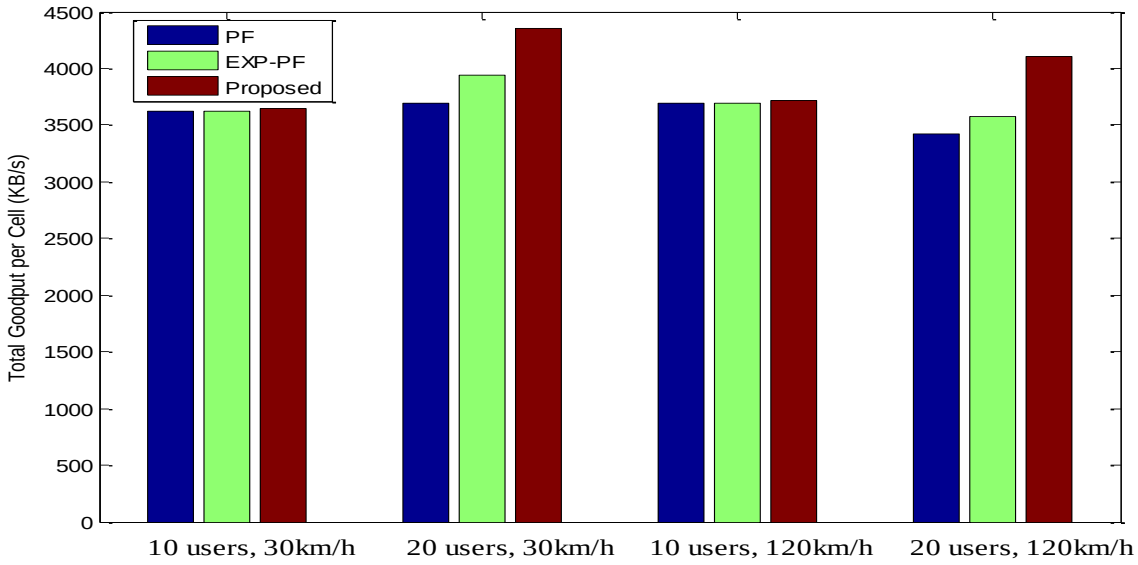
1. **The proposed scheduling algorithm outperforms PF and EXP-PF algorithms under all the simulation scenarios; (QoS Guaranteed)**
2. **The proposed scheduler uses 55.09% service time for regular flows, which is only 3.28% lower than the PF algorithm. (Fairness)**

❑ Simulation Results

- Average Goodput for Multimedia Flows

Goodput (KB/s)	10 users, 30km/h	20 users, 30km/h	10 users, 120km/h	20 users, 120km/h
PF	1310.28	1705.06	1297.35	1469.82
EXP-PF	1320.19	1959.93	1303.91	1627.71
Proposed	1335.57	2357.66	1328.40	2178.48

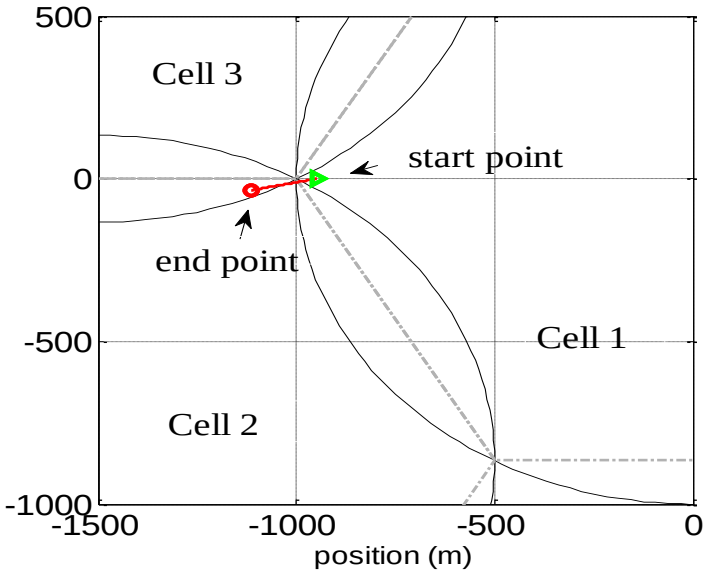
- Total Goodput



The proposed scheduler has better performance than PF and EXP-PF schedulers on both average multimedia goodput and total goodput.

❑ Simulation Results

- QoS of Video Streaming in HO Procedure



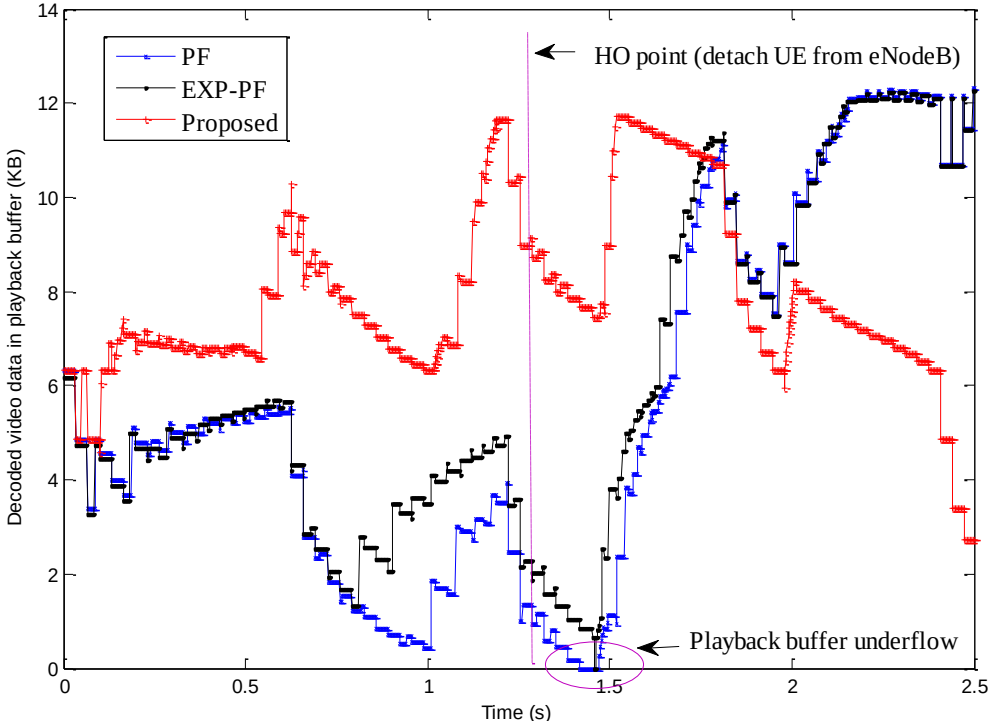


Fig.3 Video data in the playback buffer of UE

1. **A single user experiences HO;**
2. **PF and EXP-PF schedulers suffer from service interruption;**
3. **The proposed scheduler can guarantee QoS even during HO procedure .**

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❑ Conclusions

- We have developed a QoS-driven downlink scheduling scheme aiming at video streaming over LTE systems with novel composite QoS metrics considerations in video deadlines, fairness, and HO service degradation.

- The major contribution lies in the innovative design of both TDC and HOC modules. The proposed novel design is able to achieve:

  - QoS guaranteed scheduling to multimedia consumers;
  - Fairness to regular data users;
  - Continuous service to video consumers even during hard HO procedure.

Thank you!

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[2] J. H. Rhee, J. M. Holtzman, and D. K. Kim, "scheduling of real/non-real time services: adaptive EXP/PF algorithm," in *Proc. IEEE 57th Semiannual Veh. Technol. Conf*., 2003, vol. 1, pp. 462-466.

[3] G. Piro, L. A. Grieco, G. Boggia, F. Capozzi, and P. Camarda, "Simulating LTE cellular systems: an open-source framework," *IEEE Trans. Veh. Technol*, vol. 60, pp. 498-513, Feb. 2011.