ITU KALEIDOSCOPE ONLINE 2021

6-10 December 2021

Towards a robust new radio compatible with XR

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Session 1: Enabling future wireless communication systems

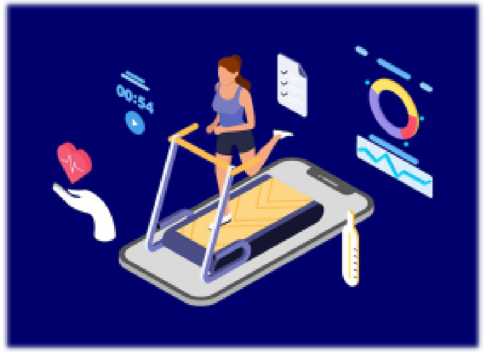
Paper S1.2: Towards a robust new radio compatible with XR

Outline

- Background of eXtended Reality
- Traffic models for XR
  - Single-stream model
    - Data fitting approaches
    - Data fitting results
  - Multi-stream model
- Proposed priority-based adaptive preemptive scheduler
  - Challenges posed by XR to Rel-16 NR
  - Elaboration of our proposed scheduler
  - Simulation results
- Further study and improvements

Background of eXtended Reality

- **Business prospects:** The market margin for XR service is expected to largely exceed US$180 million by the end of 2021 considering meta universe hype.
- **Challenge:** New radio air interface improvement from the 4 dimensions (**Capacity,** power, coverage, mobility).
- **Industrial vision:** Rel-17 RAN1 SI, Rel-18 WI, SA4 (S4aV200575), SA2 (S2-2102370)

XR	Virtual Reality	Augment Reality	Cloud Gaming
Application	 • VR1: Viewpoint dependant streams • VR2: Split/View point rendering …	 • AR1: XR distributed computing • AR2: XR Conversational …	 • Cloud game …

Traffic models for XR

- Parameters for truncated Gaussian distribution
  - Mean packet size
  - Maximum packet size
  - Minimum packet size
  - Packet size deviation

  (Note: STD/Max/Min are determined from the ratio w.r.t Mean)
- P-trace provided by SA
  - The j-th packet sizes calculation: $N_j = \sum_{i=1}^{x} n_{j\_i}$
  - The packet sizes sample: $\{N_1, N_2, \cdots\}$

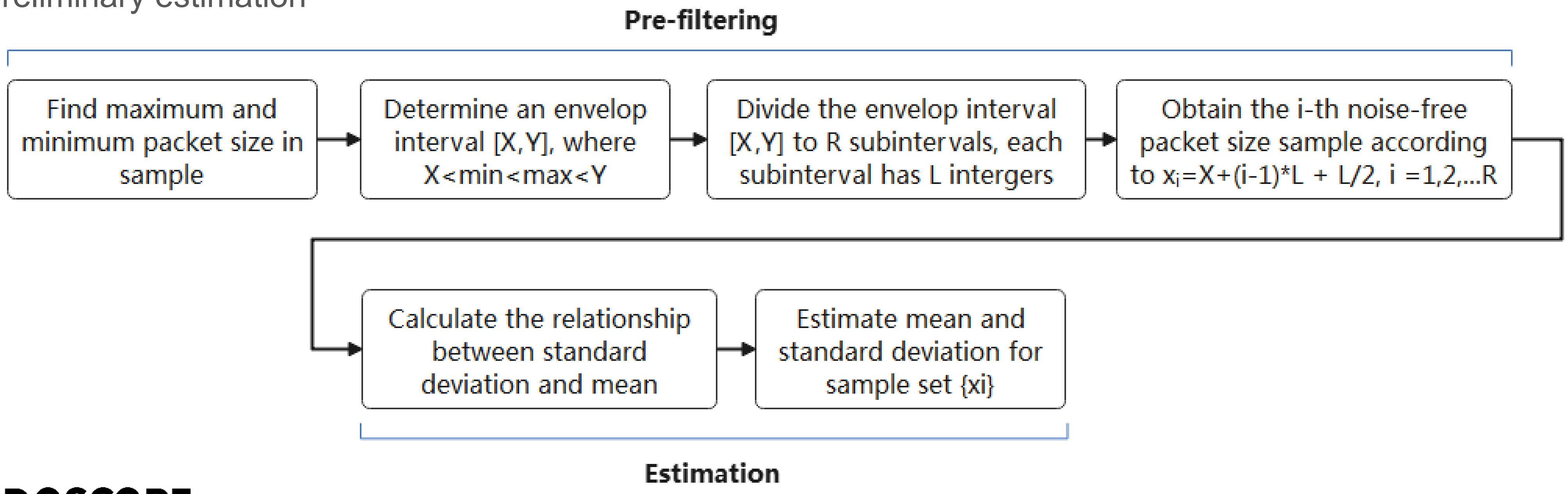
Size	...	Rendering time	...	importance	...
n_{1_1}	...	0	...	8	...
...		...		...	
n_{1_x}		0		8	
n_{2_1}	...	16667	...	7	...
...		...		...	

The IP packets in one frame **(nominal packets in Rel-17)**

Data Resource: http://dash.akamaized.net/WAVE/3GPP/XRTraffic/Traces/Candidate/VR2/

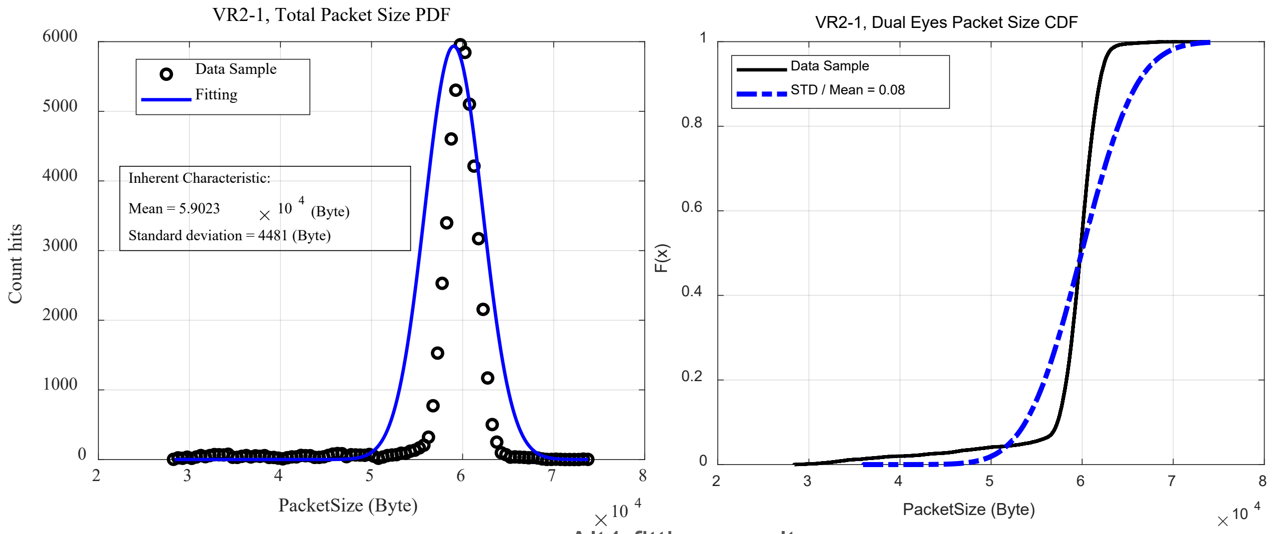
Data fitting approaches

- Alt 1: Directly use inherent feature of data samples
  - Mean packet size: $N_{mean} = \sum_{i=1}^{M} N_i \Big/ M$
  - Packet size standard deviation: $N_{STD} = \sqrt{\frac{1}{M}\sum_{i=1}^{M}(N_i - N_{mean})^2}$
  - Relationship between STD and mean: N_{STD} / N_{mean}
- Alt 2: Extract the inherent noise-free statistical characteristics
  - Pre-filtering
  - Preliminary estimation

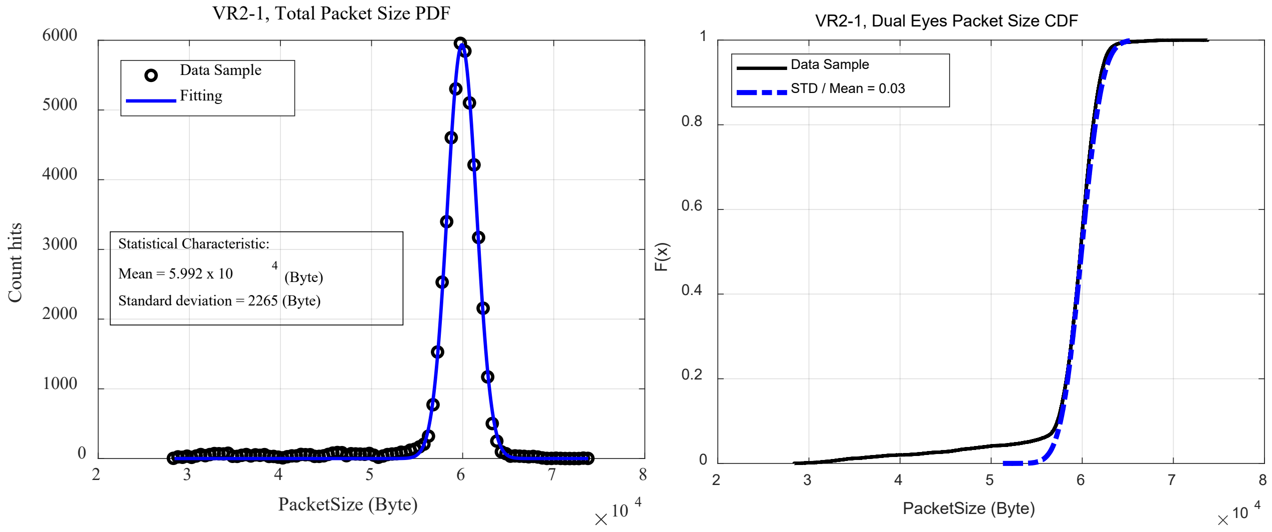


Data fitting results

- The sample noise causes some deviation in the mean and variance of the fitted data with Alt 1.
- The traffic derived with Alt2 is in much closer vicinity to actual sample distribution.
- Observations:
  - Packet size deviation = 3% * Mean packet size
  - Maximum packet size = 109% * Mean packet size (3 sigma principle)
  - Minimum packet size = 91% * Mean packet size (3 sigma principle)



Alt1 fitting results

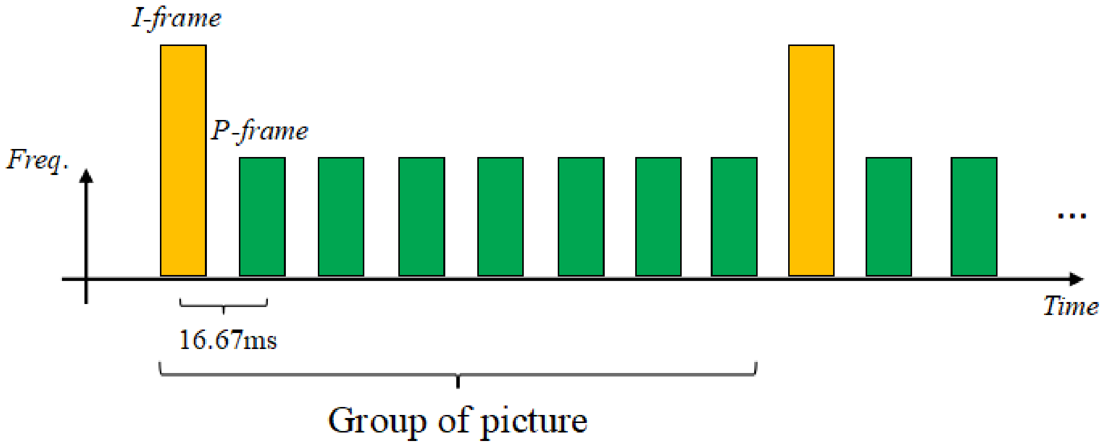


Alt2 fitting results

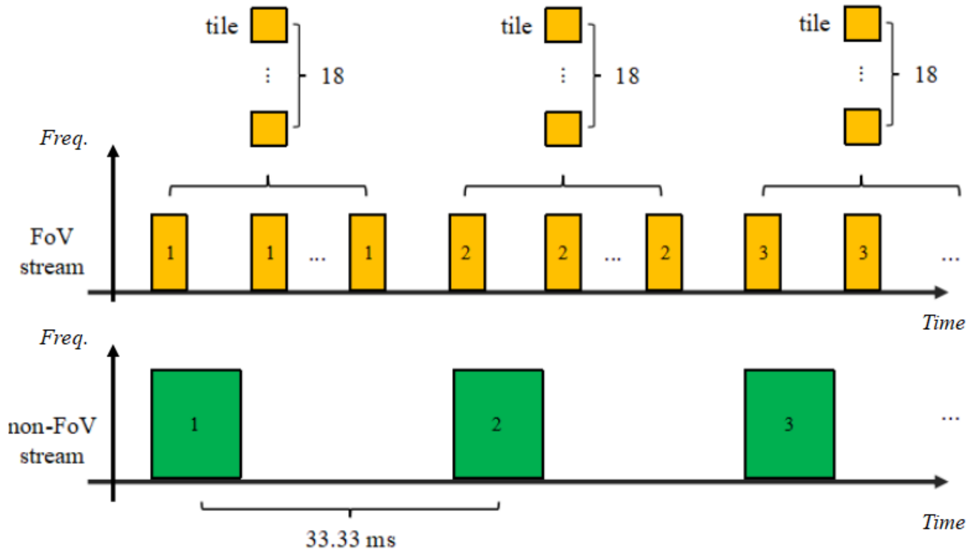
Data Resource: http://dash.akamaized.net/WAVE/3GPP/XRTraffic/Traces/Candidate/VR2/

Multi-stream model

- An XR service typically consists of multiple flows with different Quality of Service (QoS) requirements ranging differently in terms of **data rate/periodicity/reliability/latency** etc.
- Typical multi-stream model
  - **Audio stream and video-stream**
- Typical multi-stream model for XR video
  - **I-stream and P-stream** (Models for I/P-stream have been captured in TR, where packet size ratio = 2)
  - **FoV-stream and non-FoV stream**



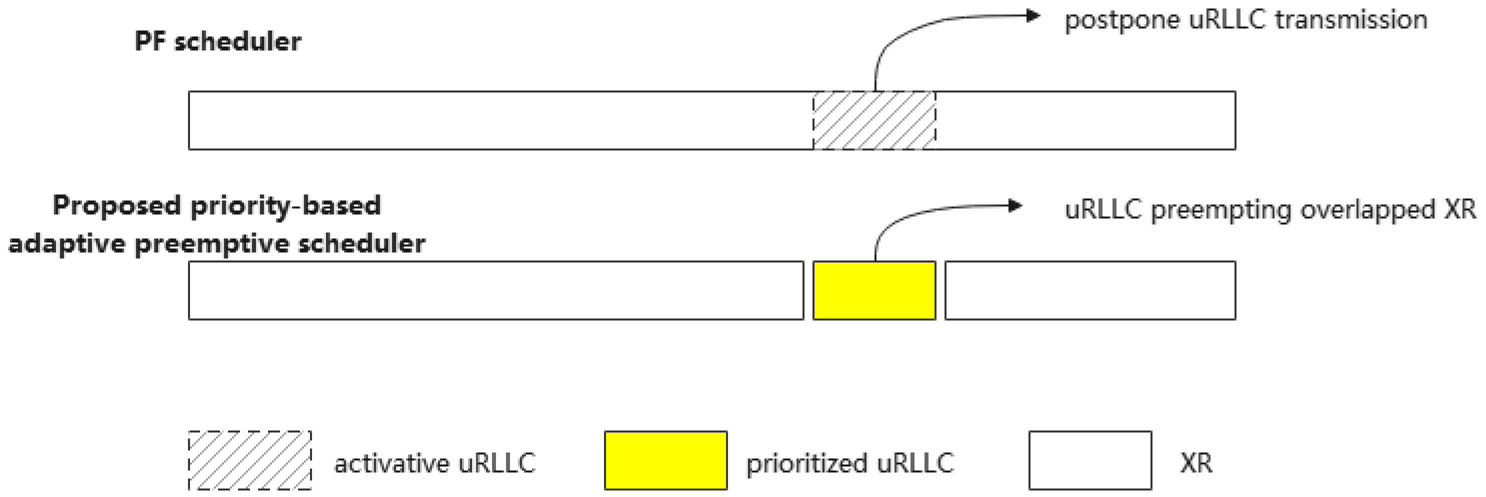
Agreed traffic model for I/P-stream traffic model traffic model



Proposed traffic model for FoV and non-FoV traffic model

Priority-based adaptive preemptive scheduler

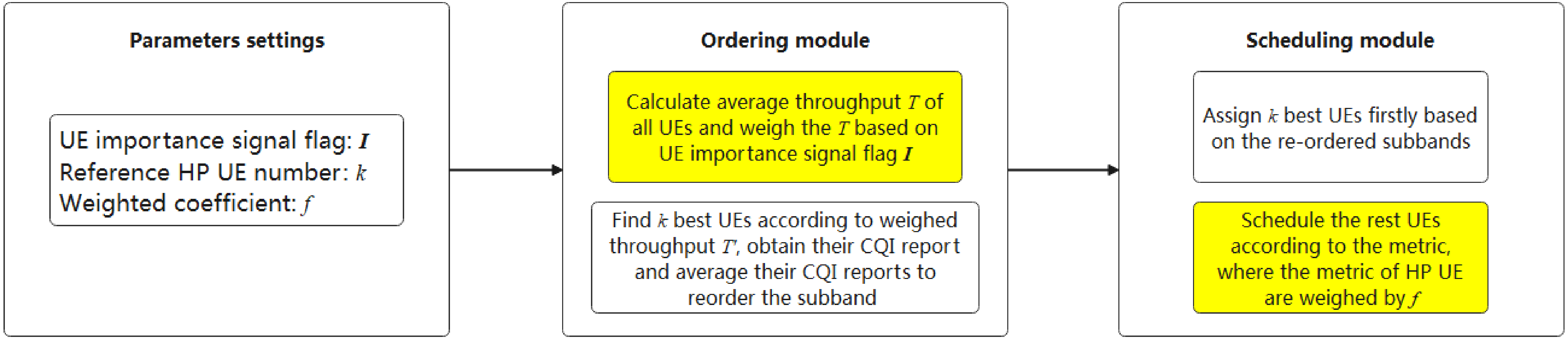
- Challenge for XR traffic transmission
  - A huge transport block in a jittering arrival manner.
  - The stringent QoS requirement of reliability and latency.
- XR transmission implementation -- Coexistence with existing uRLLC and/or eMBB.
  - How XR service coexists with current existing service like uRLLC or eMBB, without excessive performance loss.
  - Preemption mechanism can be one of the solutions for XR service coexistence.



Framework on proposed scheduler

- Proposed priority-based adaptive preemptive scheduler is capable of **ensuring high priority UEs transmission on time**.
- Proposed priority-based adaptive preemptive scheduler sacrifices low priority UEs to multiplex high priority UEs **without too much performance loss on low priority UEs**.

Priority-based adaptive preemptive scheduler



- UE importance signal flag $\boldsymbol{I}$=[0,1,0,...,0,1]: Identify HP UEs (1) and LP UEs (0) in scheduler
    - Reference HP UE number k: Limited to the number of HP UEs configured in flag $\boldsymbol{I}$. Affect HP UE fairness in scheduler.
    - Weight coefficient f: Belong to the rest UEs (remaining HP UE and LP UE) based on I and K. Affect preemption opportunities of HP UE.

- Throughput calculation:

$$T' = T.*I, \quad T = \{T_i\}_{i=1}^{UENum}$$

$$T_i = \frac{1}{N_{SB}} \sum_{j=1}^{N_{SB}} r_i(j) * N_{RB} * v, \quad i = 1, \ldots, UENum$$

    - Identify the importance of UEs to assist scheduling and resource allocation.
    - Use HP UE's CQI report for reorder subband resource for the whole system.

- Weighed metric for the rest UEs (remaining HP UE and LP UE):

$$M_i^j = \frac{T_{i,ins}^j}{T_{i,aver}^j} * F(\boldsymbol{I}(i))$$

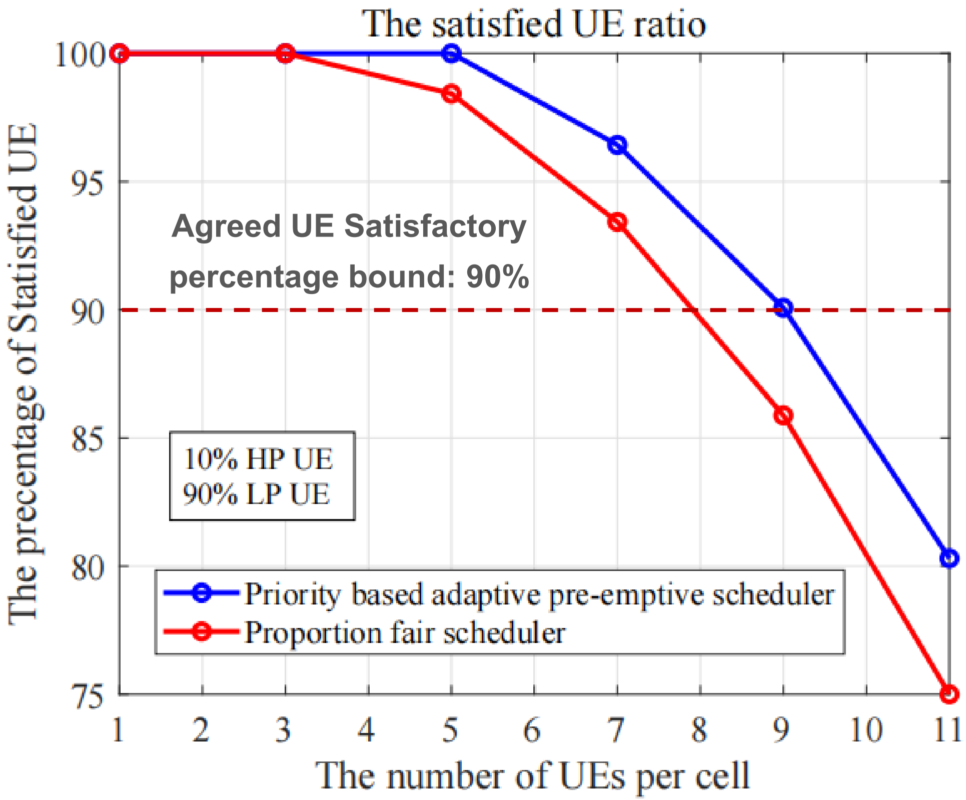
$$F(x) = \begin{cases} 1, & x = 0 \\ f, & x = 1 \end{cases}$$

    - Identify the importance of UEs to assist scheduling and resource allocation.
    - Configure the parameter f to affect the opportunities for HP UE preempting.

Simulation Results

Parameters	Values
Scenario	Indoor Hotspot
Traffic Model	(HP) Traffic 1: Bit rate = 1.8Mbps, packet delay budget = 5ms. (LP) Traffic 2: Bit rate = 30Mbps, packet delay budget = 15ms. (according to conclusions of data fitting method Alt2)
Scheduler	Option 1: Propotion fair scheduler Option 2: Proposed scheduler
TDD pattern	DDDSU
Target BLER	10% for first transmission

More simulation parameters are listed our paper S1.2: Towards a robust new radio compatible with XR



UE Satisfactory percentage for SU-MIMO system with different schedulers

Observations:

- Priority-based adaptive preemptive scheduler provides around 12.5 percent capacity gain for SU-MIMO systems.
- The proposed scheduler can also be used in multi-stream model (e.g. FoV and non-FoV) and more performance gains are expected.

Further study and enhancements

- Enhanced QoS for different services
  - QoS info. with finer granularity for better representing user experience.
  - Further study how to use this kind of information to aid RAN transmission
- Preemption in multi-user MIMO scheduler
  - How to balance the relationship between UE-pairing and preemption in scheduler.
- Priority-based adaptive preemption for Multi-stream model
  - Intra-stream preemption should also be considered in scheduler.
- CBG mechanism for re-transmission
  - CBG re-transmission is capable of increasing the radio resource utilization efficiency in system.

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Thank you!