ELASE: Enabling Real-time Elastic Sensing Resource Scheduling in 5G vRAN

Yulong Chen, Junchen Guo, Yimiao Sun,
Haipeng Yao, Yunhao Liu, Yuan He†

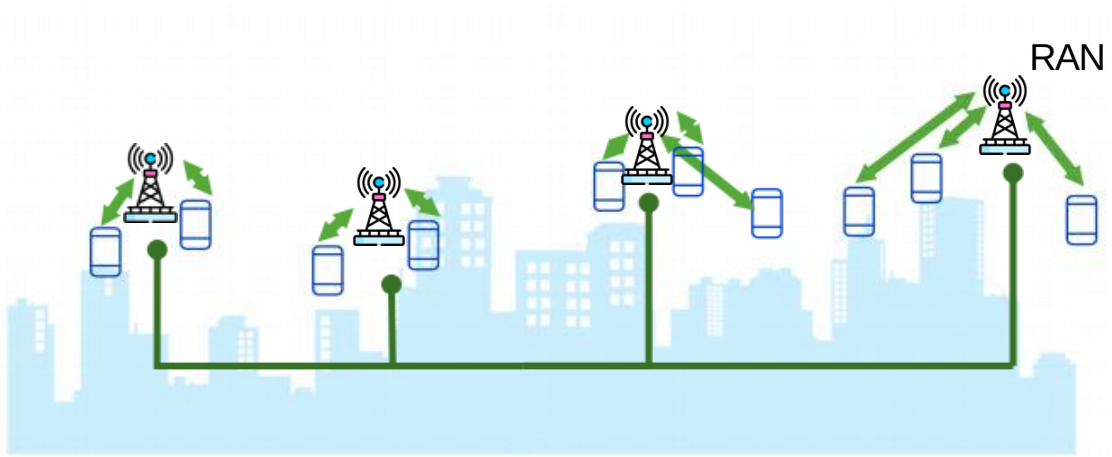
1*Tsinghua University, China* 2*Alibaba Group, China*
3*Beijing University of Posts and Telecommunications, China*

清華大學
Tsinghua University

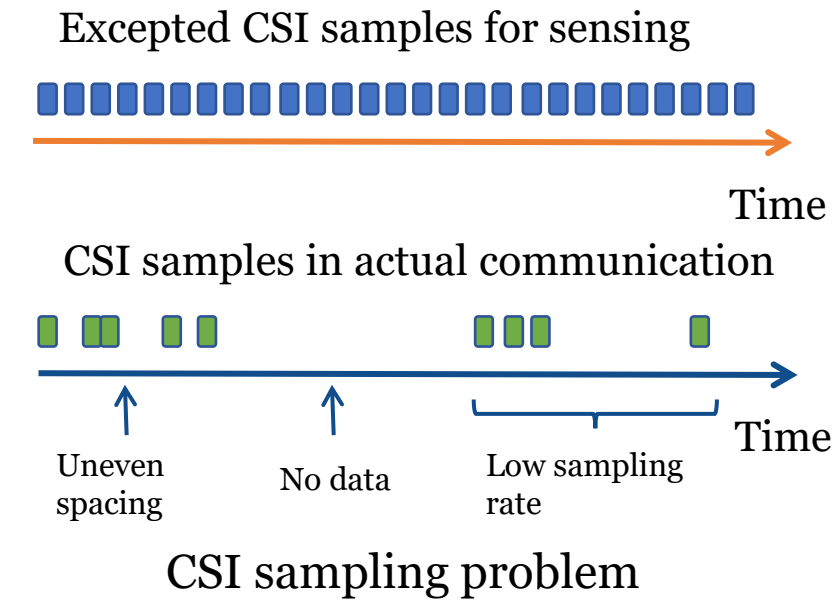
北京郵電大學
Beijing University of Posts and Telecommunications

Paradigm: Integrated Sensing and Communication

Cellular Network



Wi-Fi Network



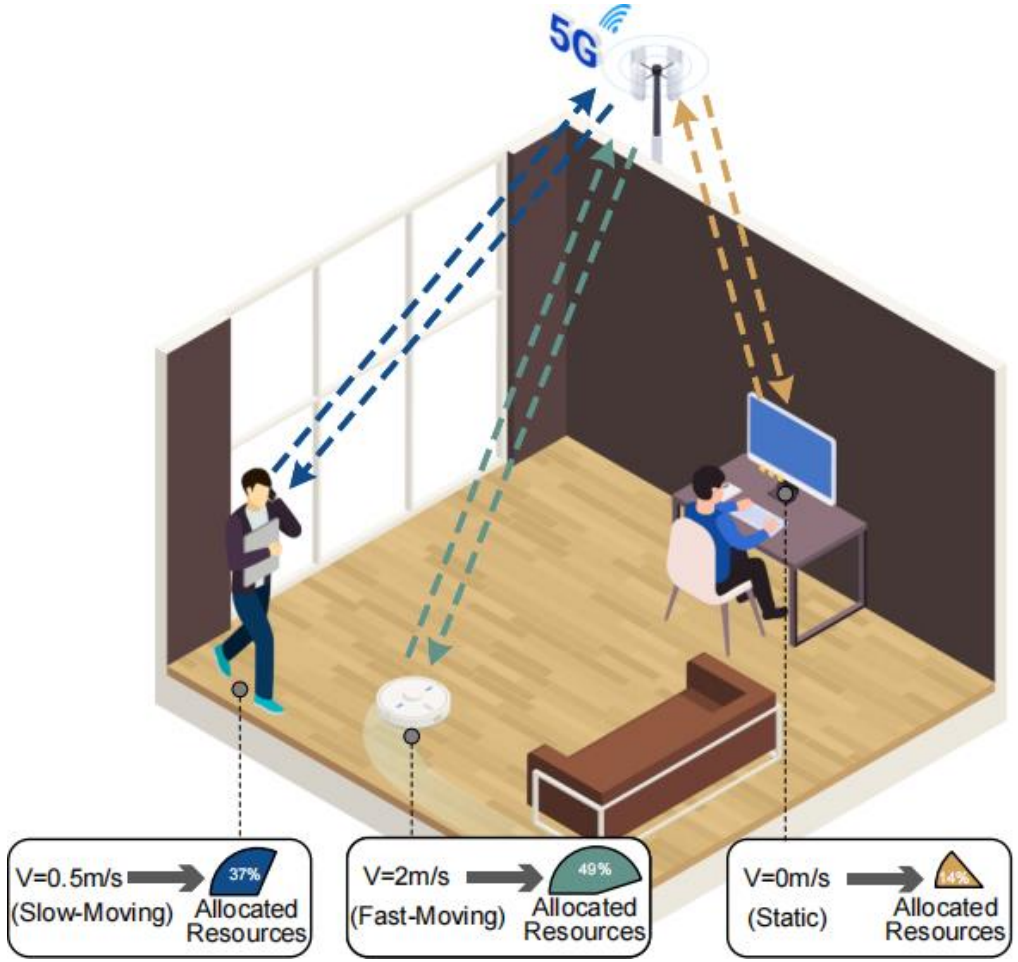
Insight: Cellular networks have the characteristics of wide distribution and centralized RF resource scheduling.

Scheduling sensing resource in multi-target scenarios

Signal Processing Algorithms

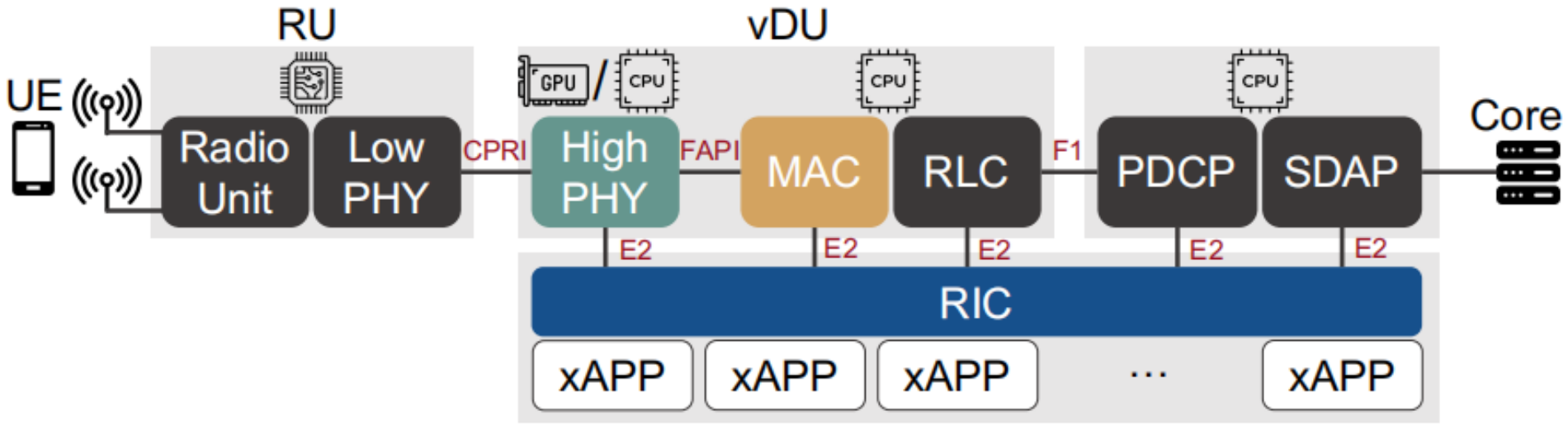
Artificial Intelligence

Multi-stream Infrastructure



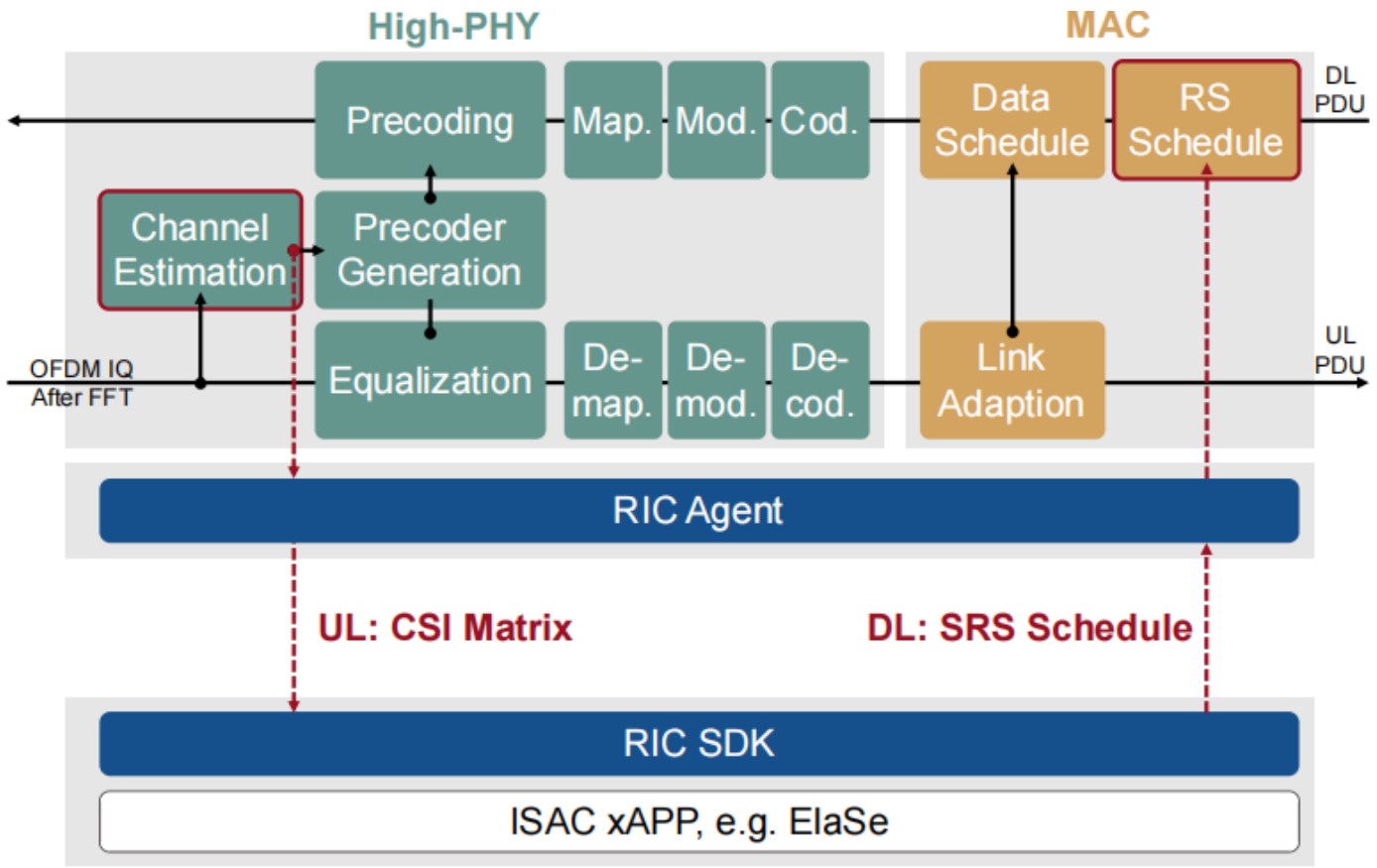
Scheduling the limited sensing resources among multi targets should be in parallel with the algorithm optimization and the infrastructure upgrading.

Virtual Radio Access Networks



Protocol stack of 5G vRAN

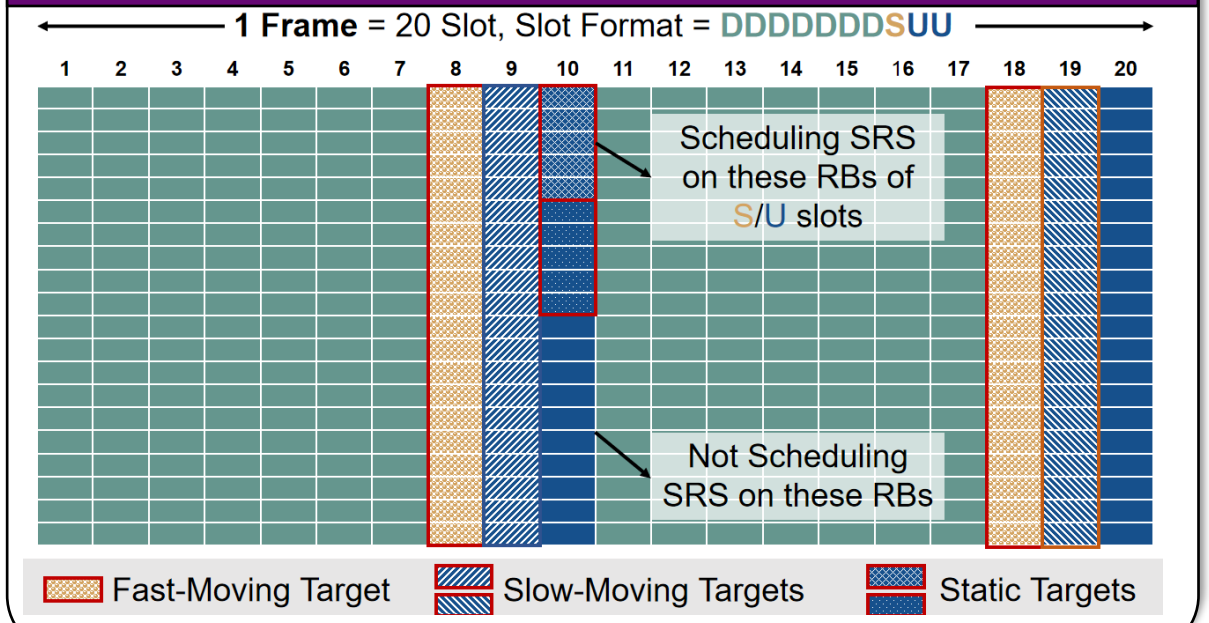
Virtual Radio Access Networks



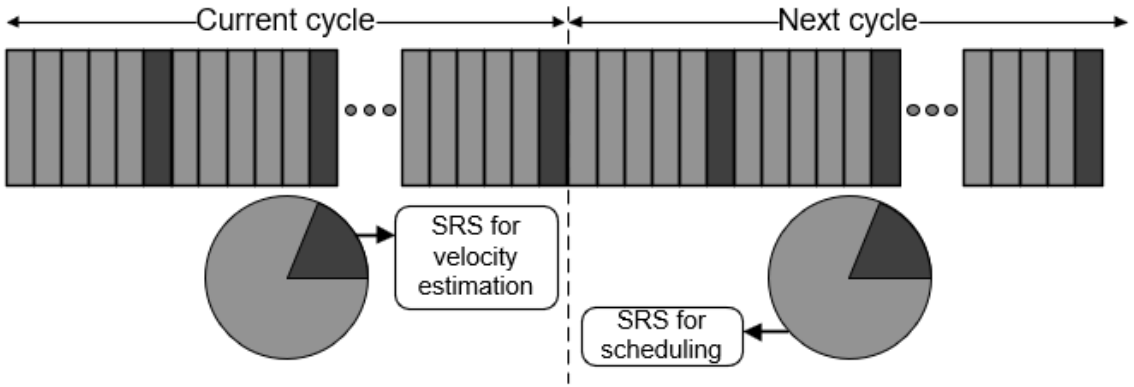
Insight: The interface of its protocol stack gives us the opportunity of deploying a dedicated RS scheduler on demand..

Technical challenges

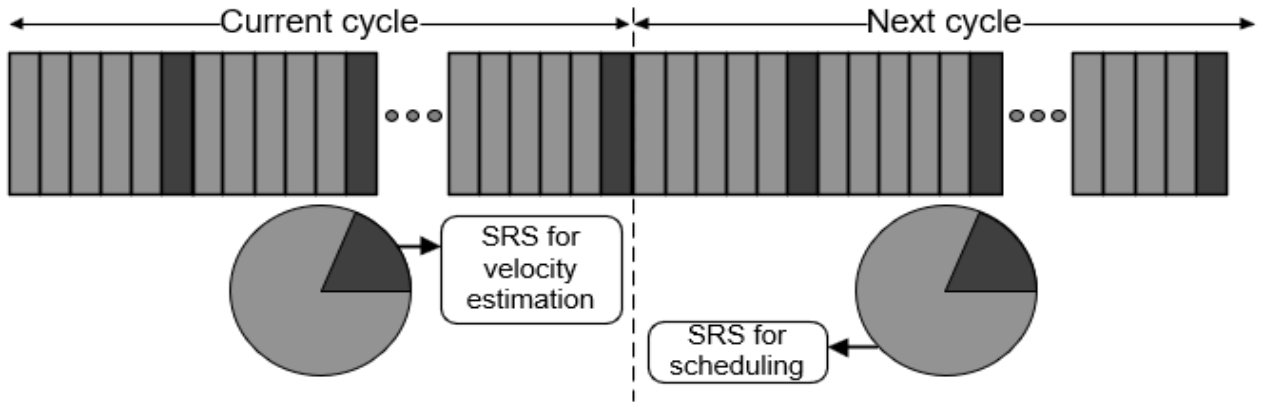
Matching demands with RS



Eliminating scheduling delays



ElaSe: Design overview



UE state recognition

We utilize the existing low sampling rate SRS available in communication and derive the velocity as an indicator of demands.

SRS resource scheduling

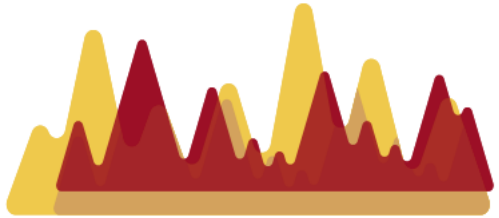
- Mapping indicator to SRS resources
- Resource allocation algorithm.

Eliminating delays

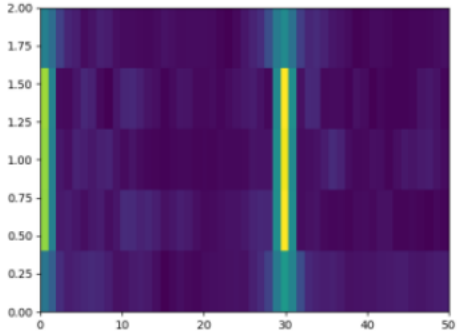
- Predictive Scheduling Scheme
- Delay between the UE acquiring sensing resources and its state change.

UE state recognition

UE state recognition



Signal preprocessing



Velocity estimation

Data preprocessing

Noise cancellation

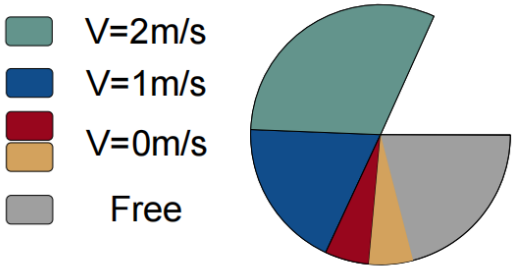
Fading enhancement

Frequency estimation

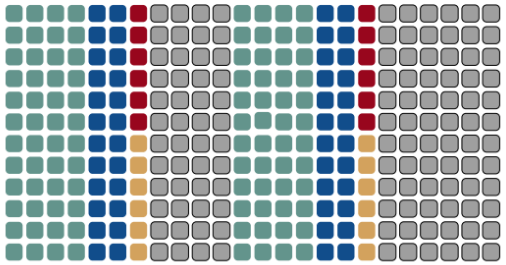
f → the median value → f_0 → $v = \frac{\lambda * f_0}{2}$

SRS resource scheduling

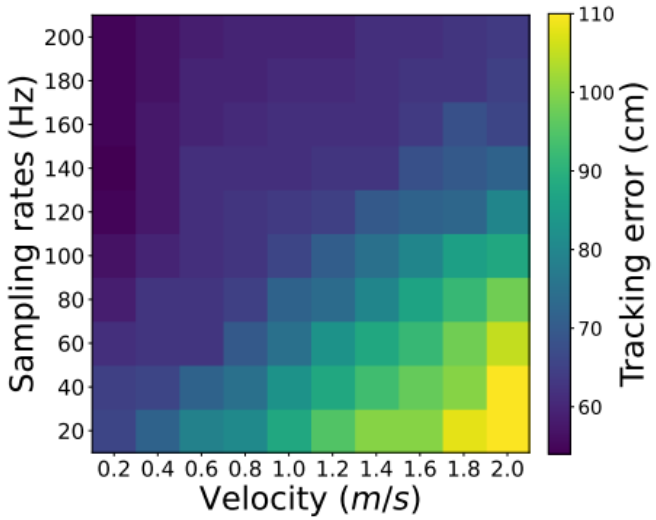
SRS resource scheduling



SRS resources mapping



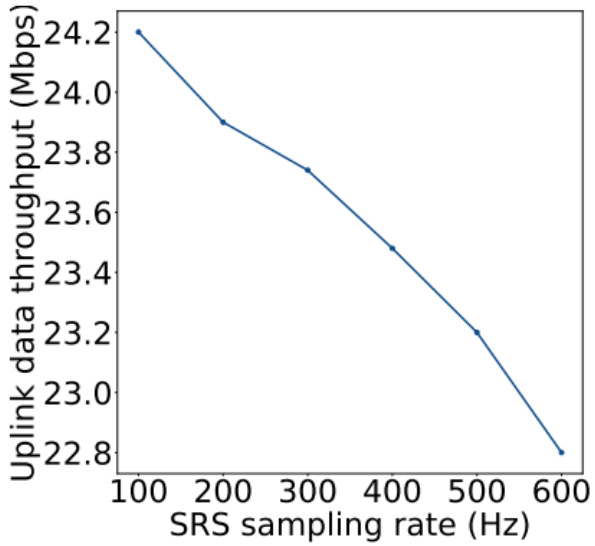
Resource allocation



Variant tracking errors under different velocities and sampling rates.

$$fs = k * v$$

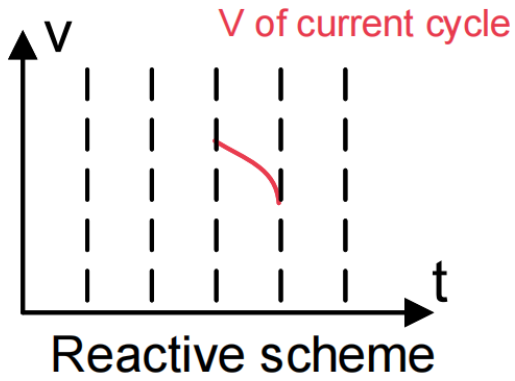
Effects of SRS slot numbers on data throughput:

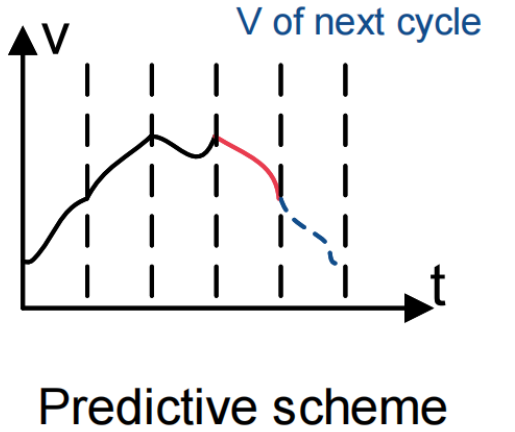


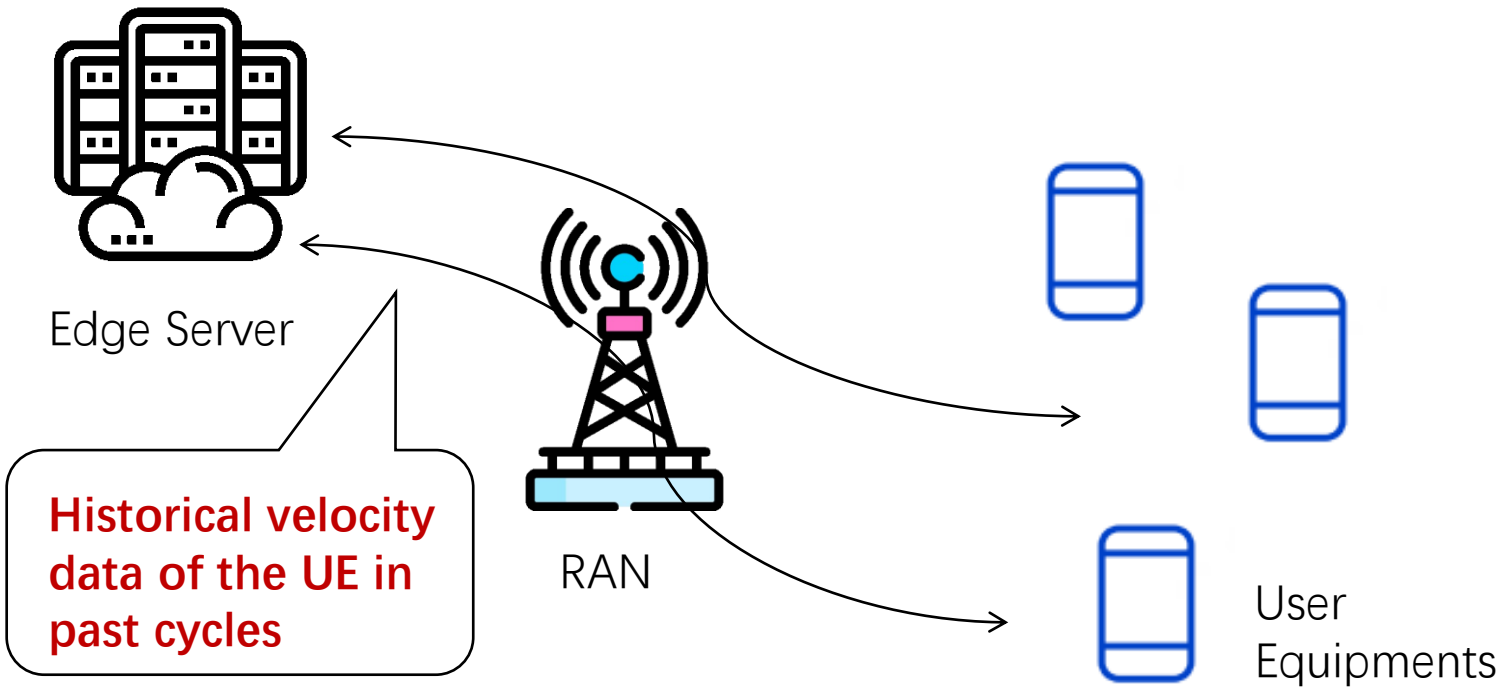
Uplink data throughput using SRS with different time slot numbers.

Elimination of scheduling delays

Elimination of scheduling delays

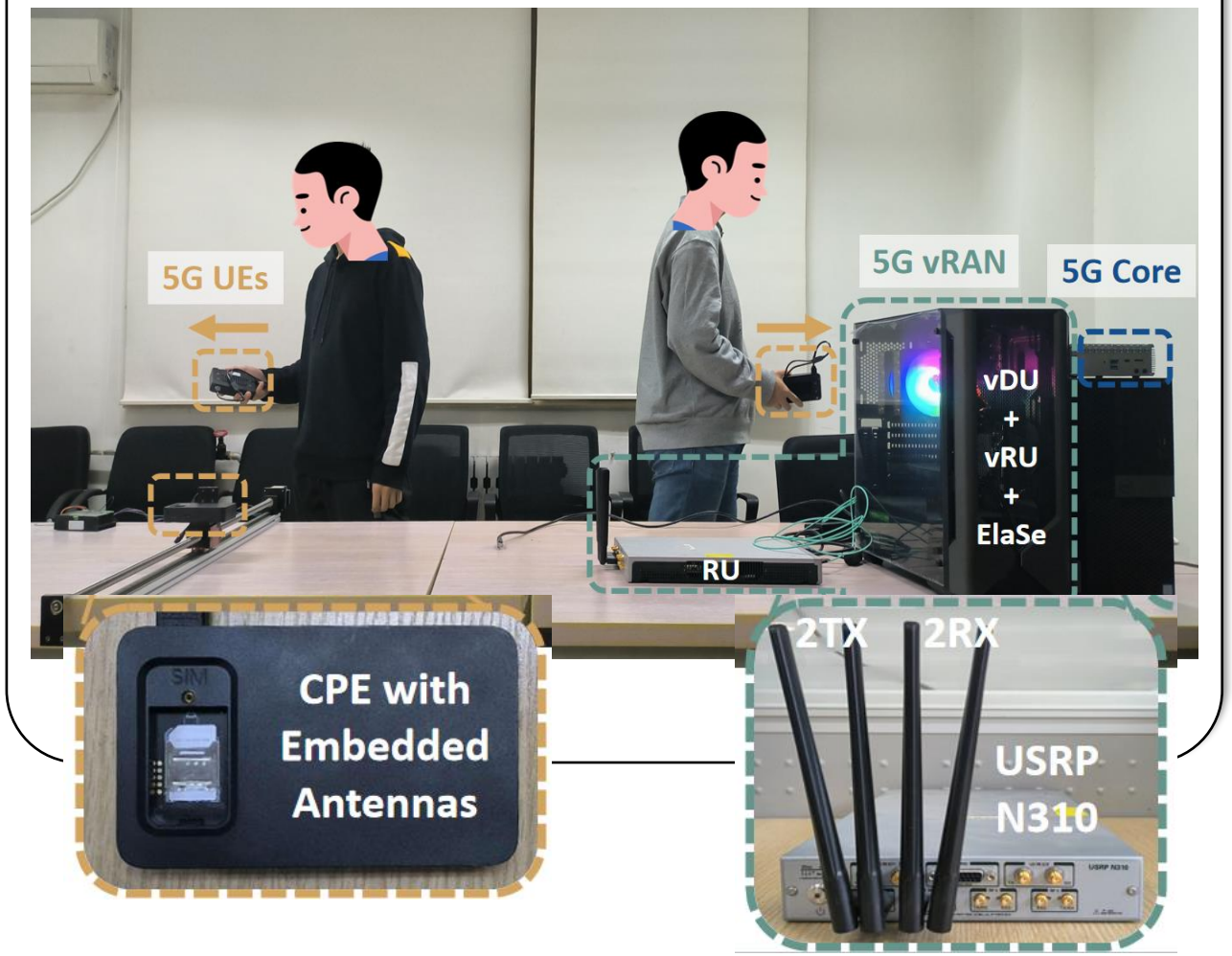






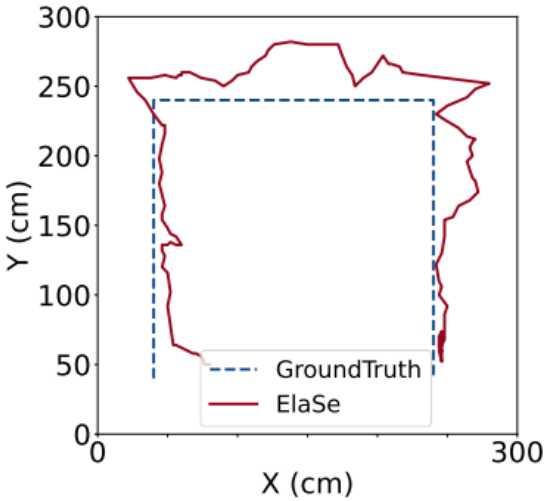
Implementation

A complete 5G testbed

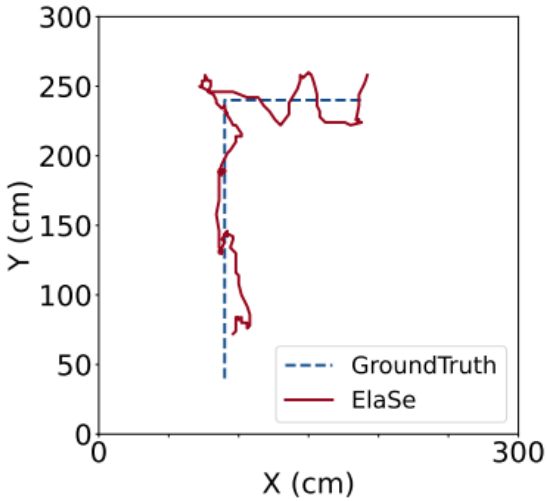


- **5G vRAN**: Adopt OpenAirInterface (open-sourced) and run at 3.7GHz.
- **5G core network**: Adopt free5GC.
- **5G UEs**: Use commercial 5G Customer Premise Equipment with **no hardware and software modifications**.

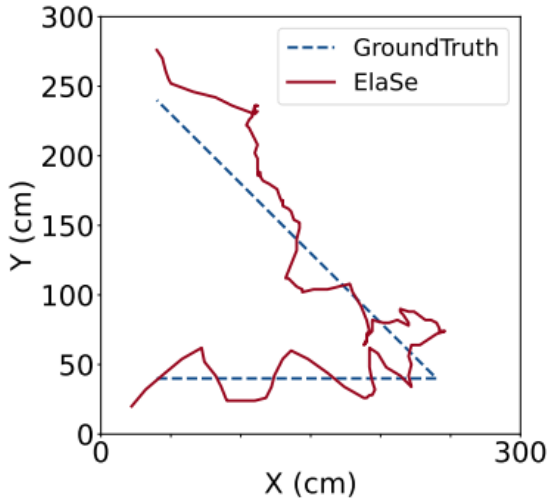
Overall Performance



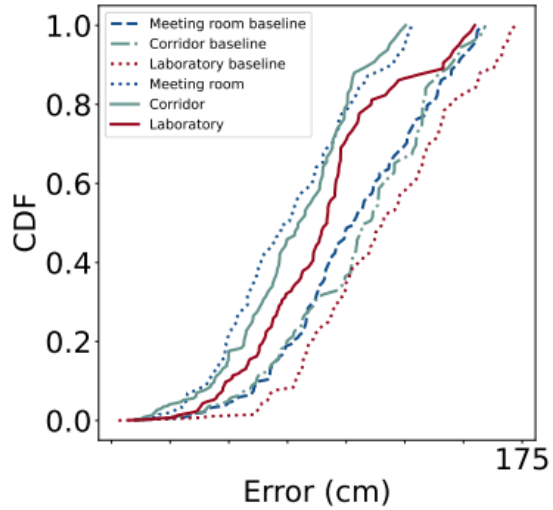
Meeting room with few multipath effects (5m×4.2m)



Narrow corridor(5m×2m)



Laboratory with rich multipath effects (5m×4m)

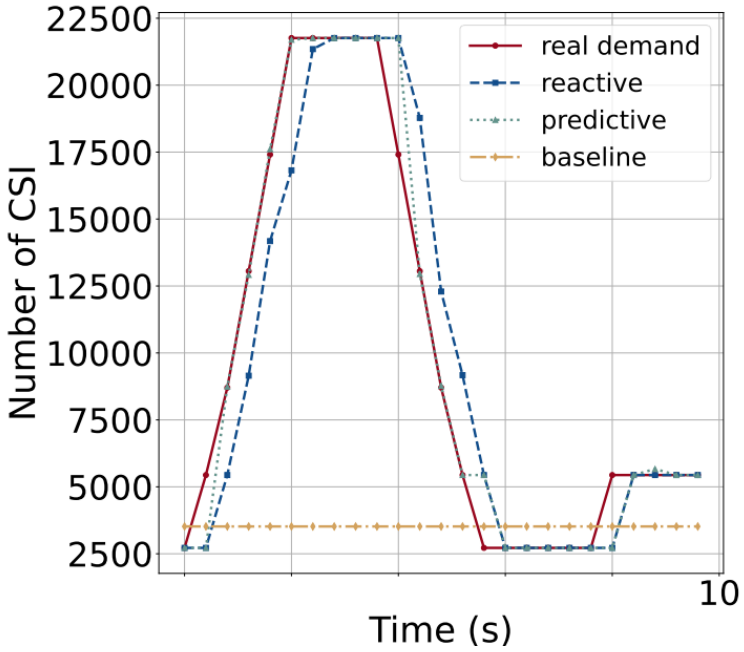


CDF of Tracking Error

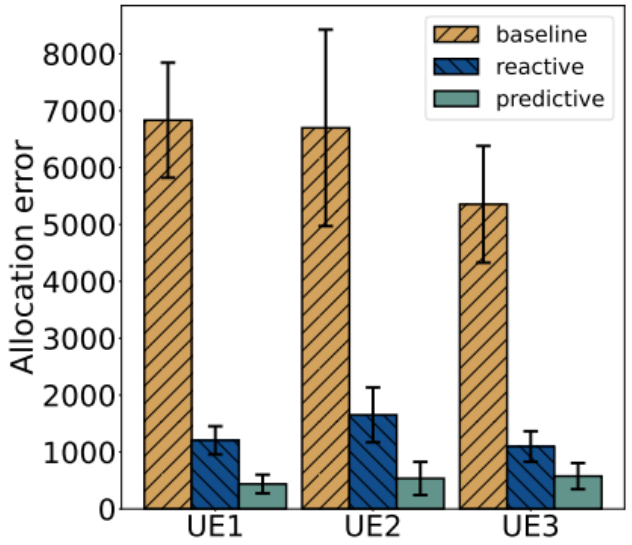
The median tracking error of ElaSe is 0.60m,0.63m,0.78m, respectively,34% less than that of baseline scheme without scheduling.

Allocation Error

The resource allocation error is defined as the absolute difference between the number of SRS allocated to one UE and the real demand in one cycle.



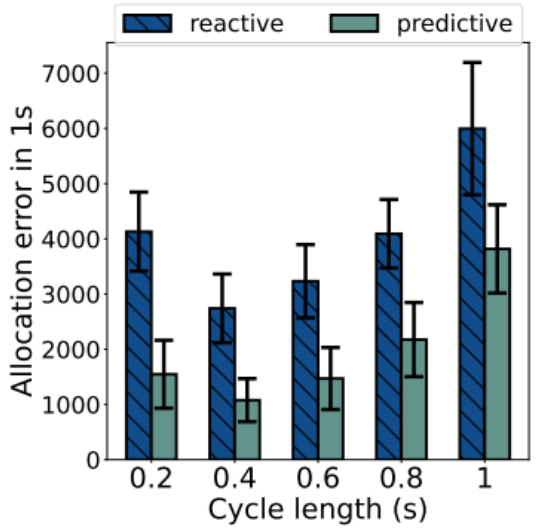
Demand and allocaton over 10s.



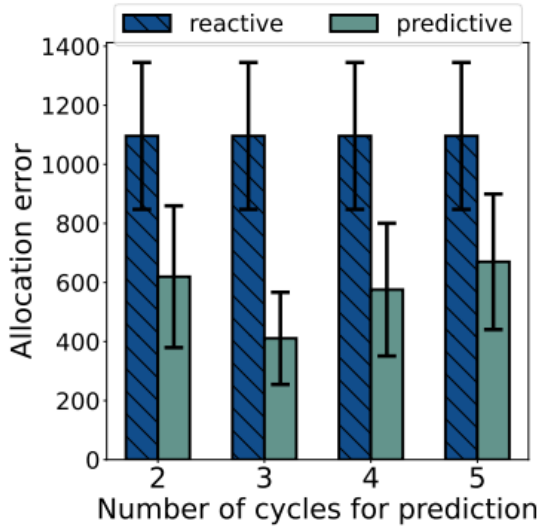
Resource allocation error of three schemes.

The resource allocation error of predictive scheme is 63% less than that of reactive scheme .

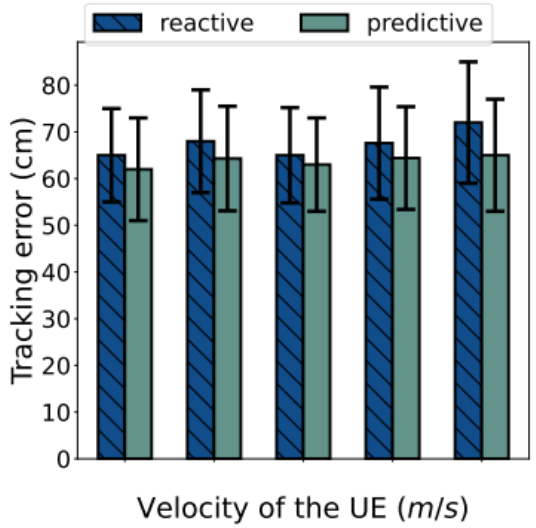
Impacting Factors



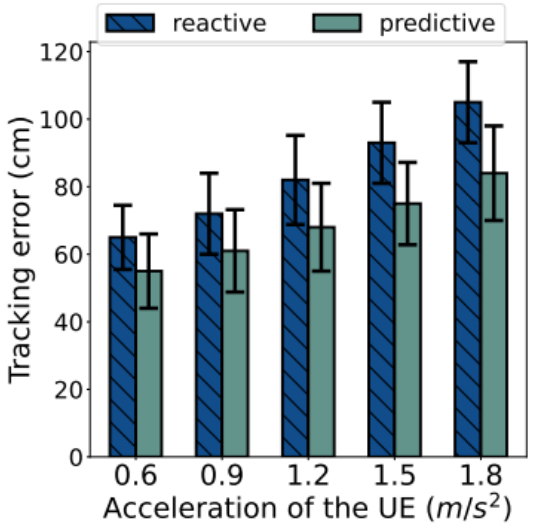
Length of the scheduling cycle



Length of prediction window



UE velocity



UE acceleration

The predictive scheduling scheme works well in different conditions.

Conclusion

- ElaSe is the first sensing resource scheduler in 5G networks and schedules RS **elastically and in time**.
- Experiments under **real-world scenarios** show that ElaSe can schedule sensing resources appropriately, achieving small trajectory tracking errors and resource allocation errors.
- **ElaSe** decouples the user state recognition and resource scheduling modules so other sensing tasks can use this **loosely coupled framework**.

Thank You!