No Reservations Required: Achieving Fairness between Wi-Fi and NR-U with Self-Deferral Only

Ilenia Tinnirello (University of Palermo, CNIT, Italy)
Alice Lo Valvo (University of Palermo, Italy)
Szymon Szott (AGH University, Poland)
Katarzyna Kosek-Szott (AGH University, Poland)

Scope

MOTIVATION

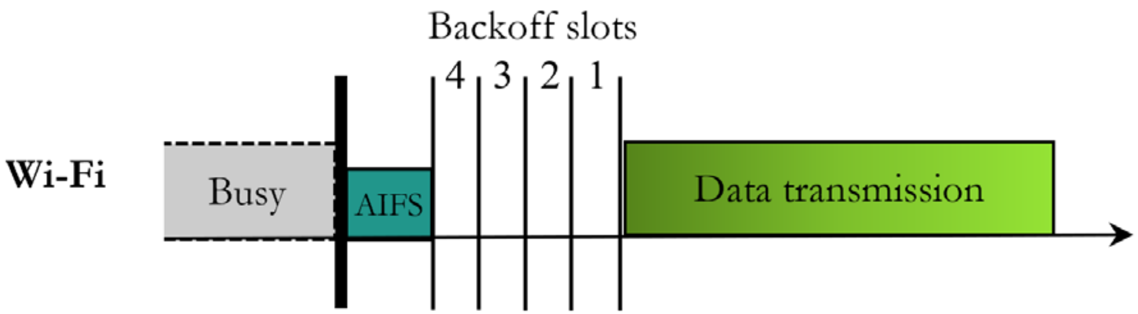
DEVELOPED MODELS AND TESTBED

IMPORTANT OBSERVATIONS

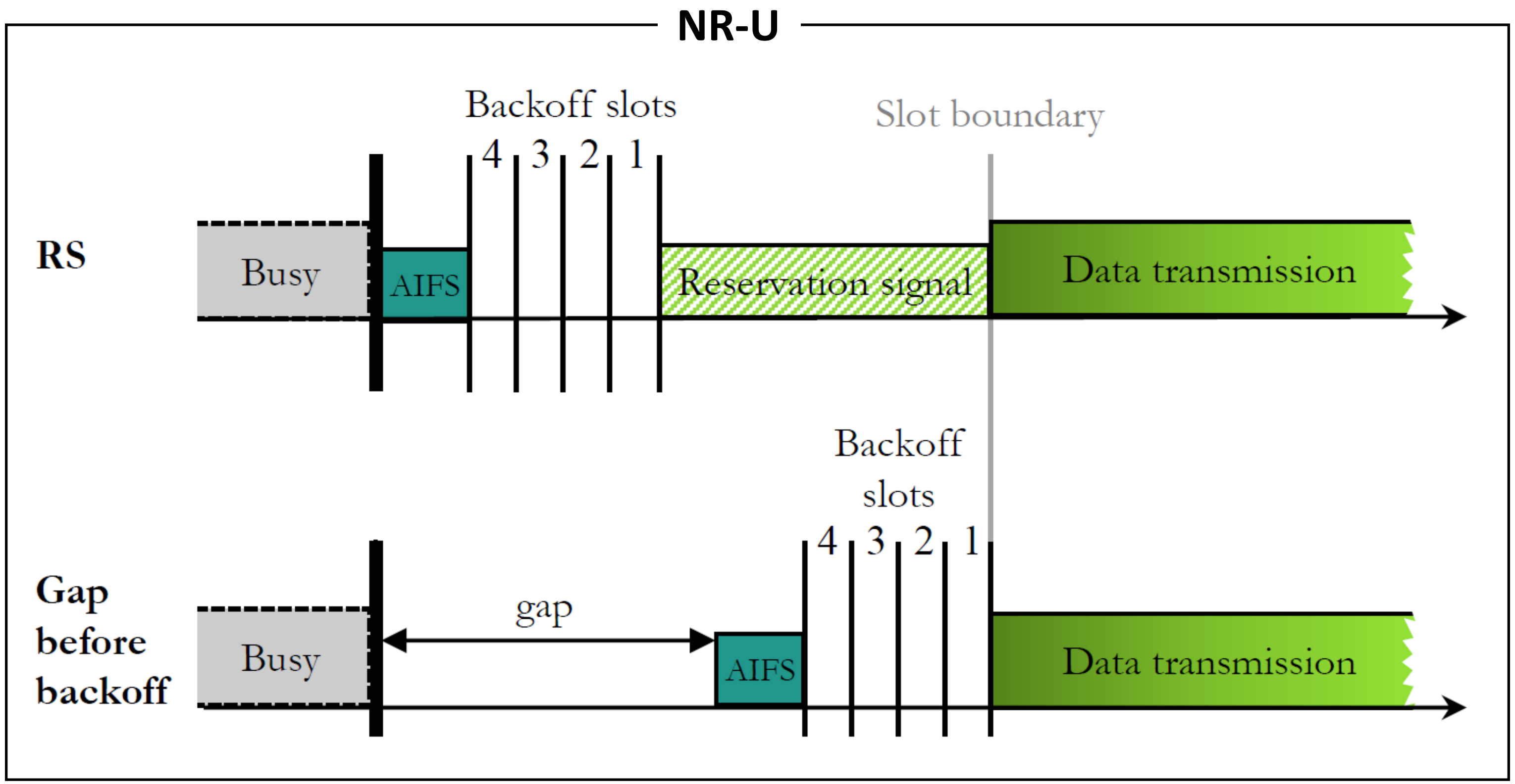
CONCLUSIONS

Motivation

- Improved coexistence between Wi-Fi (random channel access) and NR-U (scheduled channel access)
- Fair channel access in unlicensed bands
- Improved usage of channel resources



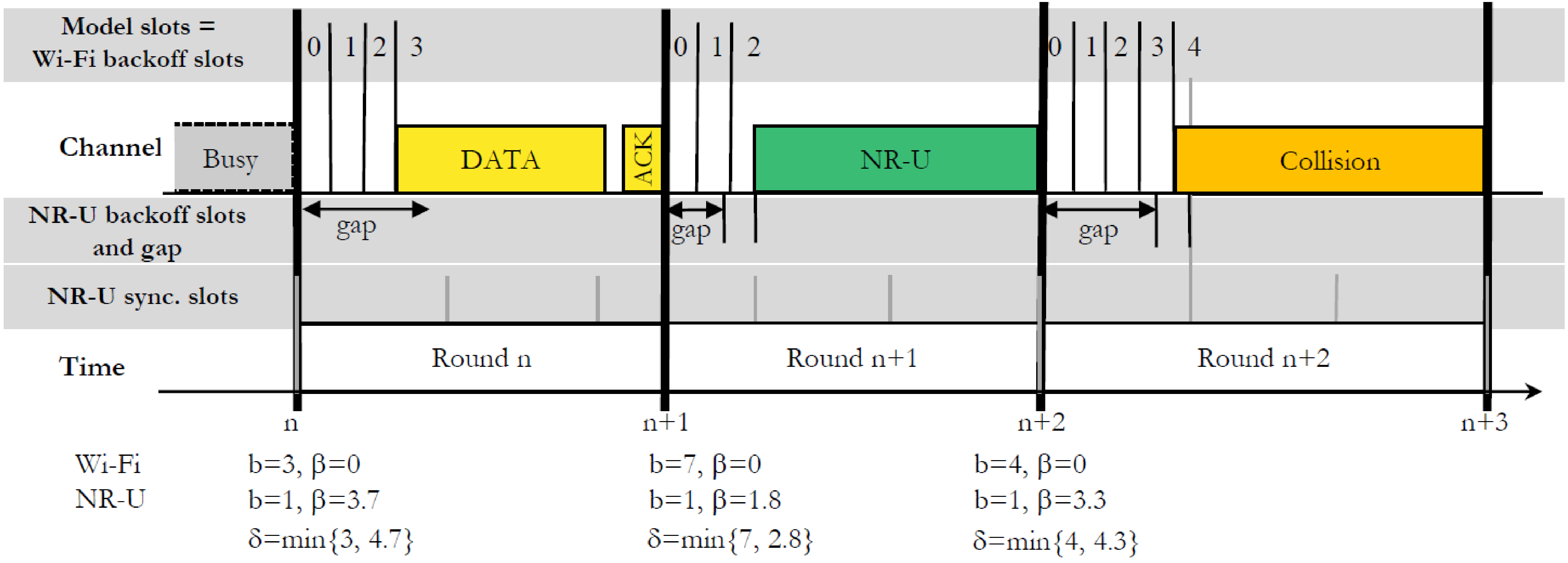
Backoff Time = RandInt(0, **CW**) x SlotTime



Models & Testbed

- **Analytical model** for performance evaluation
  - Evolution of the backoff counter value at the end of each transmission/collision event delimiting the contention round
- **Simulation model** for performance evaluation & analytical model validation
  - Monte Carlo simulator developed in Matlab
- **Testbed** for simulator validation
  - SDR devices
- **Multi-input multi-output regression model** for performance prediction
  - Predicting settings resulting in fair channel access
  - Trained with data from our Matlab simulator

Backoff evolution process
Coexistence scenario: 1 x Wi-Fi + 1 x NR-U



b – backoff counter, β – additional gap interval, δ – idle time required for starting a new transmission, channel sensing time = 0.5 x backoff slot

Simulator

- Existing simulators lack the gap-based approach
- Assumptions
  - No hidden nodes, network saturation, downlink traffic
- Iterations over consecutive contention rounds
- Contention rounds consists of
  - A waiting period
  - A transmission period
- The simulator logic determines which nodes win the contention
  - Wi-Fi node (lowest backoff value)
  - NR-U node (lowest backoff and gap value)
  - Set of transmitting nodes determines successful transmissions/collisions

Measured metrics

- Normalized airtime (A)
  - Total channel occupancy time normalized to the total simulation time
- Fairness
  - Jain’s fairness index
- **Joint airtime-fairness (F)**
  - Product of the aggregate normalized airtime of all nodes and the fairness

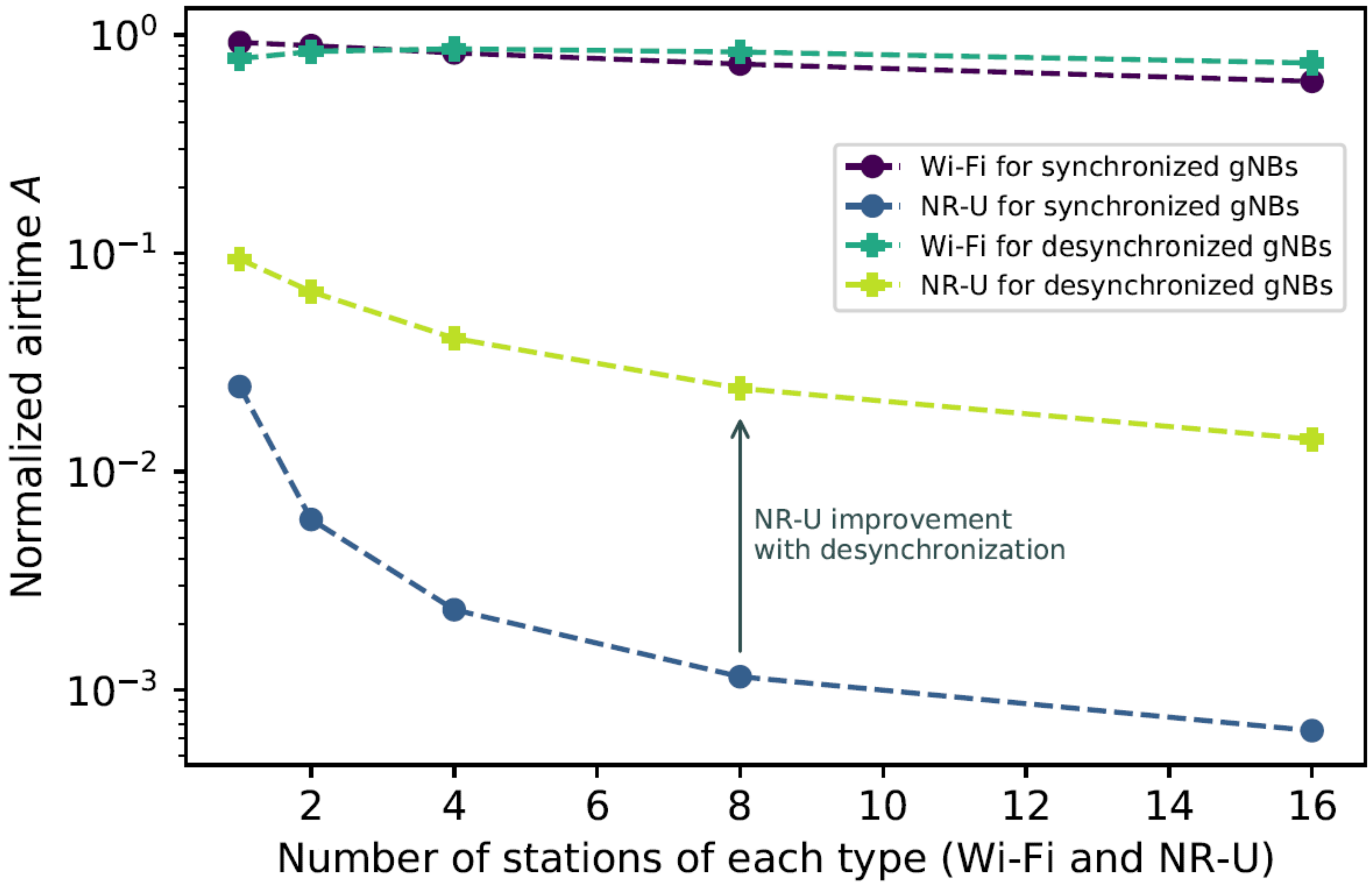
Default simulation parameters (Downlink)

Parameter	Value
Operation band	5 GHz
Wi-Fi CWmin, CWmax	15, 63
NR-U CWmin, CWmax	15, 63
Wi-Fi transmission duration (w/o ACK)	2 ms
NR-U transmission duration	2 ms
NR-U synchronization slot duration	1000 µs

Impact of **gNB synchronization** on NR-U performance

Observation #1

NR-U gNBs contending in shared channels should be desynchronized

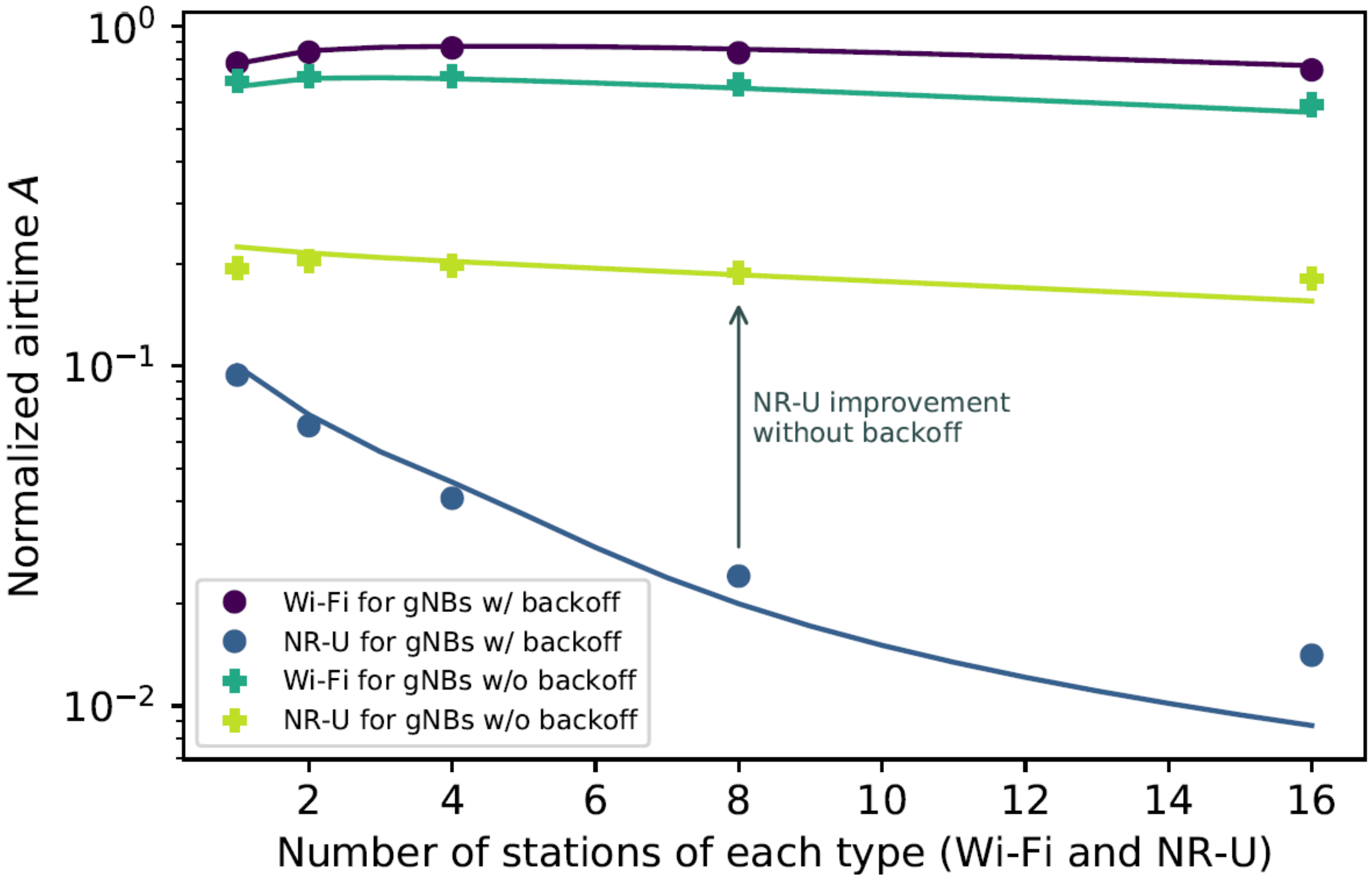


Settings: synchronization slot =1000 μs

Impact of **disabling backoff** at gNBs on NR-U performance

Observation #2

Backoff can be disabled for gap-based channel access

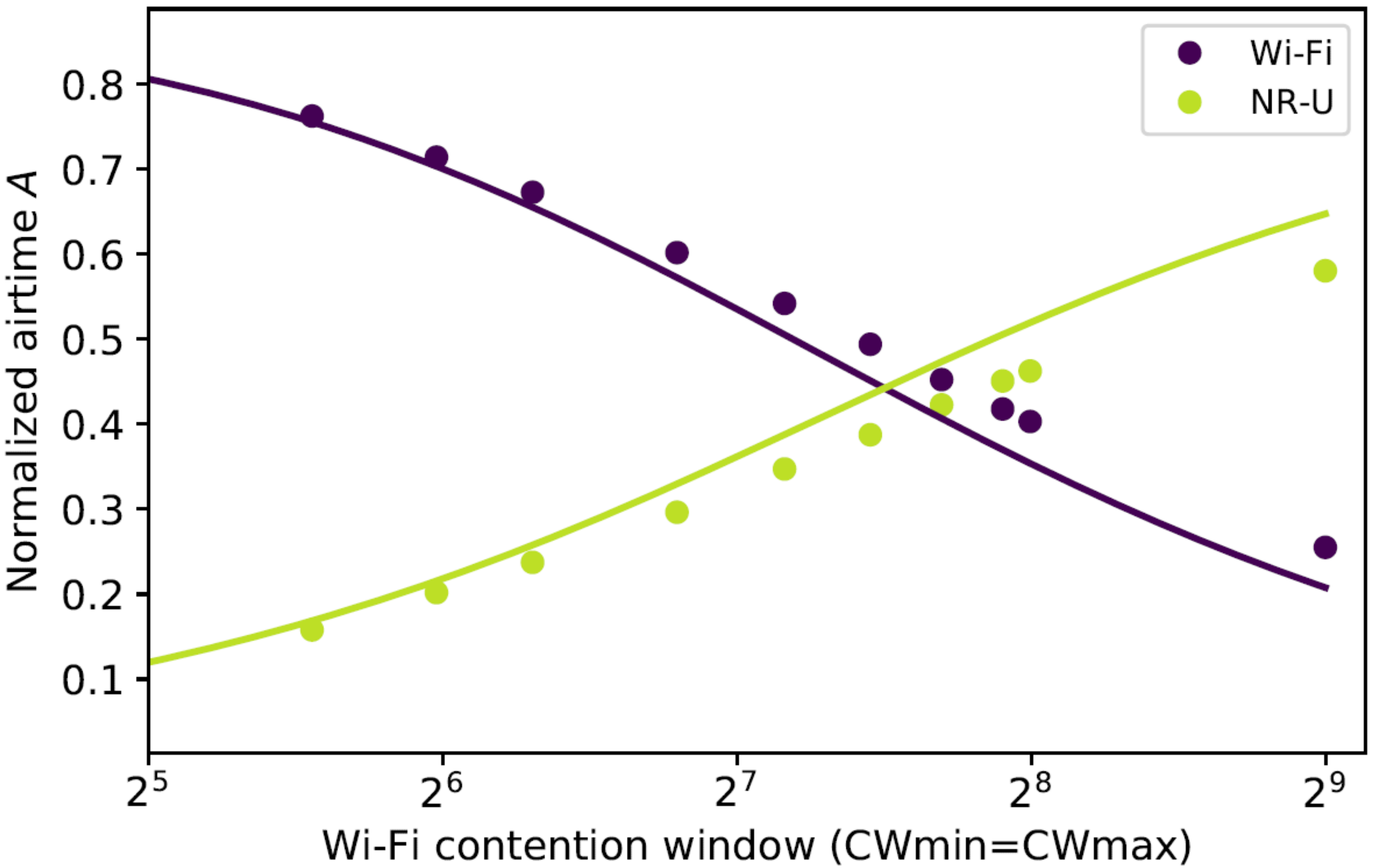


Settings: synchronization slot =1000 μs

Achieving equal airtime distribution by **equalizing the channel access delay**

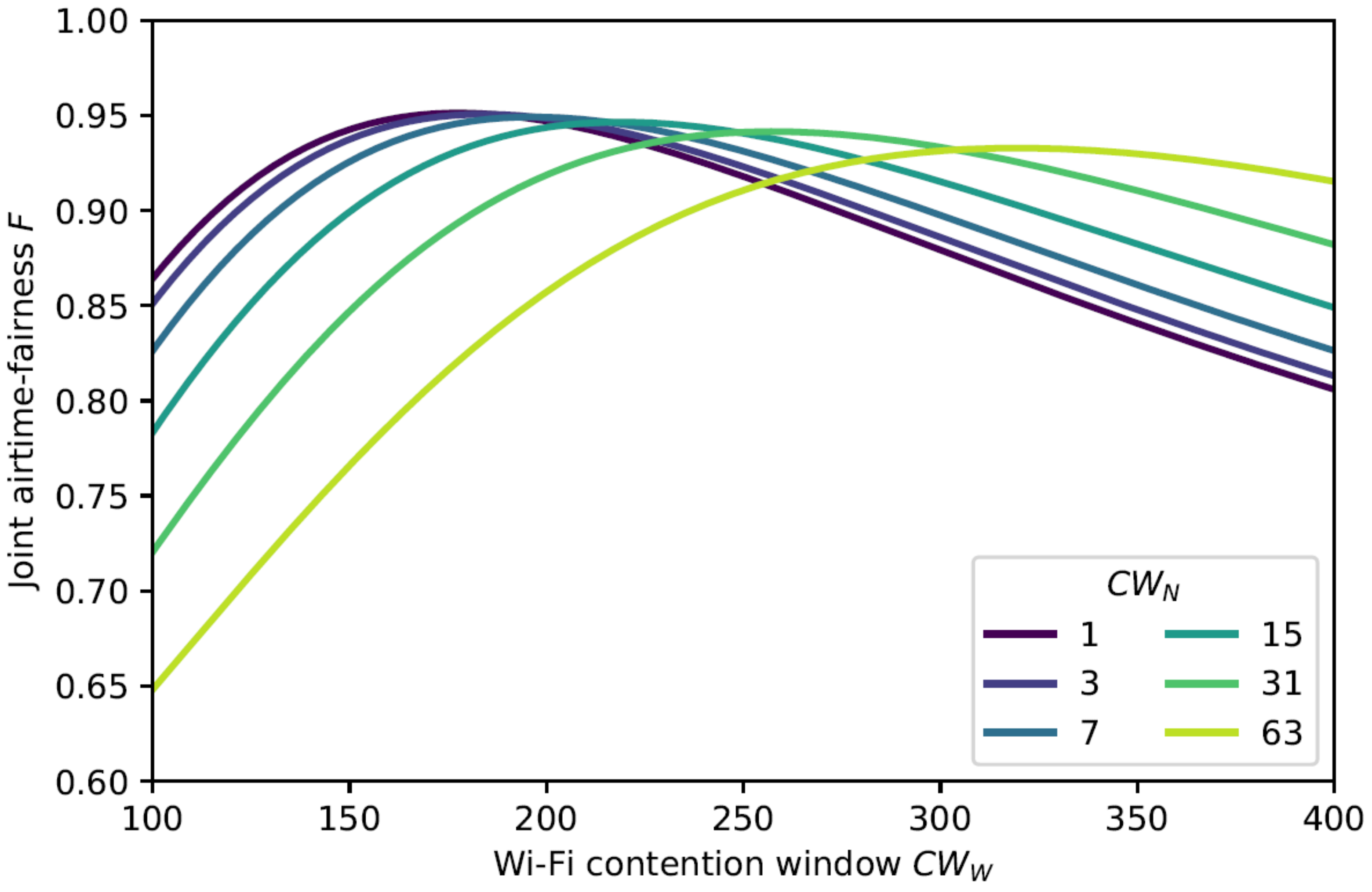
Observation #3

It is possible to achieve a fair airtime distribution between Wi-Fi and NR-U by finding optimal CW settings for both technologies



Settings: $N_W = N_N = 2$, $CW_N = 0$

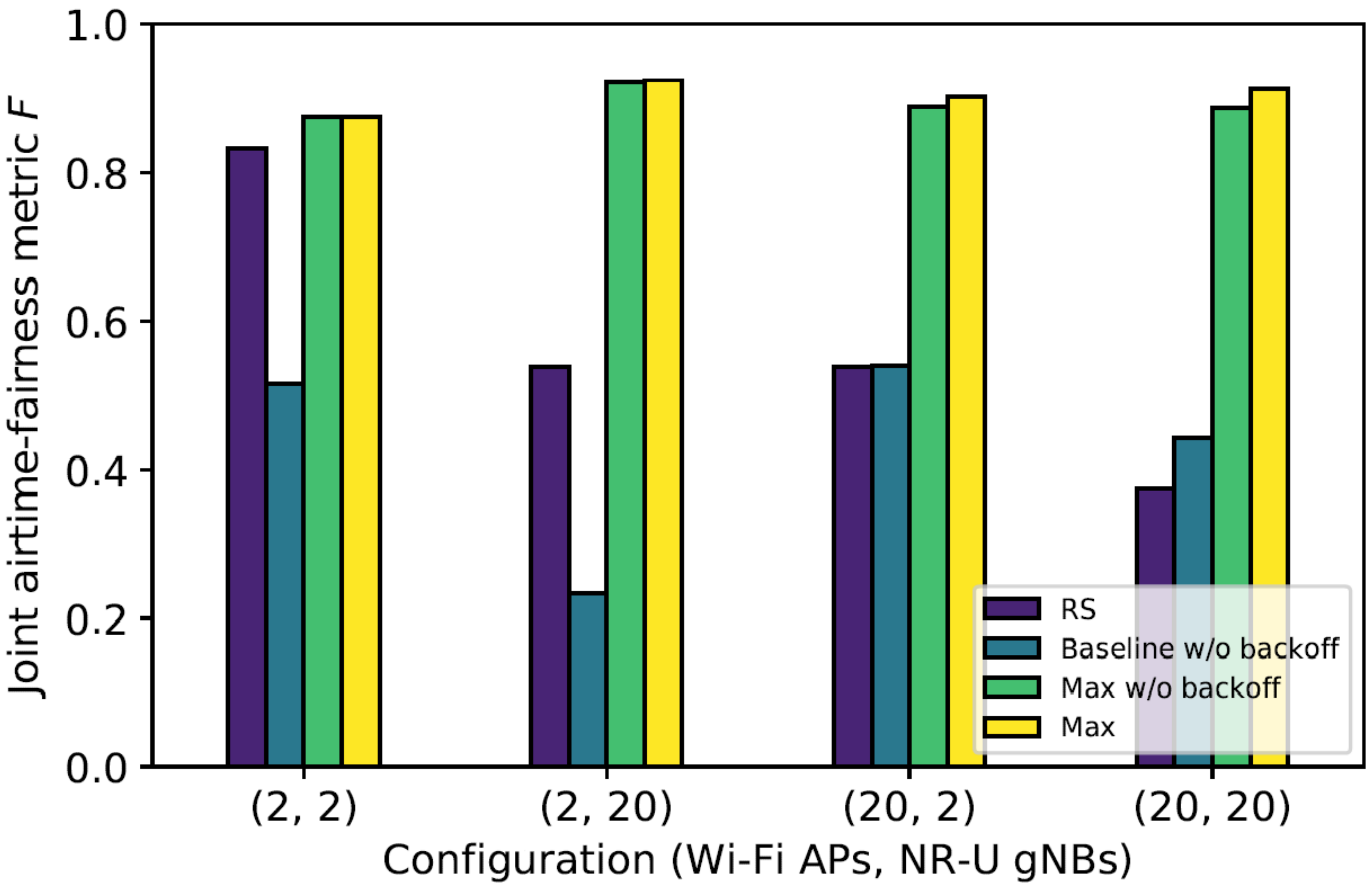
Maximizing joint-airtime fairness F with different (CW_W, CW_N) pairs for $N_W = N_N = 2$



Joint airtime-fairness metric

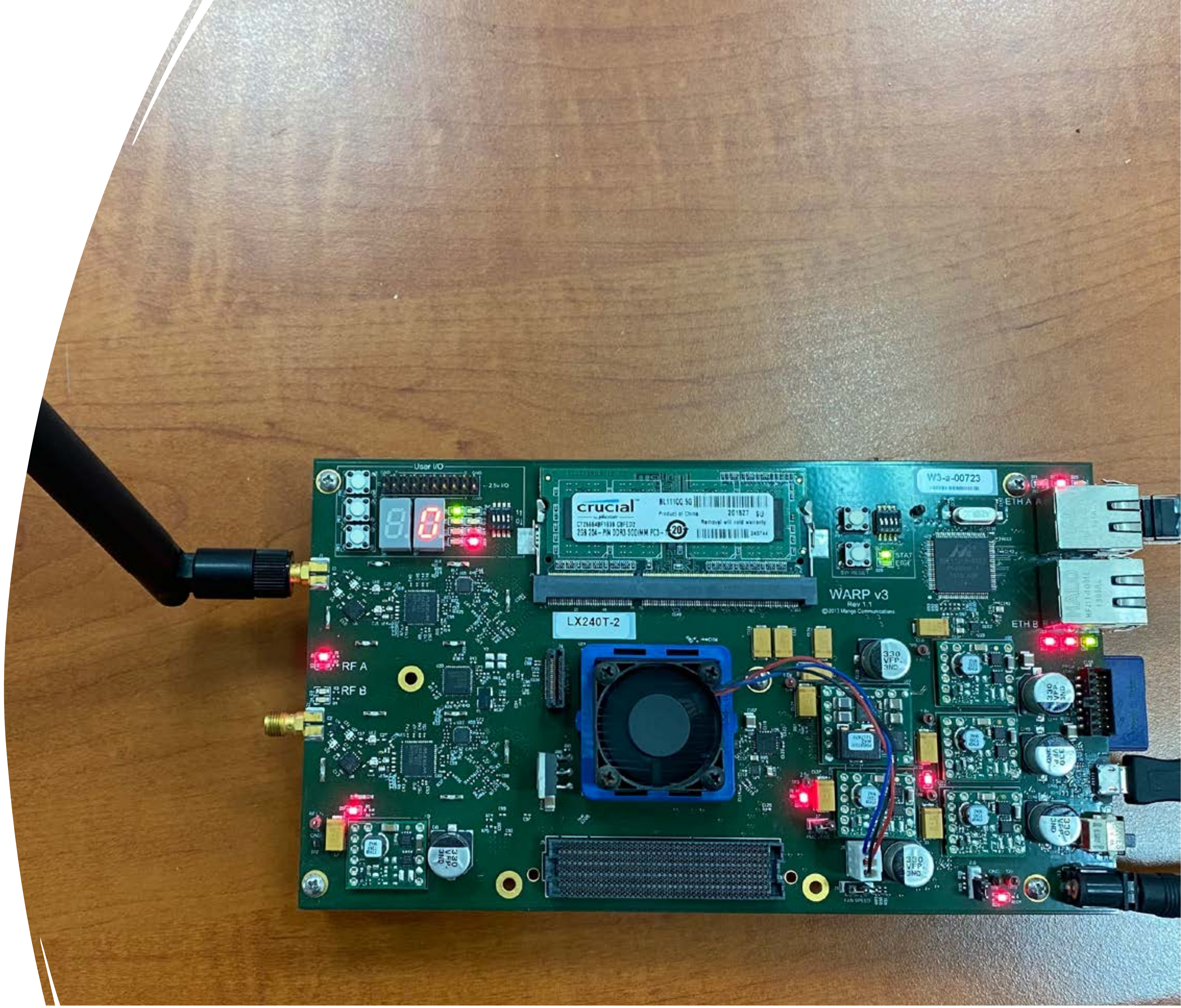
Observation #4

CW tuning is better in terms of airtime-fairness for both Wi-Fi and NR-U in comparison to the case of NR-U using RSs



Testbed

- 5 WARPs
  - 2 Wi-Fi transmitters
  - 1 Wi-Fi receiver
  - 2 NR-U transmitters*



*K. Kosek-Szott, A. Lo Valvo, S. Szott, P. Gallo, and I. Tinnirello. Downlink channel access performance of NR-U: Impact of numerology and mini-slots on coexistence with Wi-Fi in the 5 GHz band. Computer Networks, 2021. https://doi.org/10.1016/j.comnet.2021.108188

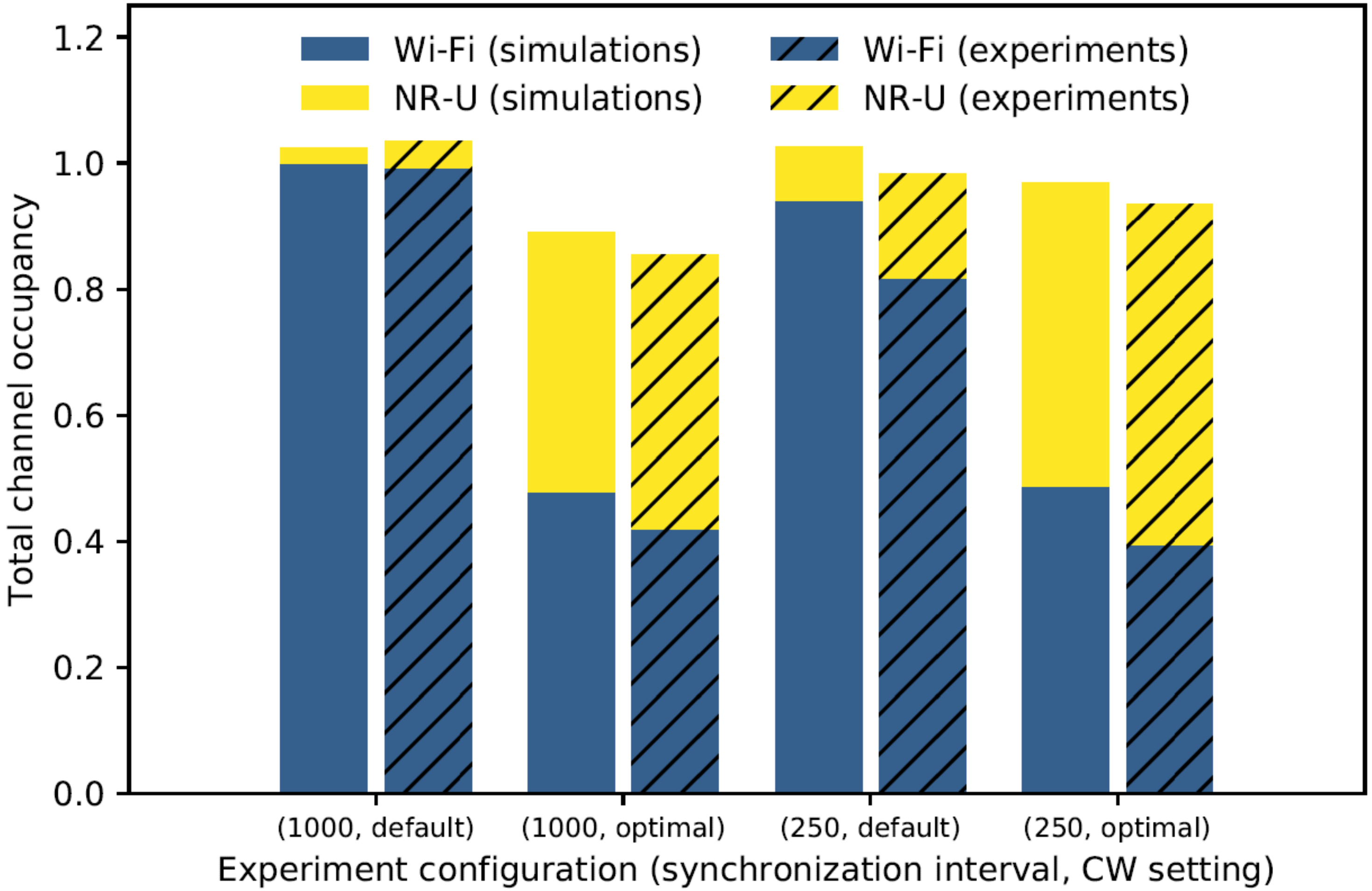
Comparison of simulation and testbed results

Settings

- Sync: 250, 1000 [µs]
- CWs: default, optimal

Results

- Under optimal CW values the airtime-fairness is improved
- Validation of the simulation model



Regression model

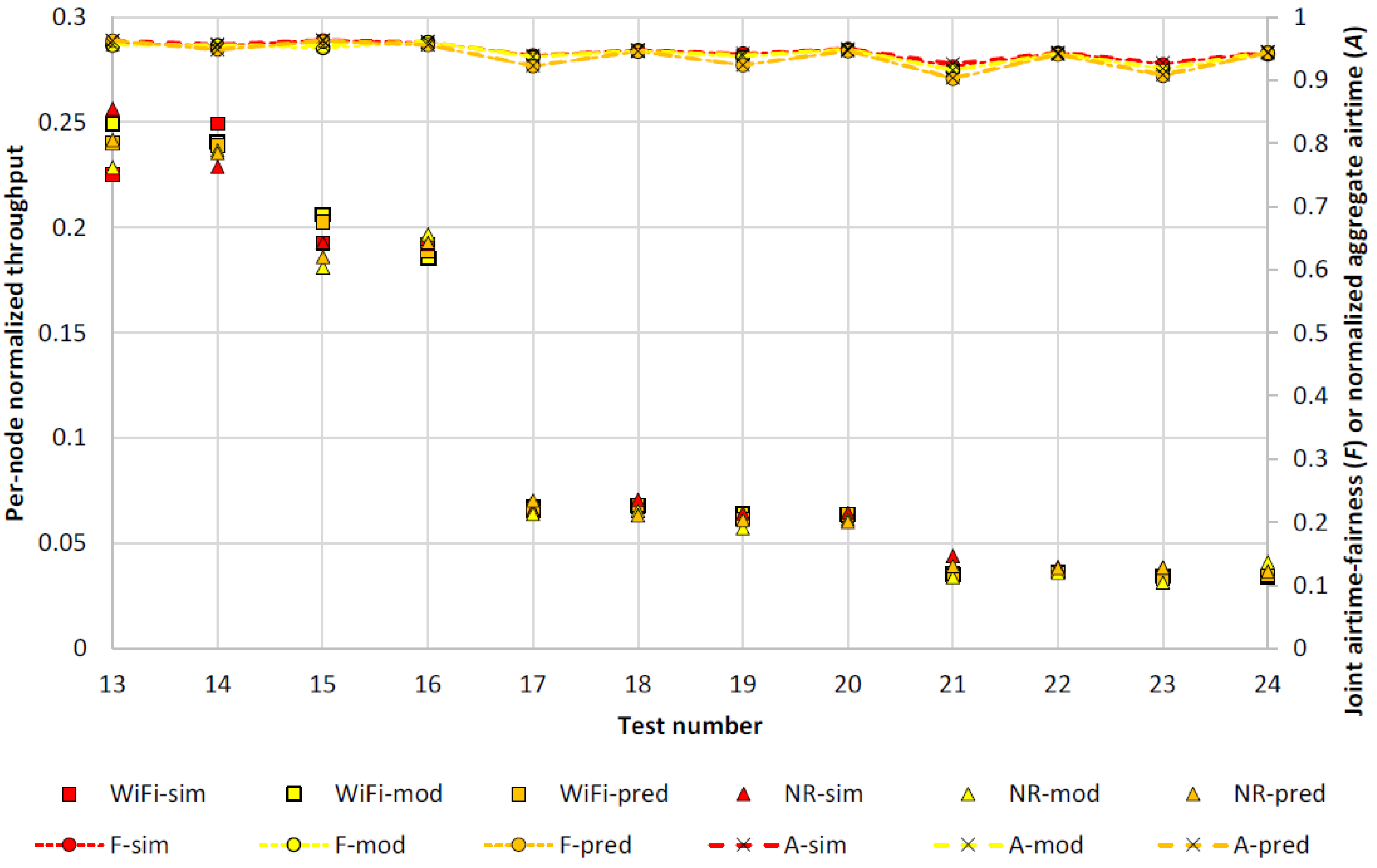
- LSTM-based
- Grid search to find hyper-parameters
- Model training
  - 40,800 samples
- Model testing
  - 9,792 samples

No.	N_W	N_N	Δ	L	No.	N_W	N_N	Δ	L
1	2	2	250	2.1	13	2	2	250	6
2	2	2	1000	2.1	14	2	2	1000	6
3	2	3	250	2.1	15	2	3	250	6
4	2	3	1000	2.1	16	2	3	1000	6
5	12	2	250	2.1	17	12	2	250	6
6	12	2	1000	2.1	18	12	2	1000	6
7	12	3	250	2.1	19	12	3	250	6
8	12	3	1000	2.1	20	12	3	1000	6
9	24	2	250	2.1	21	24	2	250	6
10	24	2	1000	2.1	22	24	2	1000	6
11	24	3	250	2.1	23	24	3	250	6
12	24	3	1000	2.1	24	24	3	1000	6

Comparison of results

Results for parameters

- predicted by the regression model (pred)
- tuned using the analytical model (mod)
- resulting with maximum test results (sim)



L = 6 ms

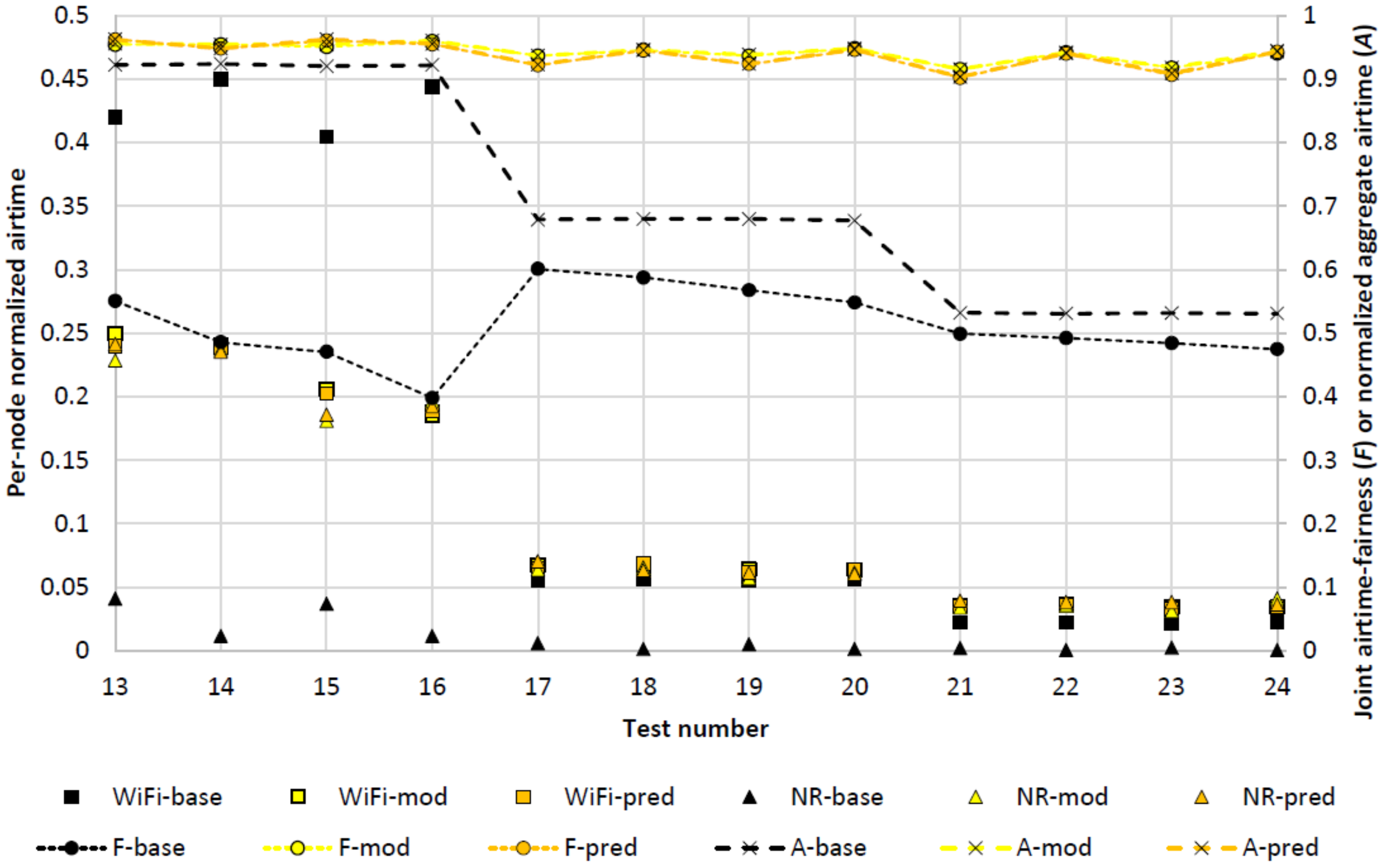
Comparison of results

Result for parameters

- predicted by the regression model (**pred**)
- tuned using the analytical model (**mod**)

vs.

Legacy operation (**base**)



L = 6 ms

Conclusions

- **Re-evaluation of the gap mechanism**
  - Gap periods can serve as a partial backoff
  - Preserves fairness between Wi-Fi and NR-U
  - Allows resigning from RS
- **Especially useful for long synchronization periods**
  - For short synchronization periods the behavior of Wi-Fi and NR-U converge
  - Can symbol-based scheduling be implemented in practical NR-U deployments?

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Thank you for your attention!

Q&A

Katarzyna Kosek-Szott: kks@agh.edu.pl