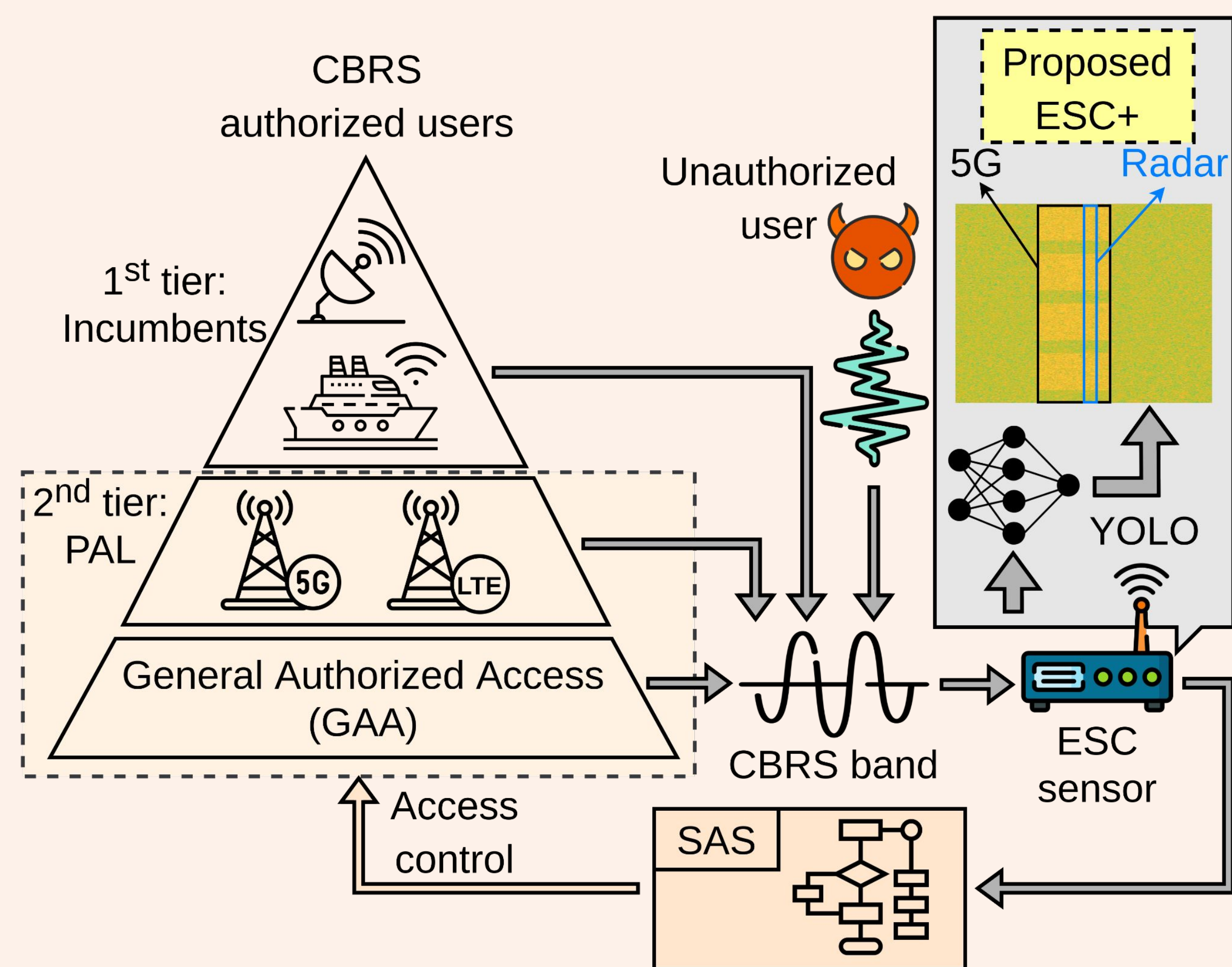


Finding Waldo in the CBRS Band: Signal Detection and Localization in the 3.5 GHz Spectrum

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Problem: Signal Detection in CBRS



Citizen Broadband Radio Service (CBRS) components:

- Environmental Sensing Capability (ESC): RF sensors deployed in coastlines.
- Spectrum Access System (SAS): Central entity that grants spectrum access.
- Whisper zone: Regions near ESC sensors where Radar signals must be protected.

Whisper zone regulations:

- Standard noise and interference level: below -109 dBm/MHz.
- Standard Radar peak power: above -89 dBm/MHz.

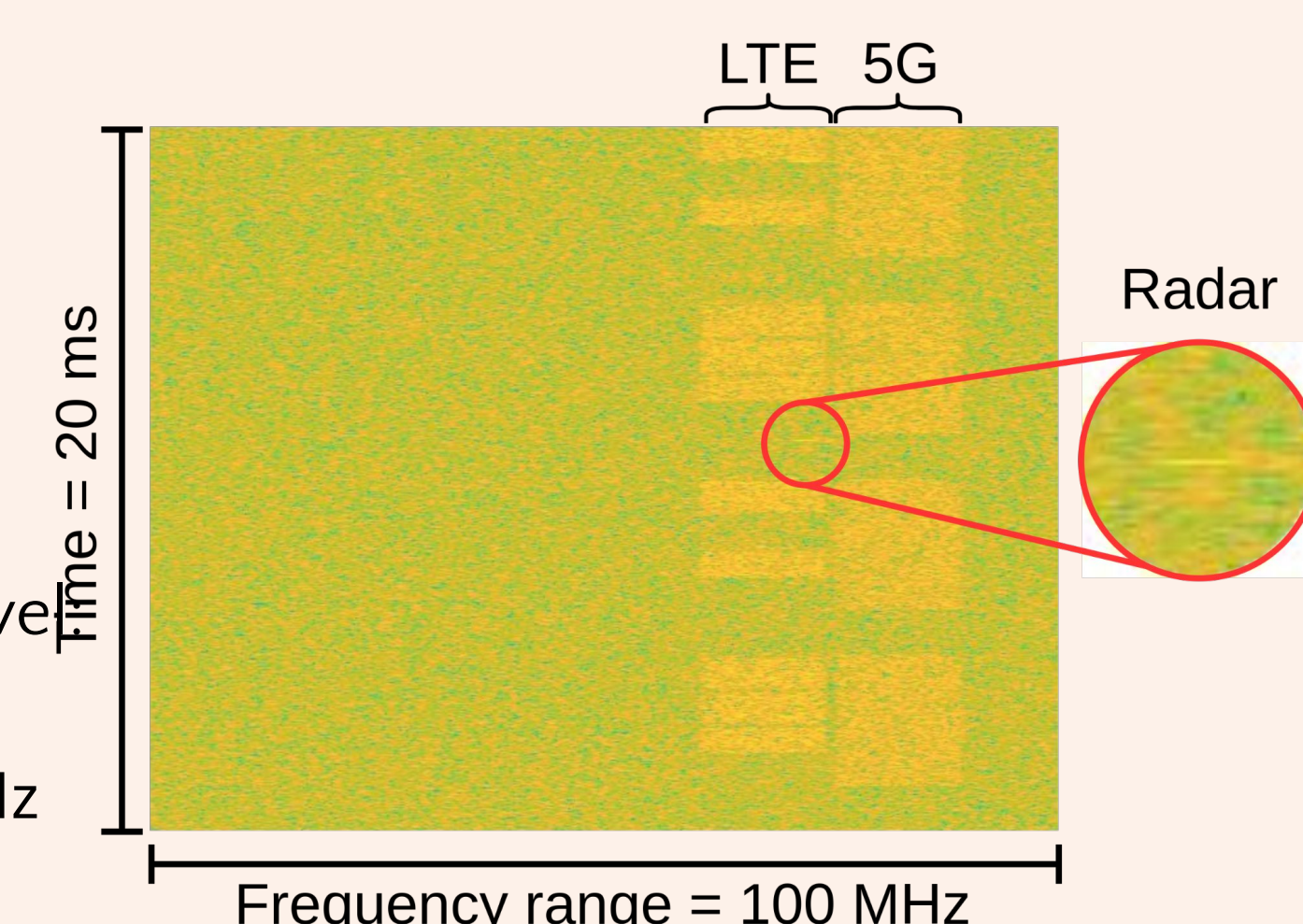
Current ESC detects Radar signals within the standard interference and noise levels using classical peak detection algorithms.

Proposed ESC+:

- Detects Radar pulses in higher interference and noise regimes.
- Detects other transmissions in the CBRS band to identify unauthorized users.

Dataset

- 1300+ spectrograms
- Three Signal types: Radar, LTE, 5G
- LTE/5G bandwidth: 5-40 MHz
- LTE/5G spectrum usage: TDD
- Radar pulse width: 0.5 μ s
- Radar pulse per burst: 20
- Pulse repetition rate: 1010
- Noise and interference level: -104 to -109 dBm/MHz
- Radar peak power: -89 to -79 dBm/MHz
- Sampling frequency: 100 MHz
- Sampling duration: 20 ms



Solution: Object Detection by YOLO

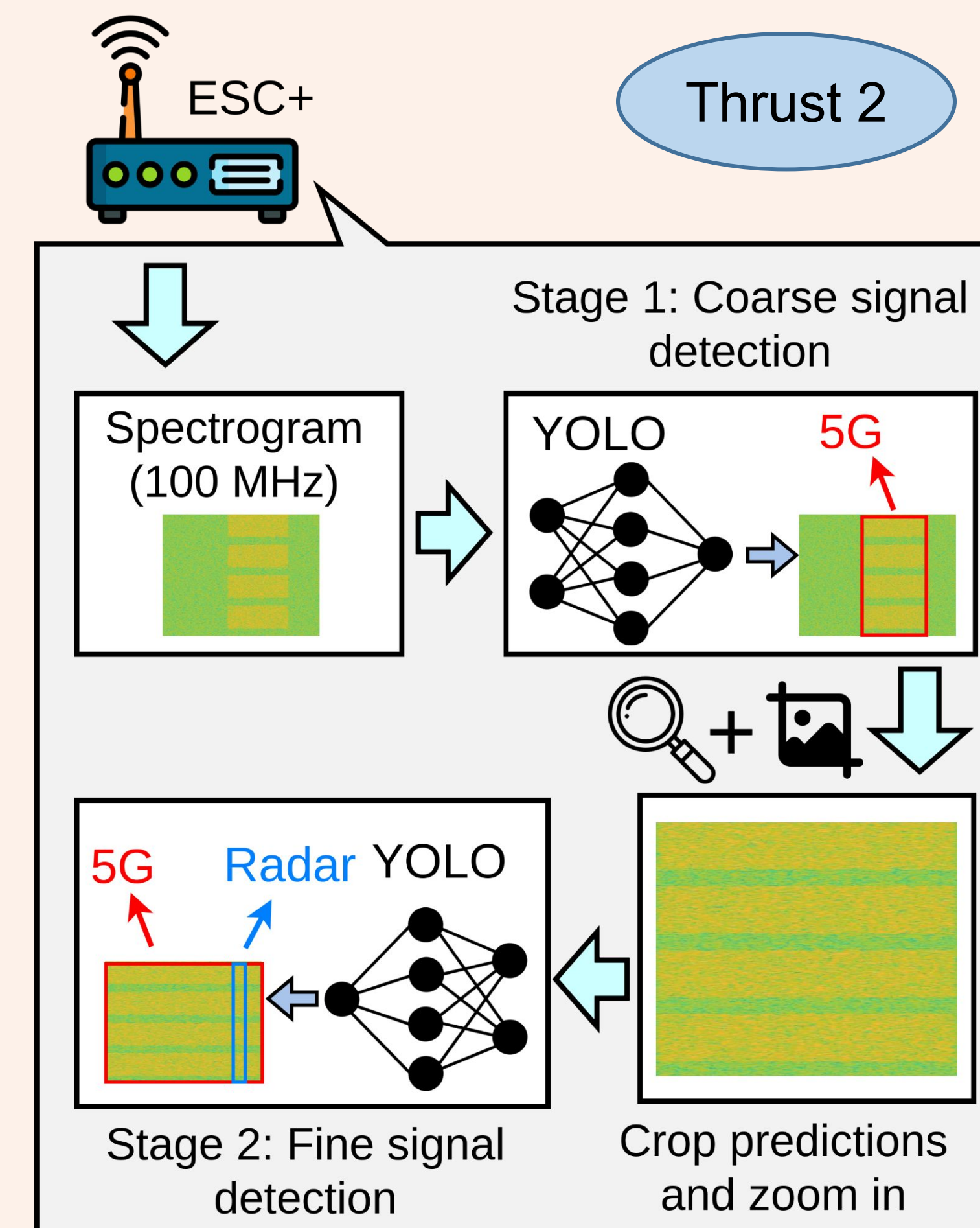
Signal detection solution:

YOLO object detection framework to detect signals in the CBRS spectrograms. YOLO:

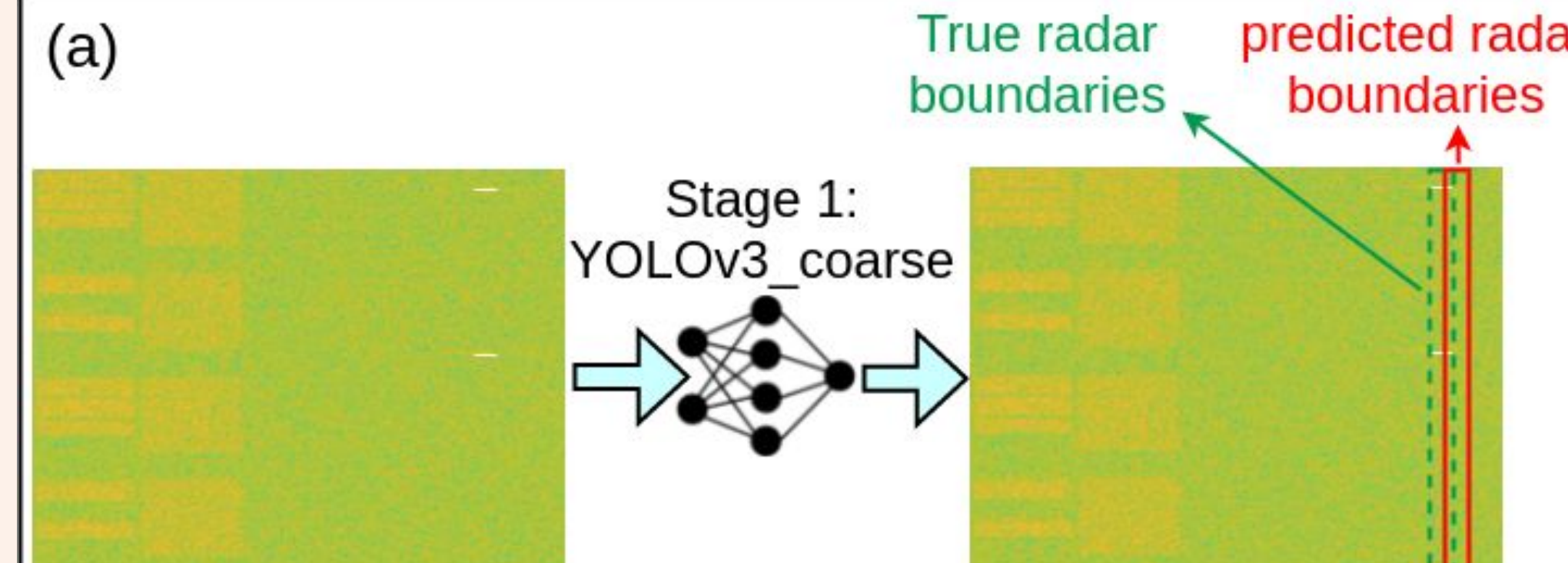
- Detects
- Classifies (Radar, LTE, 5G)
- Localizes by returning bounding boxes signals in the spectrogram

ESC+ steps:

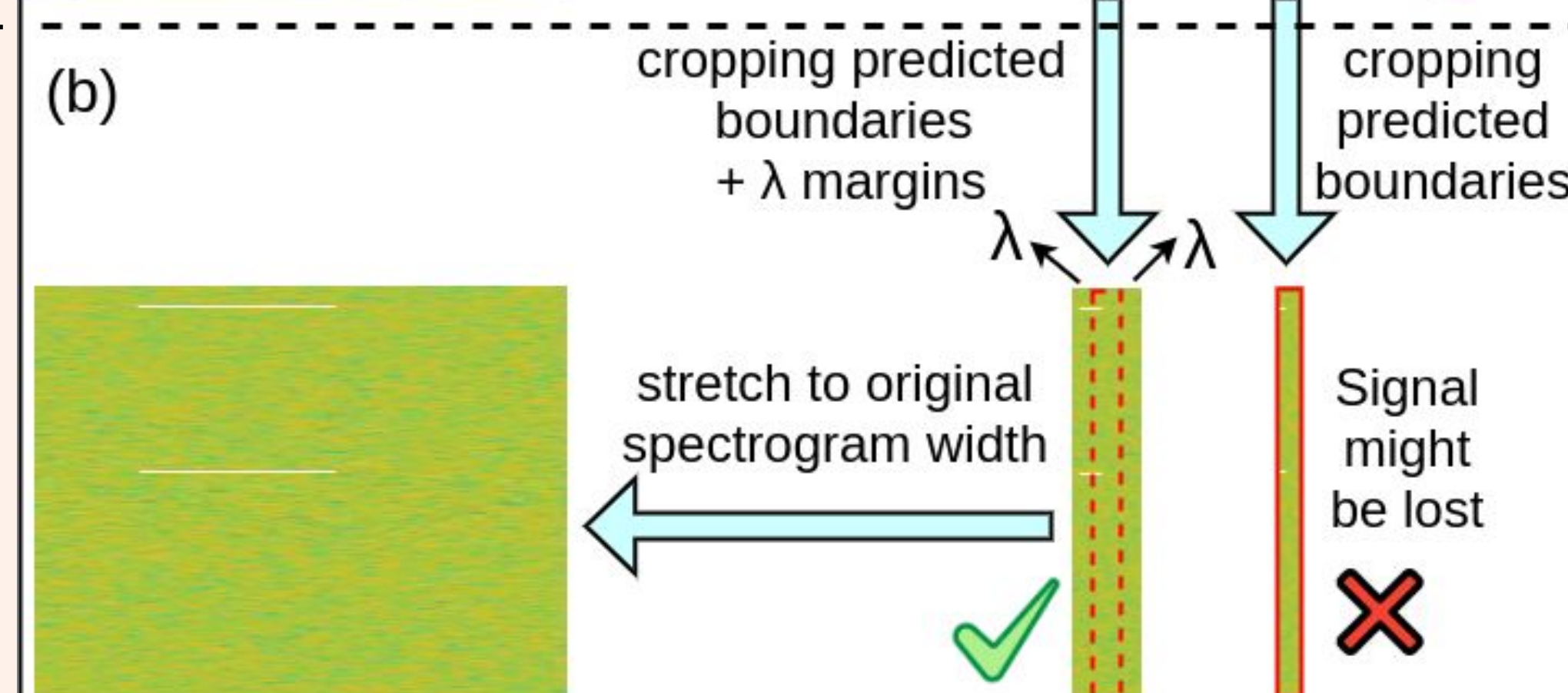
- Coarse signal detection for detecting and coarsely localizing signals. In the
- Cropping the independent signals (LTE/5G and those radar signals that do not overlap with LTE/5G)
- Zooming in the cropped spectrogram by stretching it.
- Fine signal detection through another YOLO that is trained using cropped and stretched spectrograms.



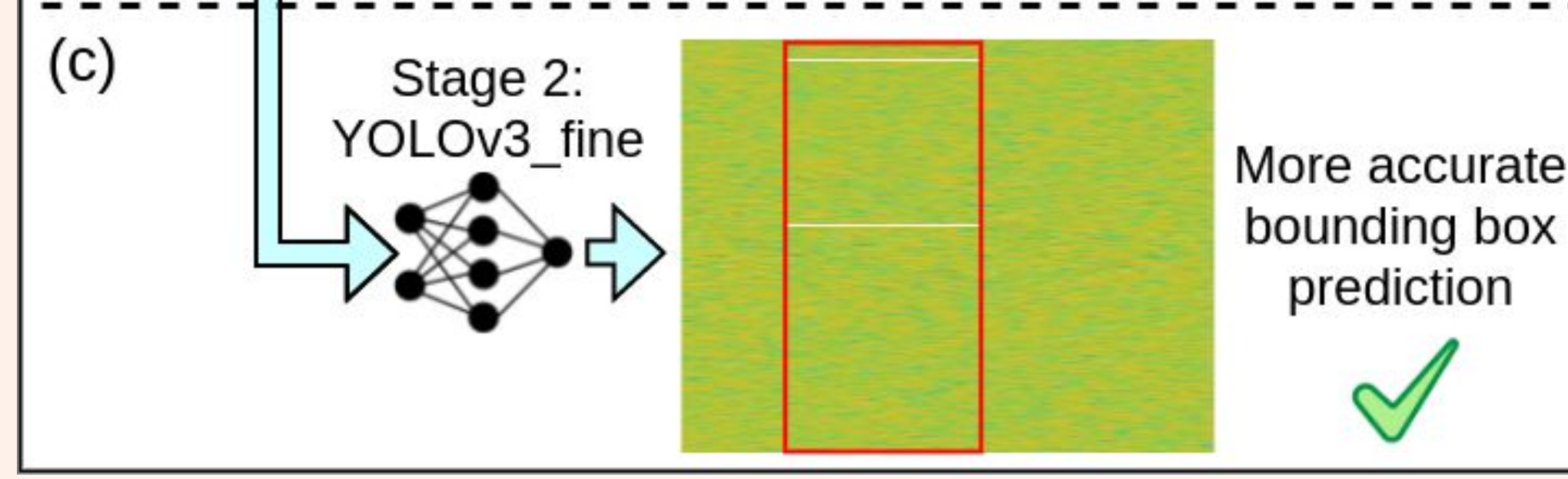
(a) Passing spectrograms through coarse signal detector in Stage 1. Predicted boundaries might not be same as true boundaries.



(b) To avoid cropping errors, we define a λ margin at both sides of predicted boundaries. We crop the signal from margined boundaries and stretch it.



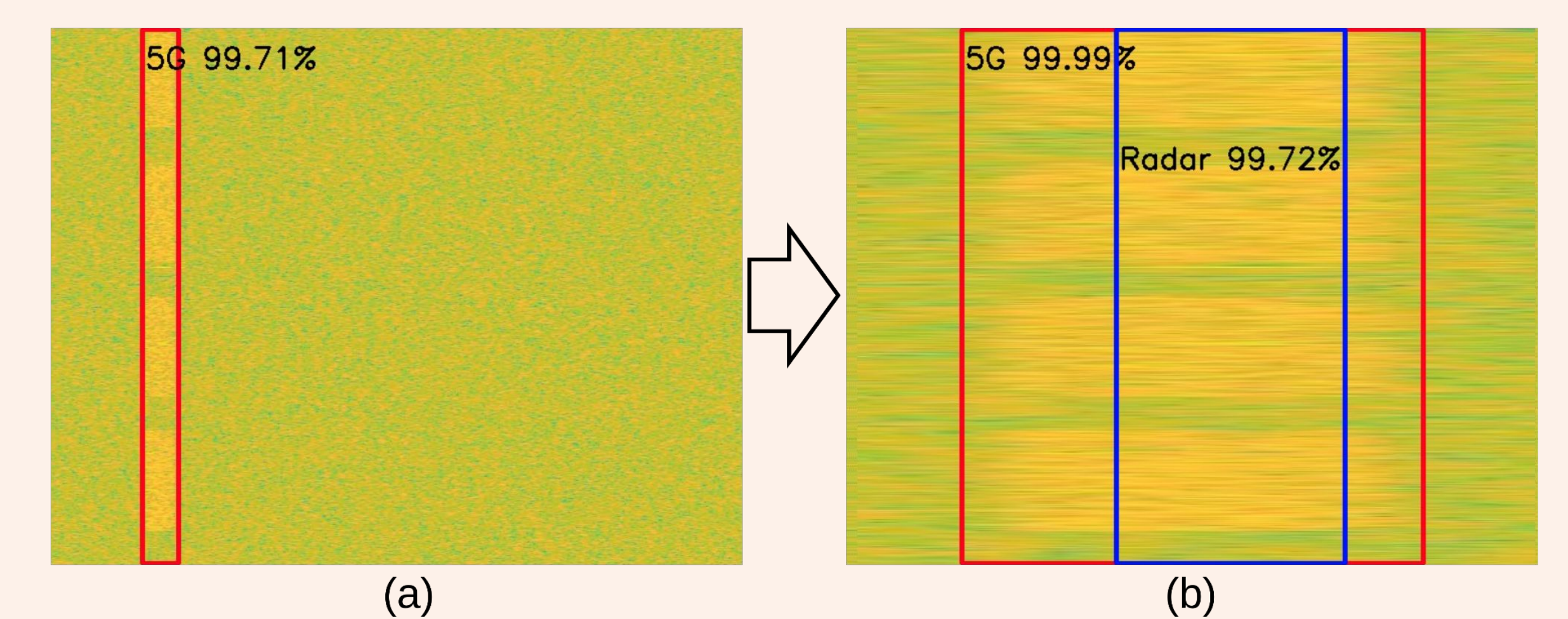
(c) The signal falls within the cropped boundaries and is detected by fine signal detector at Stage 2 with accurate bounding boxes.



λ margin is achieved empirically using the validation set:

- Pixel errors of predicted bounding boxes at inference at Stage 1 are recorded.
 - λ is calculated as the maximum of errors for each signal type.
- We achieve 3λ s in the end, one for each signal type.

Results



The narrow Radar signal within 5G is detected after the second stage.

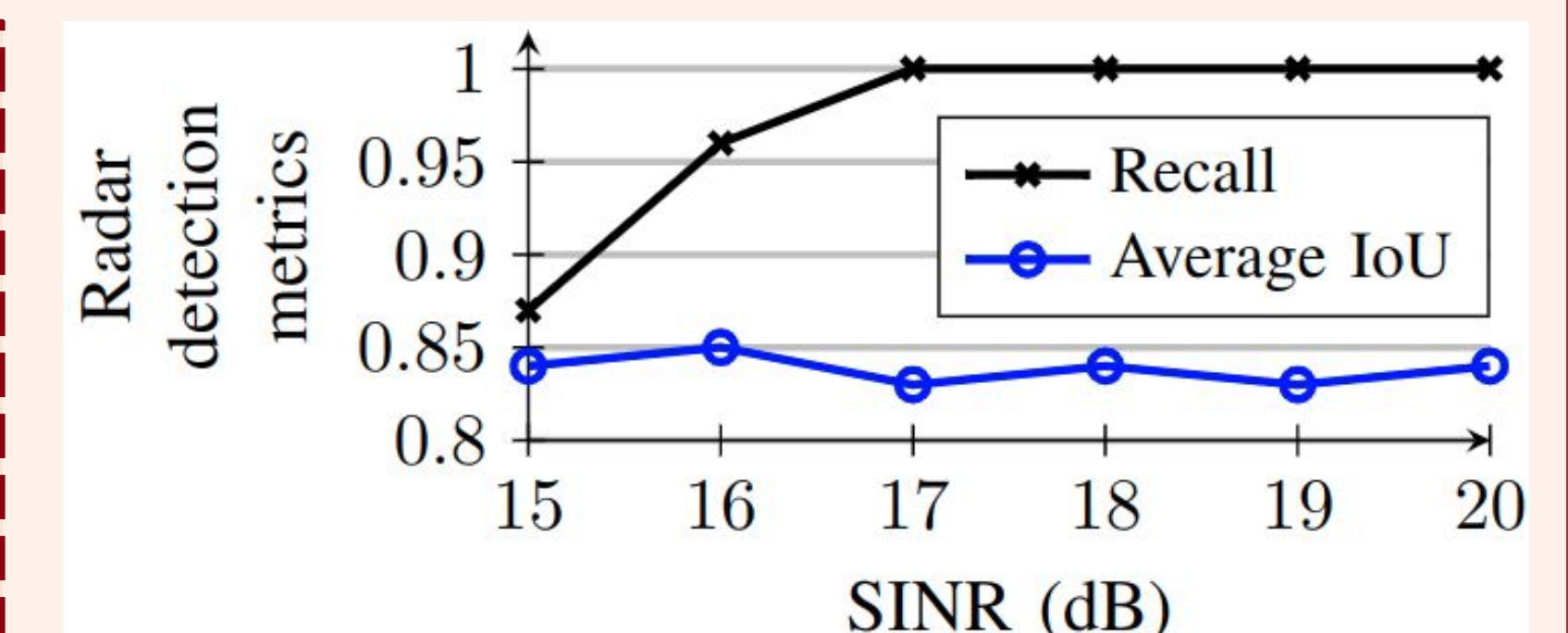
	Metric	Signal Type		
		Radar	5G	LTE
Stage 1	Recall	98%	100%	100%
	Average IoU	0.75	0.95	0.94
	False Positives	30	1	1
	Average Precision	0.89	0.99	0.99
Stage 2	Recall	99%	100%	100%
	Average IoU	0.85	0.97	0.97
	False Positives	10	0	0
	Average Precision	0.96	1.00	1.00

Detection metrics for all signals improve at Stage 2, compared to Stage 1.

- Radar recall reaches 99%.
- Radar average IoU improves by 13%.
- Radar false positives improves by 66%.
- Radar average precision improves by 7%.

Radar detection:

- Recall: 100% in $\text{SINR} \geq 17$ dB
- Average IOU: 83% in $\text{SINR} \leq 20$ dB



Conclusion

The proposed ESC+ is able to detect 100% of Radar signals as well as LTE and 5G in SINRs 3 dB lower than FCC-mandated limits.

LTE and 5G base stations can transmit in the CBRS band with higher power in the whisper zone.

Better cellular connectivity can be achieved in the CBRS band near coastlines.