An Efficient Data Transmission Framework for Connected Vehicles

Yichen Luo[1], Yongtao Yao[2], Junzhou Chen[1], Sidi Lu[1], Weisong Shi[2]

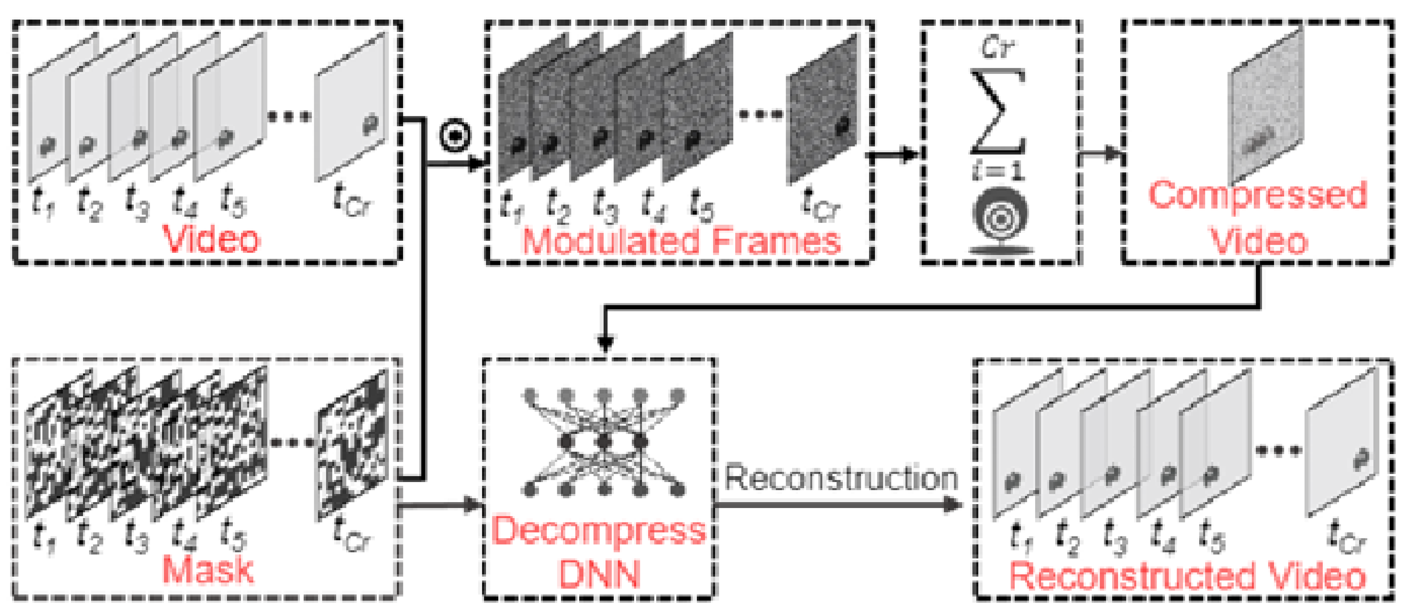
[1]William & Mary, [2]University of Delaware

yluo11@wm.edu

Paper   Lab Website   Contact Details

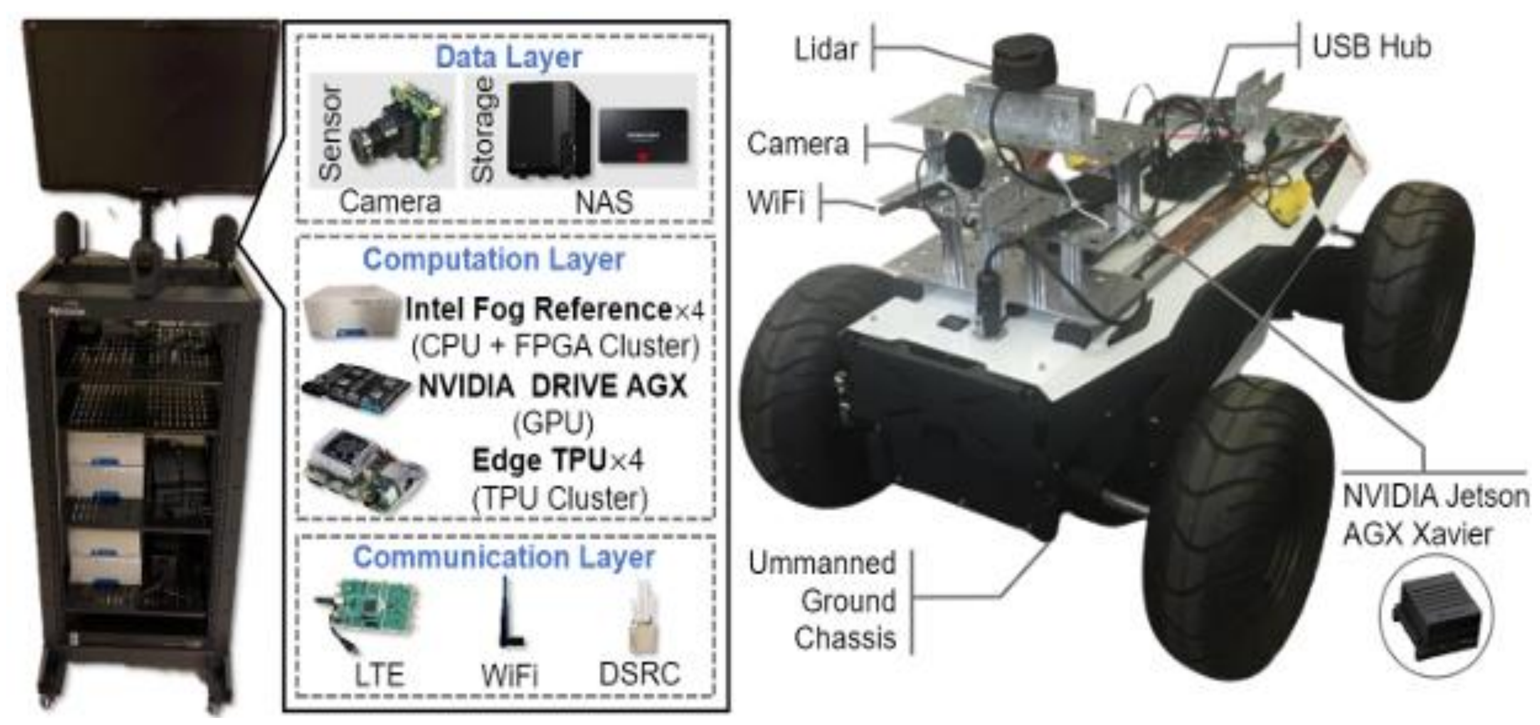
Background

- ❖ **Connected vehicles** (CV)
  - CVs transmit over 10EB of data per month
  - Continuous data transmission→$1B bandwidth cost
  - Latency-sensitive & resource-hungry applications
- ❖ **Temporal compressive sensing** (TCS)
  - Optical-domain compression
  - Mapping every continuous *Cr* frames into a single compressed video image (measurement)

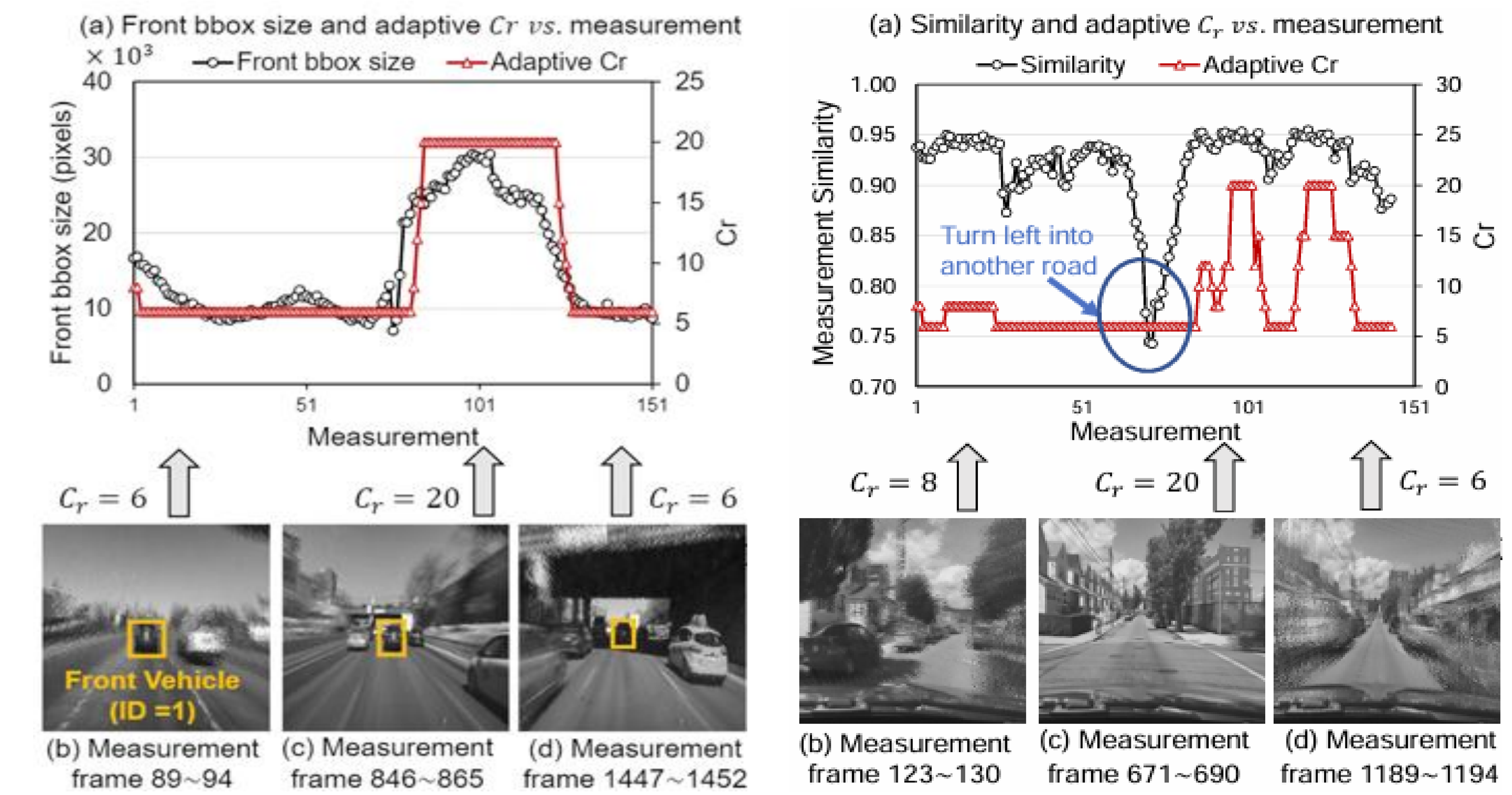


VEC Closed-loop Framework

- ❖ **Vehicle:** detection directly on the measurements w/o reconstruction controlled by RL policies & send compressed video
- ❖ **EdgeServer**: reconstruct high-speed data with a triggered event
- ❖ **Cloud:** aggregates all useful information
- ❖ Testing on industry-grade hardware



Adaptive Sensing Results based on Two RL



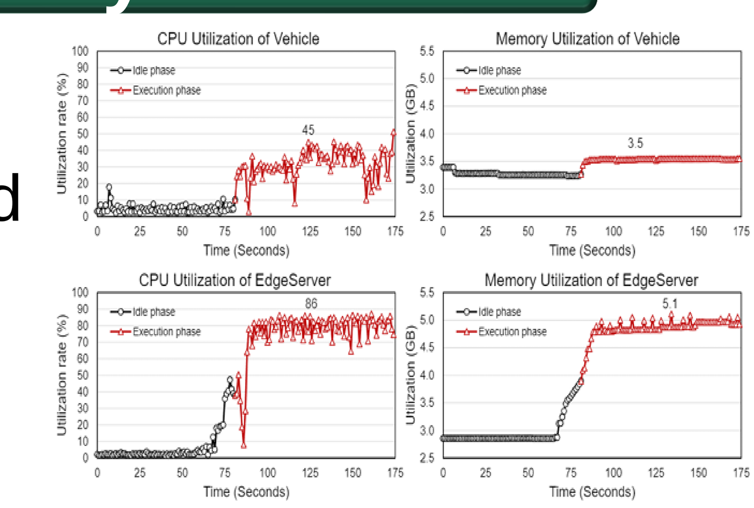
Average Inference Speed in Vehicle

❖ YOLOv3-Tiny: 16ms + CenterTrack (RL-I): 26ms

When a CV is driving at 40km/h in an urban area, real-time tasks' execution time should be less than **100ms**

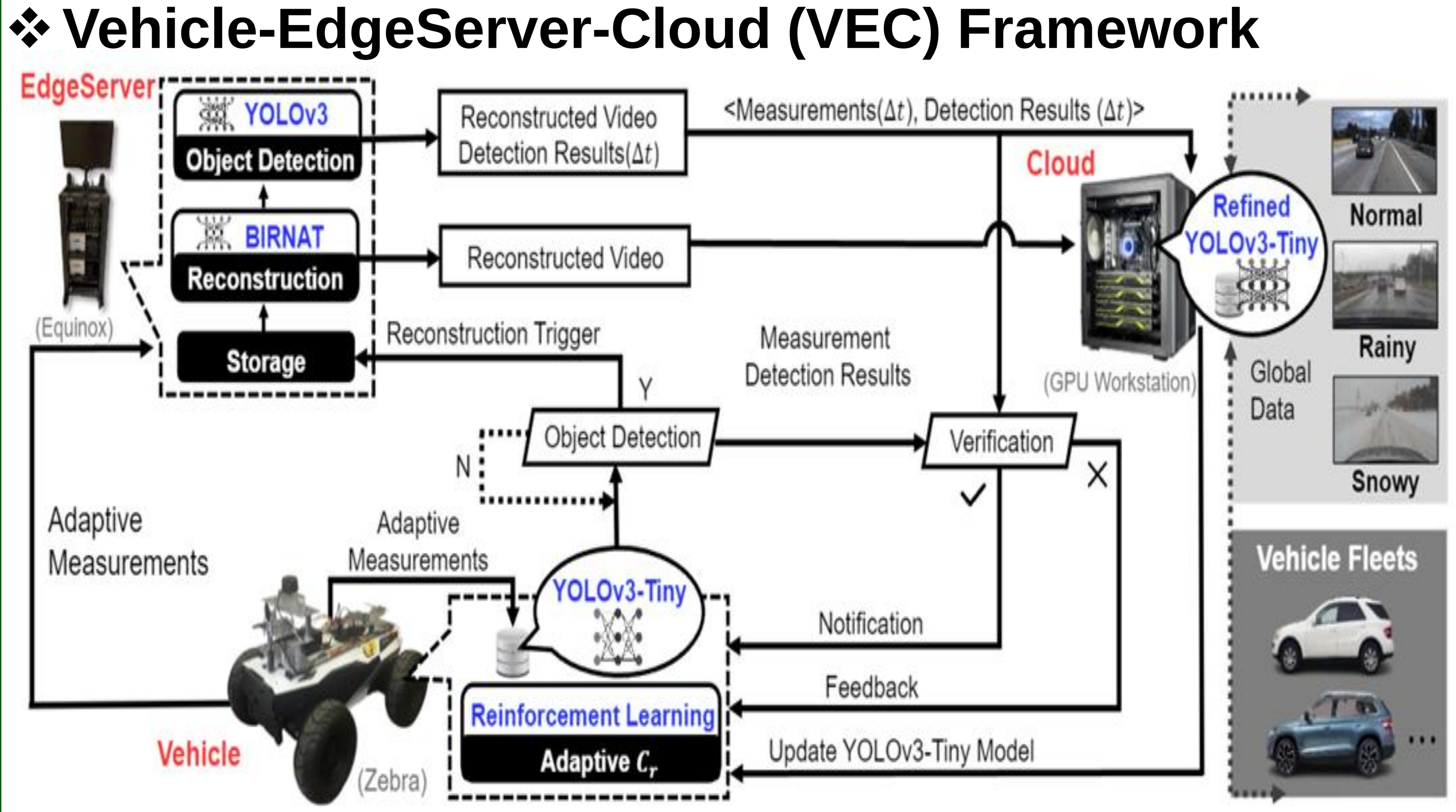
CPU and Memory Utilization

❖ The VEC framework offloads significant CPU and memory pressure from the vehicle to the EdgeServer.



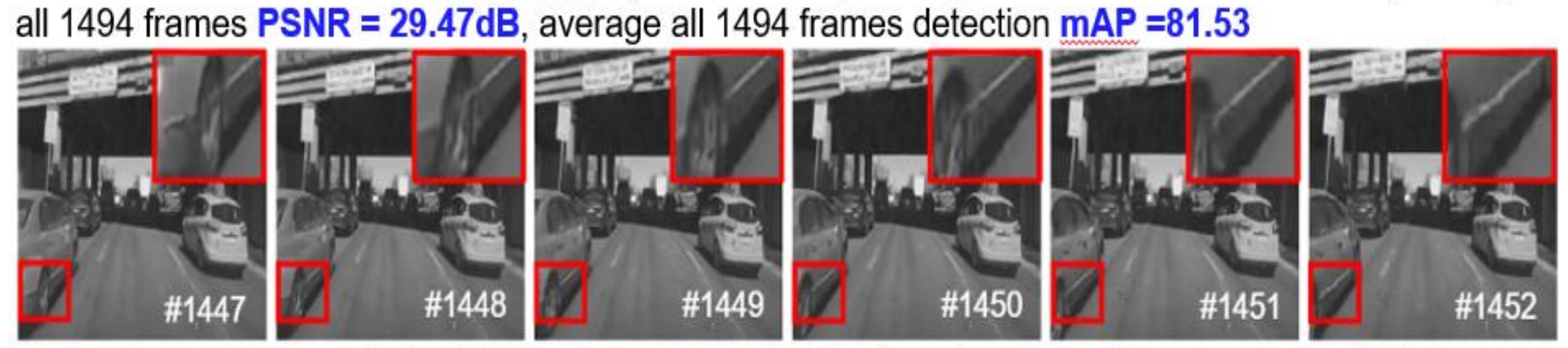
Takeaways

- ❖ **Adaptive TCS: high-speed & low-speed**
  - High-motion scenario (highway) → small *Cr*
  - Low-motion scenario (urban) → large *Cr*
- ❖ **Two designed reinforcement learning (RL) policies for adaptive compression**
  - RL-I: tracking-driven (front vehicle tracking)
    - Deep SORT *vs.* CenterTrack
  - RL-II: similarity-driven (measurement similarity)
  - - MobileNets + Cosine distance
- ❖ **Vehicle-EdgeServer-Cloud (VEC) Framework**

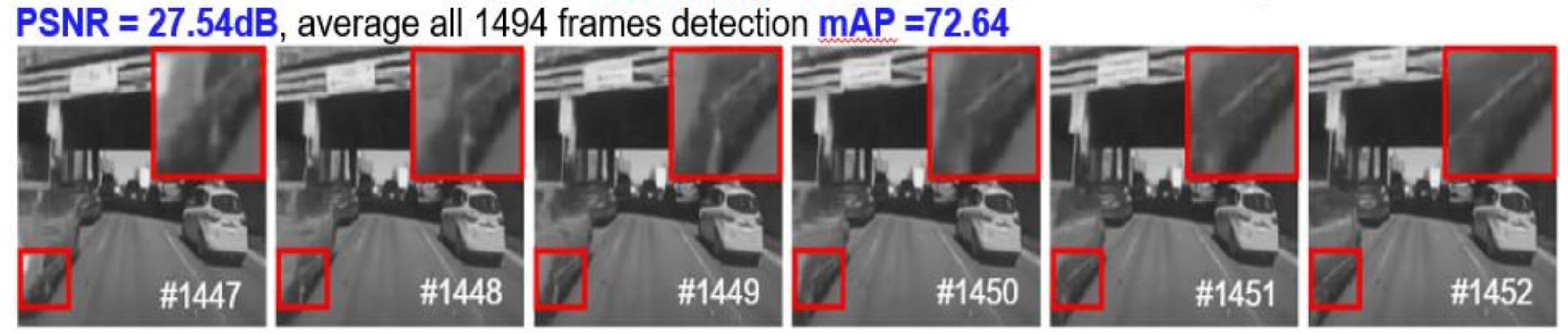


Effectiveness of TCS

Reconstructed frames with **adaptive *Cr*** (current *Cr* = 6, average all 1494 frames *Cr* = 10.89) average all 1494 frames **PSNR = 29.47dB**, average all 1494 frames detection **mAP =81.53**



Reconstructed frames 1447~1452 with **non-adaptive *Cr*** (constant) *Cr* = 10, average all 1494 frames **PSNR = 27.54dB**, average all 1494 frames detection **mAP =72.64**



❖ **Adaptive Cr *vs.* Non-adaptive Cr** (expected value):
- Higher reconstruction quality (29.47 vs. 27.54)
- Higher average detection rate (81.53 vs. 72.64)

Reconstruction Quality

❖ **Reconstruction model**: BIRNET *vs.* E2E-CNN
- Winner: BIRNET (Cr = 6, 8, 10, 12, 15, 20)

Algorithm	Cr = 6	Cr = 8	Cr = 10	Cr = 12	Cr = 15	Cr = 20
E2E-CNN	27.76	26.40	25.77	24.74	24.52	23.33
BIRNAT	34.71	32.60	29.97	29.41	29.32	28.48

Recovery from Noisy Measurement

❖ Add different Gaussian noise
- PSNR is still above 25dB
- Detection rate is still high

PSNR, DR \ B / σ	6	10	15
0	28.73, 85.43	28.44, 85.57	28.33, 81.38
0.005	28.56, 85.21	28.30, 84.36	28.19, 80.18
0.010	28.18, 83.74	27.99, 81.62	27.89, 77.45
0.050	24.70, 75.34	24.62, 76.33	24.52, 71.26
0.100	21.58, 71.47	21.52, 71.23	21.44, 68.49

Communication Bandwidth

- ❖ Required Bandwidth
  - RGB image: 5761KB/s
  - Grey-scale: 1921KB/s
  - Measurement: 320KB/s
- ❖ Demonstrate an 18× reduction in bandwidth at 320KB/s while maintaining high detection accuracy