Aggressive Compression of MobileNets Using Hybrid Ternary Layers

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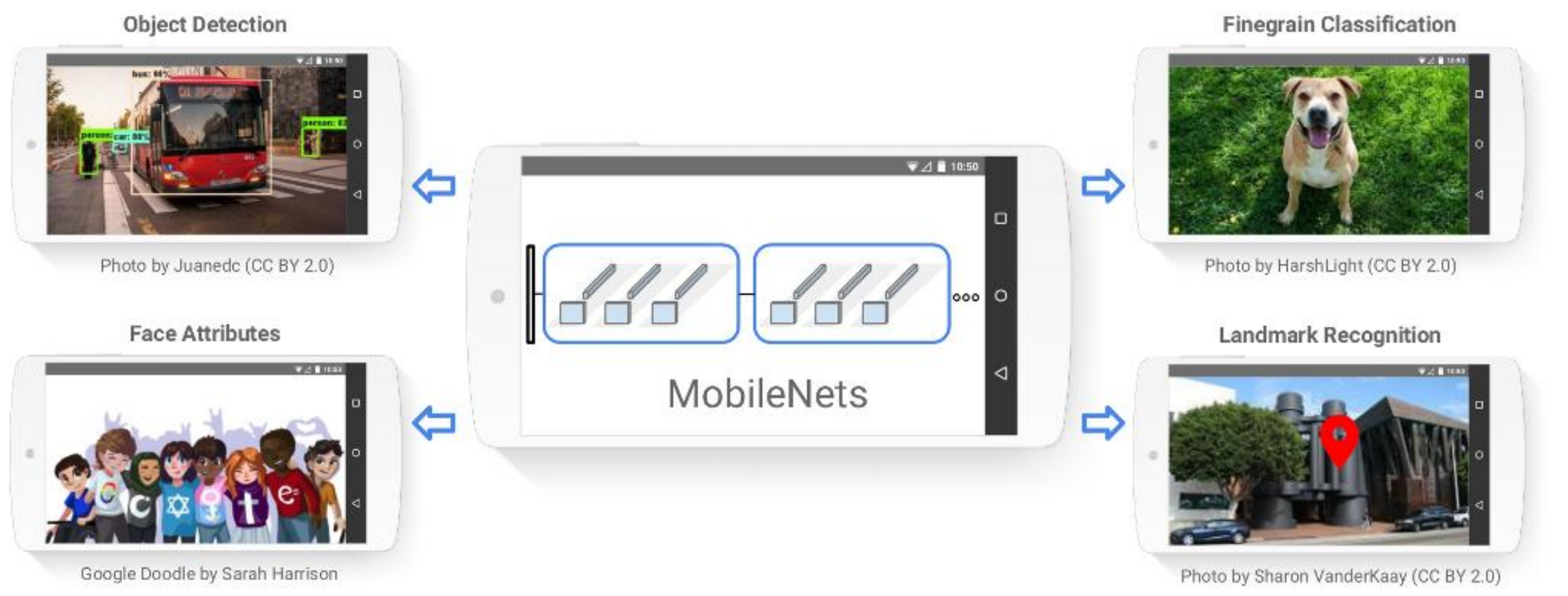
Challenge

- MobileNets [1] family of CV networks are increasingly deployed at mobile/edge devices
- Quantizing MobileNets to ternary weights (2-bit) is necessary to realize siginificant energy savings and runtime speedups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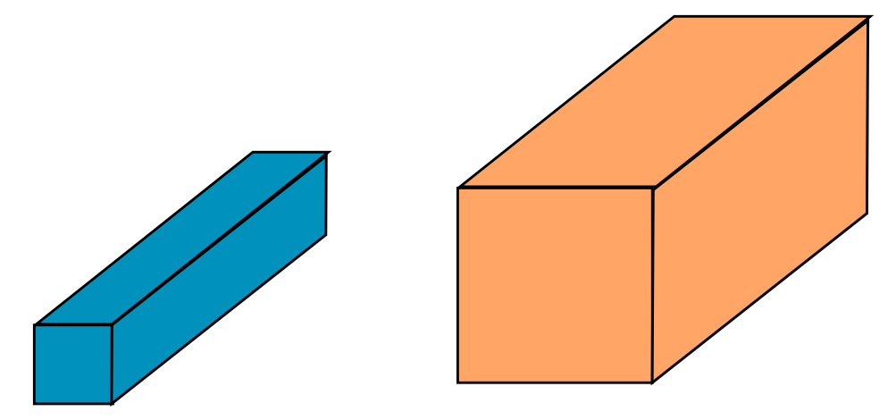


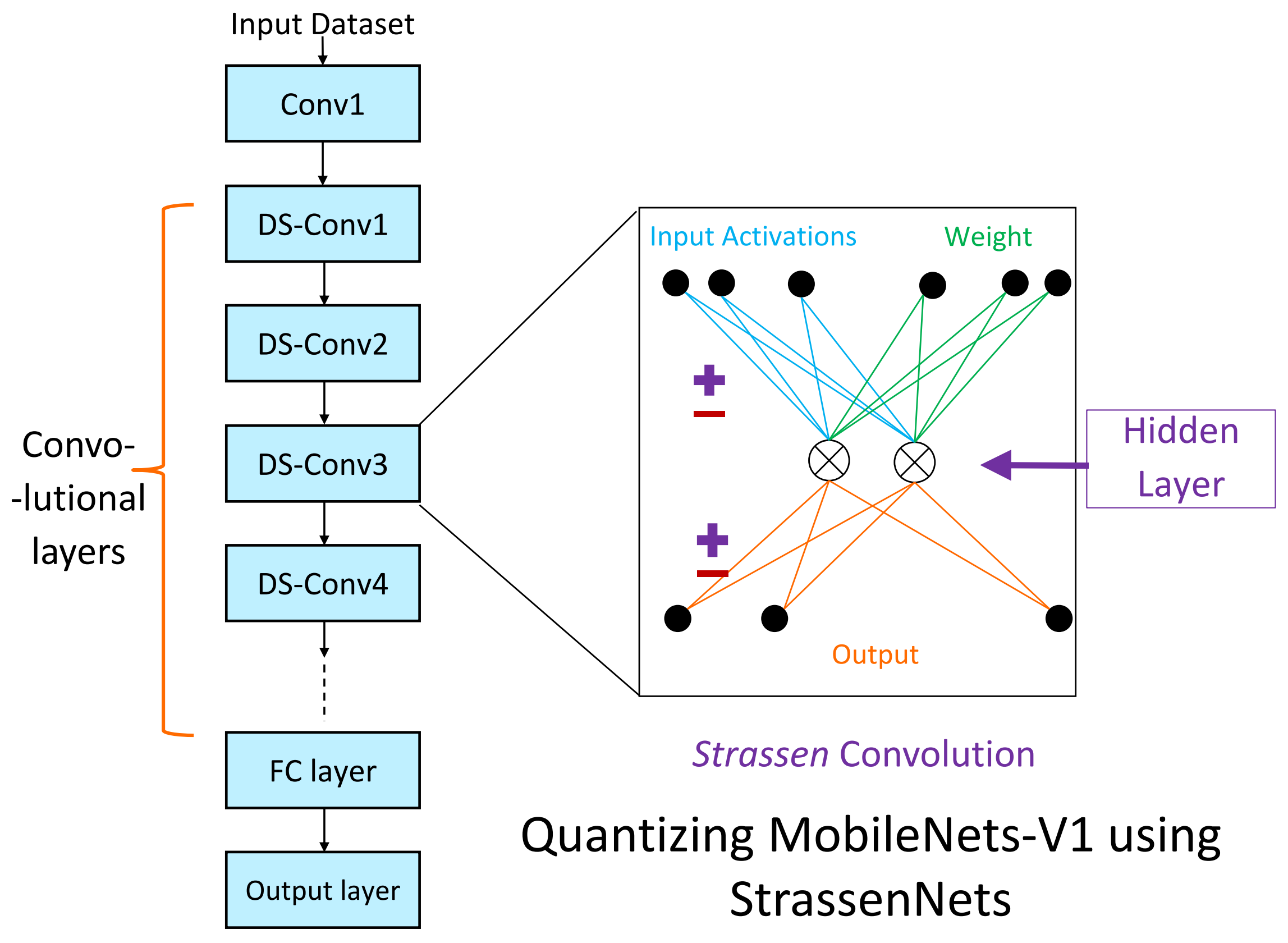
1 x 1 filter — Very compact

3 x 3 filter — Over parametrized

- MobileNets V1 – 13 depthwise separable (DS) convolutional layers
- Model complexity dominated by compact 1 x 1 filters

Prior Solutions

- Ternary weight networks (TWN) [2]
  - (-) Drops accuracy
- StrassenNets [3]
  - (+) 99% reduction in MULs for 3 x 3 filters
  - (+) mostly ternary weights, preserve accuracy
  - (-) Never looked into DS (1 x 1) layers
- Prior solutions come with their own advantages and limitations

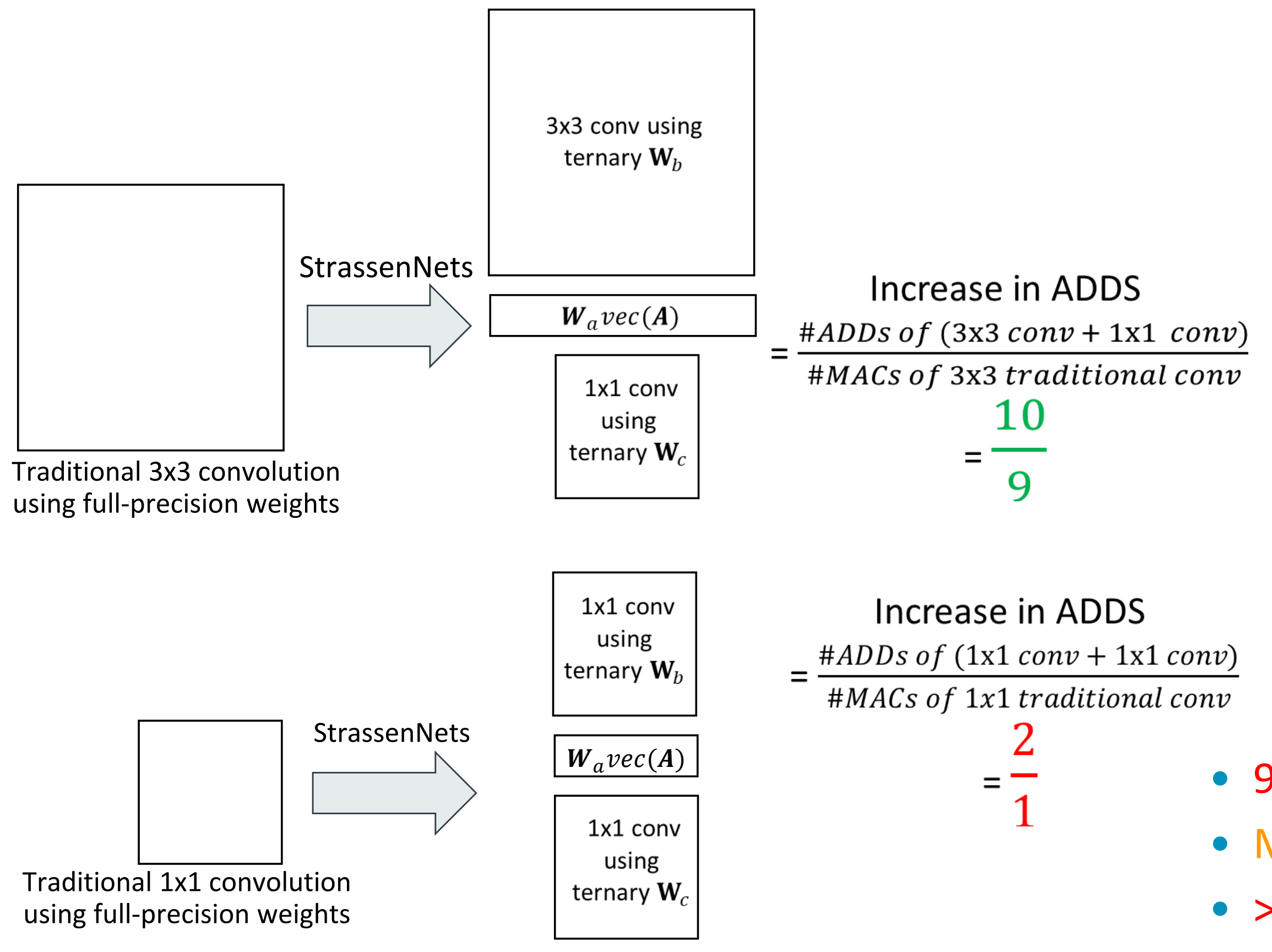


Strassen Convolution

Quantizing MobileNets-V1 using StrassenNets ternary quantization scheme

MobileNets-V1

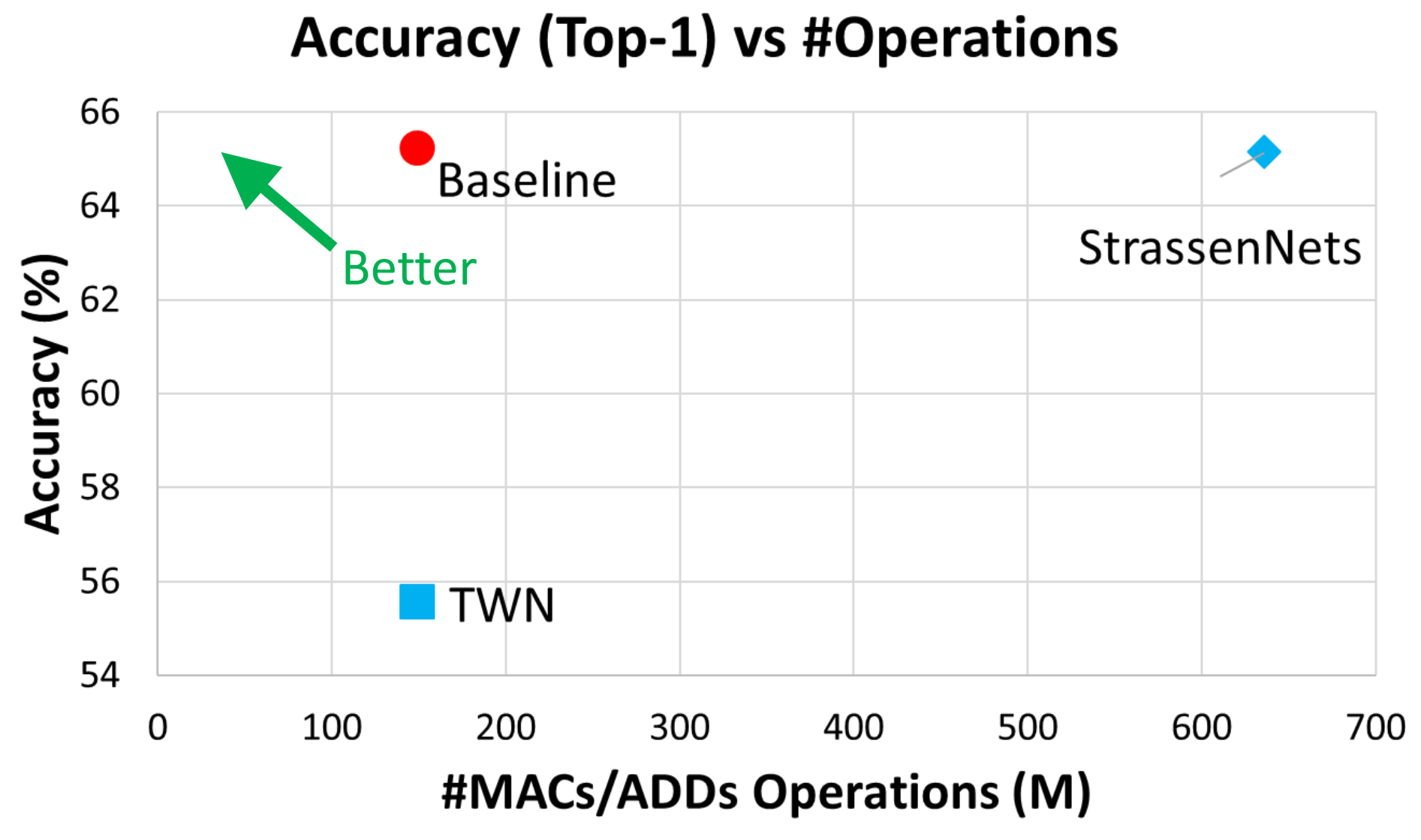
Observations with Prior Solutions



Increase in ADDS
$$= \frac{\#ADDs\ of\ (3x3\ conv + 1x1\ conv)}{\#MACs\ of\ 3x3\ traditional\ conv} = \frac{10}{9}$$

Increase in ADDS
$$= \frac{\#ADDs\ of\ (1x1\ conv + 1x1\ conv)}{\#MACs\ of\ 1x1\ traditional\ conv} = \frac{2}{1}$$

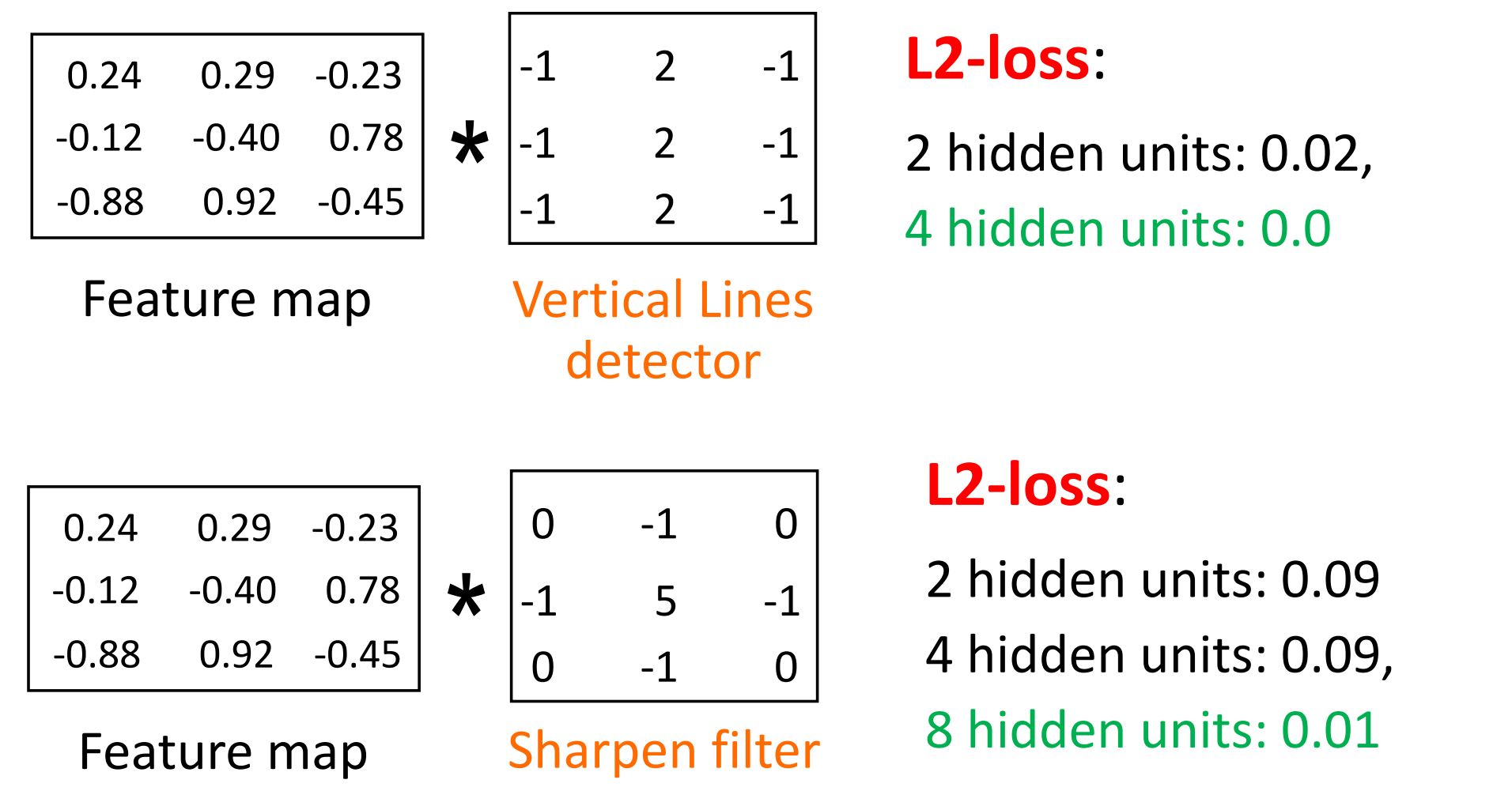
Application of StrassenNets to 3 x 3 and 1 x 1 convolution



- 9.6% drop in accuracy using Ternary Weight Networks
- Modest savings in model size using StrassenNets
- >300% increase in ADDs/Ops for iso accuracy using StrassenNets
- Use of Wide hidden layers for closely approximating each 1 x 1 filter of MobileNets → >300% increase in ADDs using StrassenNets

Different filters respond differently to ternary quantization

Different sensitivity of individual filters to StrassenNets

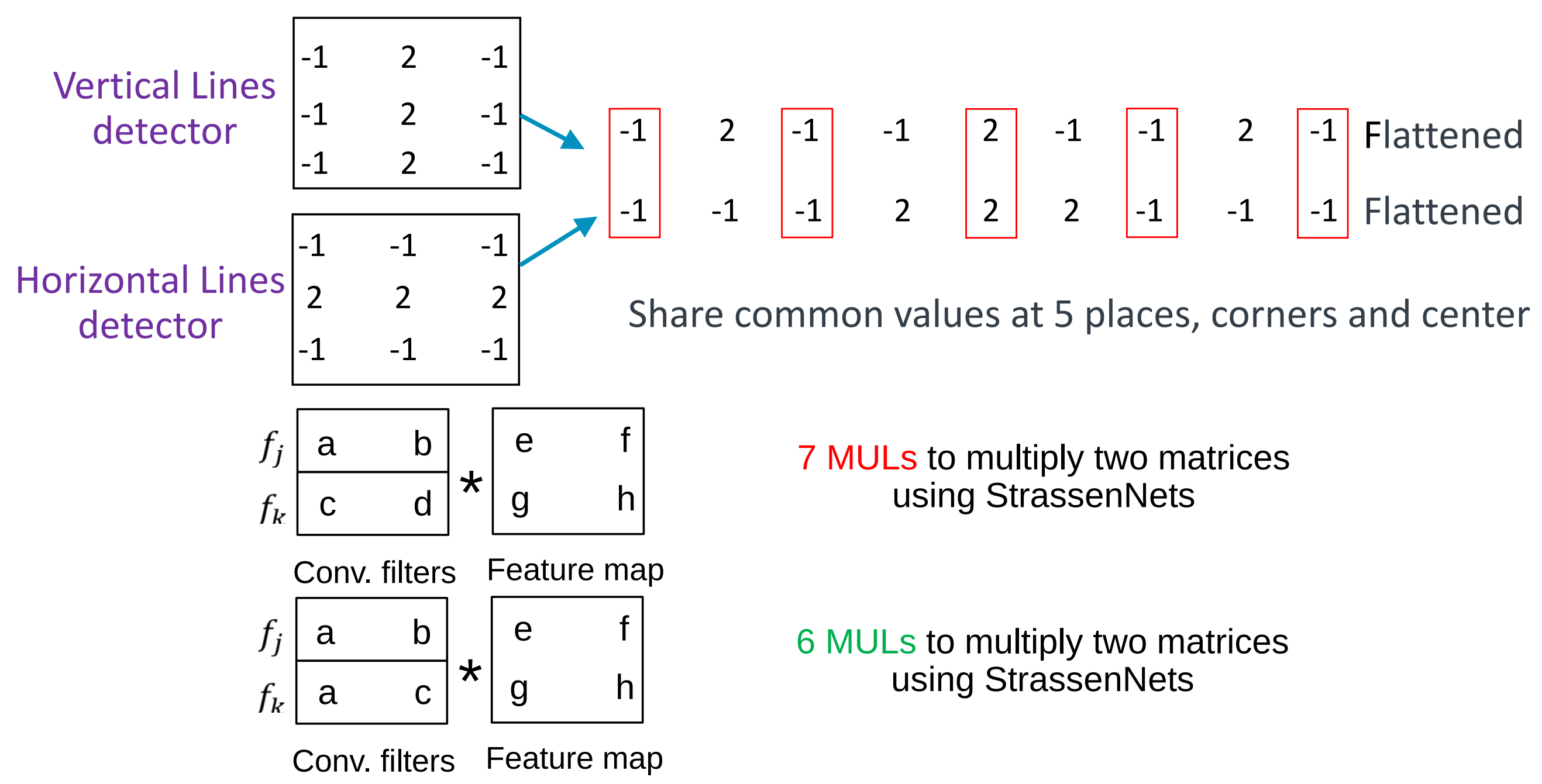


L2-loss:
2 hidden units: 0.02,
4 hidden units: 0.0

L2-loss:
2 hidden units: 0.09
4 hidden units: 0.09,
8 hidden units: 0.01

Not all filters do require wide hidden layers to be approximated well using StrassenNets

Different sensitivity of group of filters to StrassenNets



Share common values at 5 places, corners and center

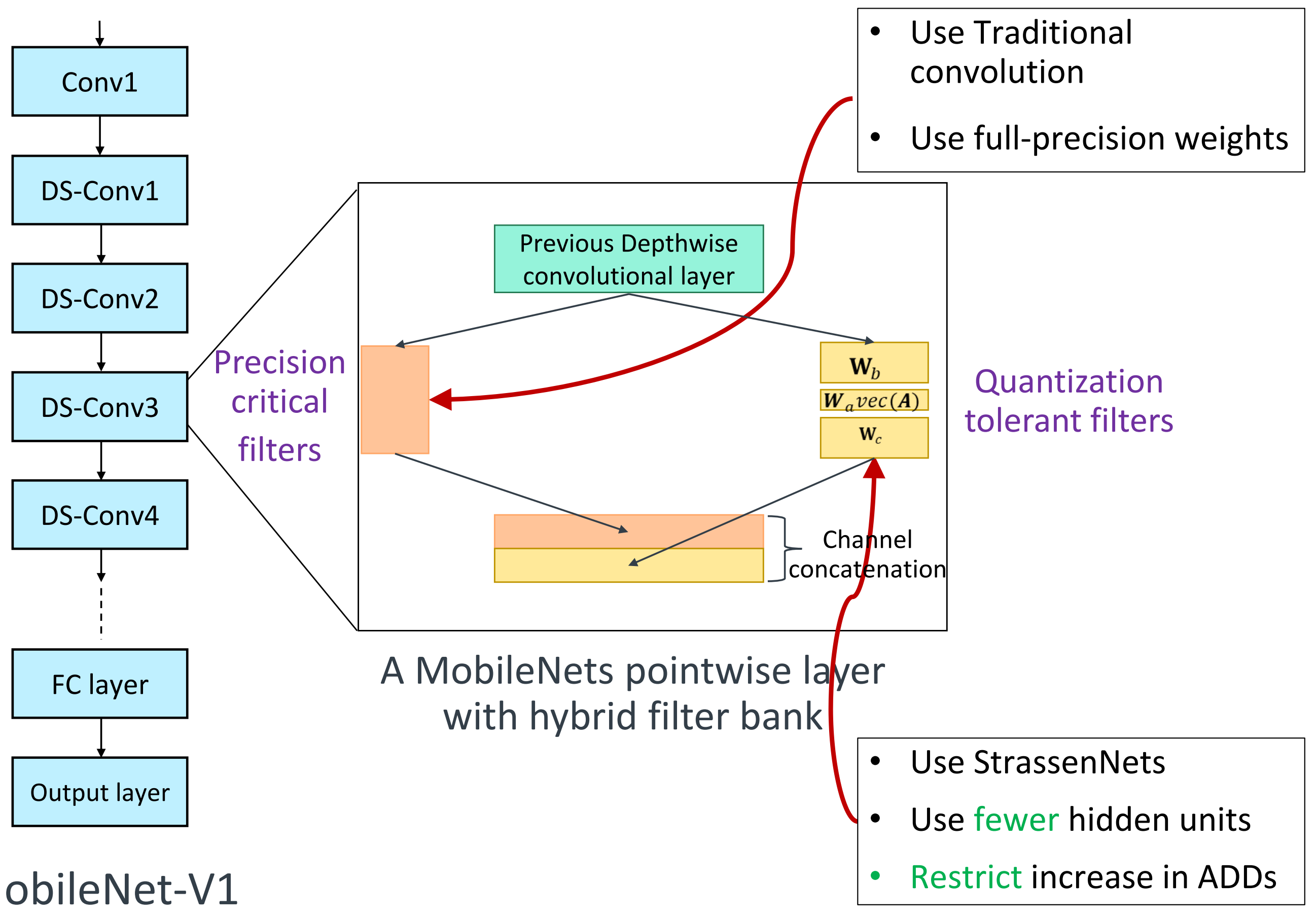
7 MULs to multiply two matrices using StrassenNets

6 MULs to multiply two matrices using StrassenNets

Per-Layer Hybrid Filter Banks

Exploit the difference in sensitivity of individual and groups of filters to ternary quantization

- Bank similar value structure filters together
- Share hidden units of StrassenNets
- Use fewer hidden units → fewer ADDs/Ops to approximate a major portion of filters at each layer
- See our paper (https://arxiv.org/abs/1911.01028) for Mathematical proof, details



- Use Traditional convolution
- Use full-precision weights

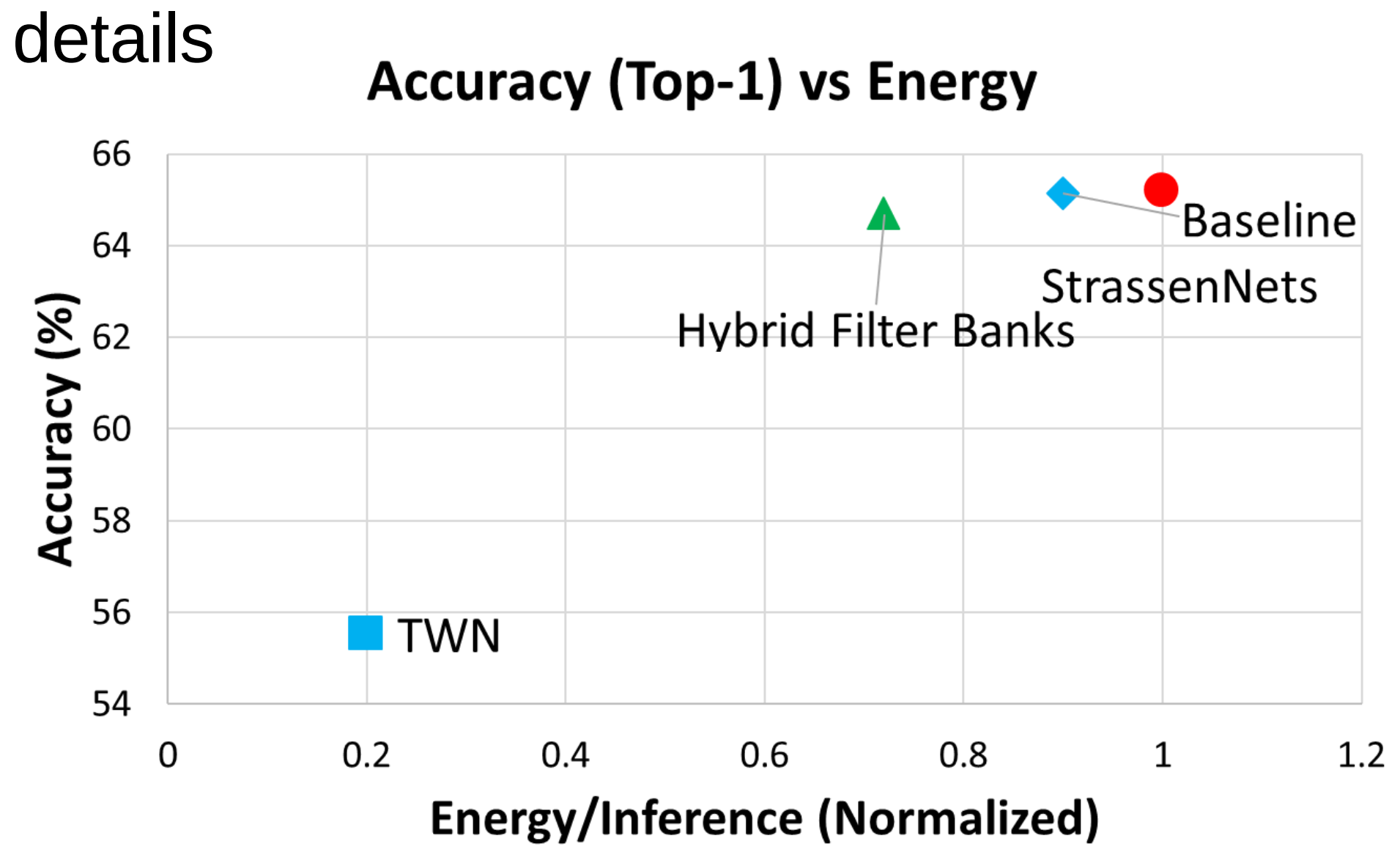
- Use StrassenNets
- Use fewer hidden units
- Restrict increase in ADDs

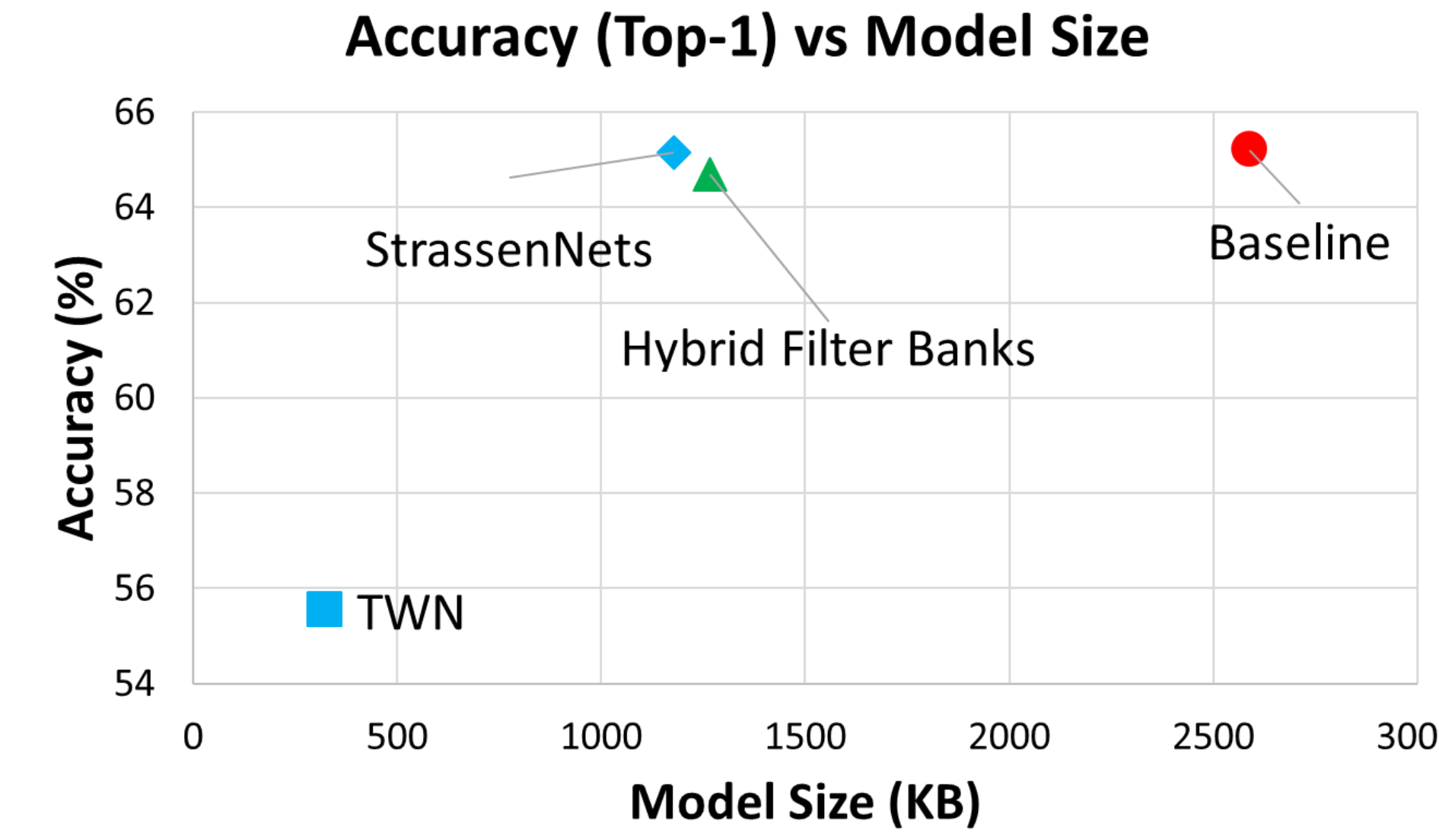
A MobileNets pointwise layer with hybrid filter bank

MobileNet-V1

Evaluation Results

- Dataset: ImageNet, Network: MobileNet-V1 (width multiplier of 0.5)
- 47% reduction in MULs, only 48% reduction in ADDs, when compared to >300%
- 51% reduction in MobileNets-V1 model size,
- 28% reduction in energy/inference
- No degradation in inference throughput on an area-equivalent ML accelerator comprising both MAC and adder units
- 0.27% loss in top-1 accuracy
- Hybrid filter banks is effective in compressing ResNet architecture comprising 3x3 convolutional filters also; see our paper for details





Top-1 accuracy, energy/inference, and model size of hybrid filter banks and improvement over state-of-the-art ternary quantization schemes

Read Our Paper for Details

Gope et al., "Ternary MobileNets via Per-Layer Hybrid Filter Banks", 2019

arXiv link: https://arxiv.org/abs/1911.01028

References

[1] Howard et al., "MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications", 2017

[2] Li et al., "Ternary weight networks," NeurIPS 2016

[3] Tschannen et al., "StrassenNets: Deep Learning with a Multiplication Budget", ICML 2018