Accelerating AES

with Vector Permute Instructions

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Fast AES Implementations

- Lookup table for (MixColumns $\circ$ S-box) [DR '99, . . . , BS '08]
  - Vulnerable to cache-timing attacks
- Composite fields for hardware [R '00, RDJKRR '02]
- Bitslicing [B '97, . . . , KS '09]
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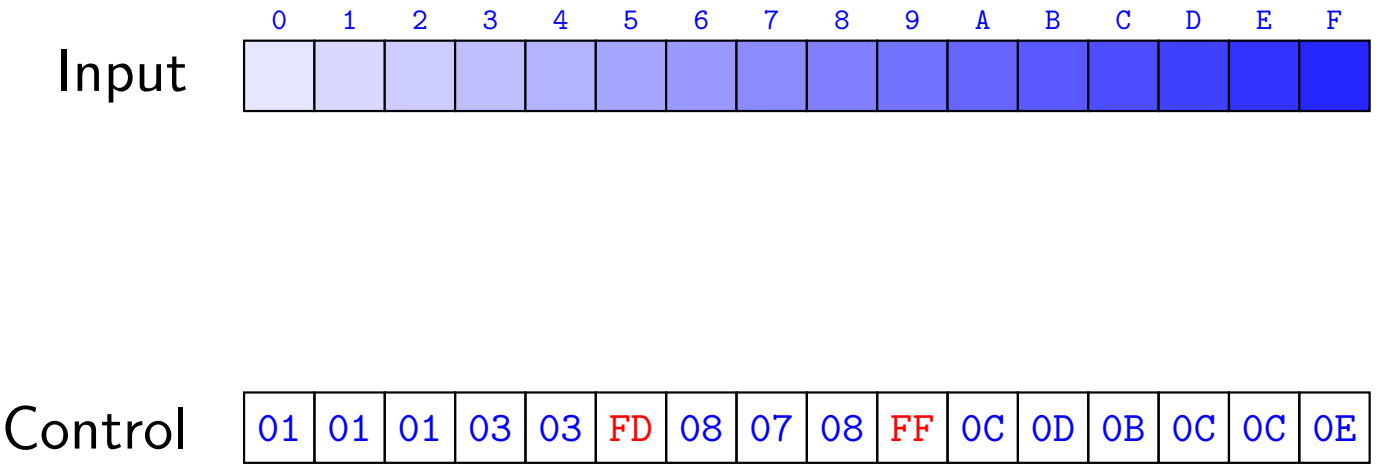
  - Very fast when encrypting ≥ 8 blocks in parallel
- Today: composite fields and vector permutations
  - Fast even for only one block

Vector permute instructions

- Available on AltiVec, ARM NEON, SSSE3



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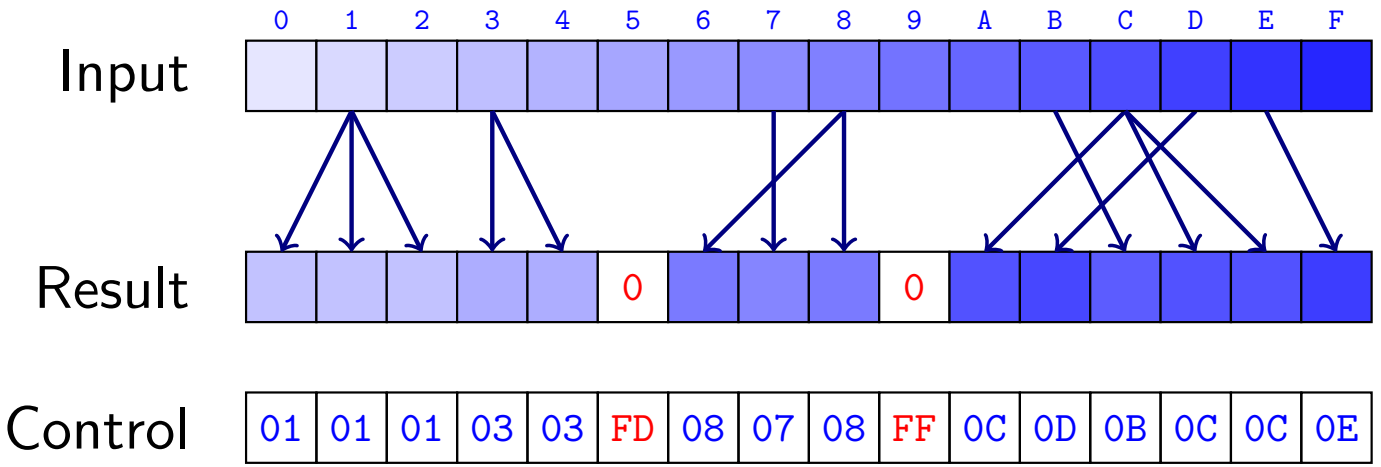

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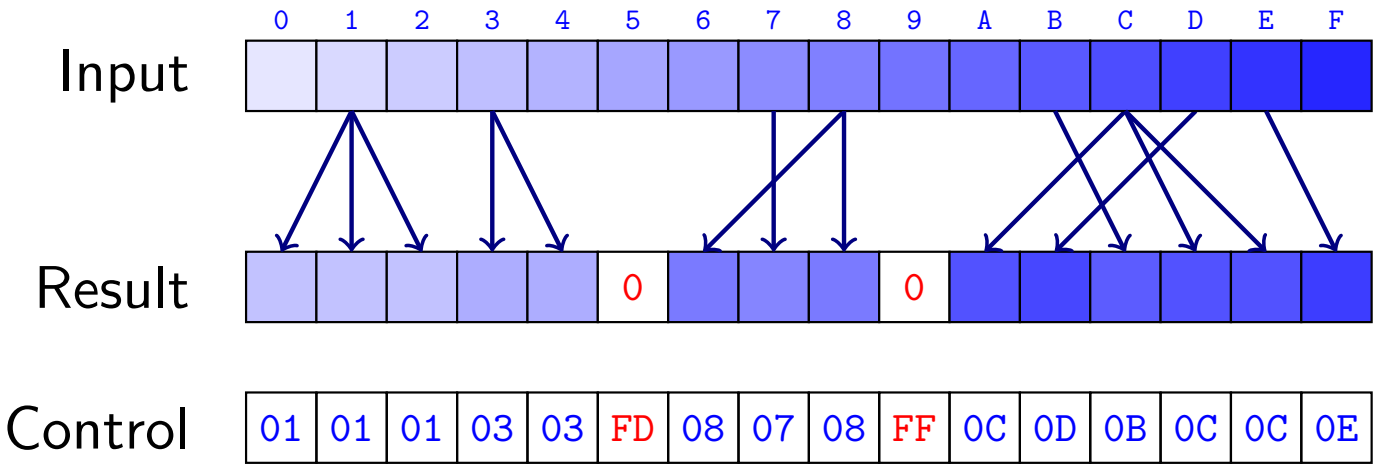

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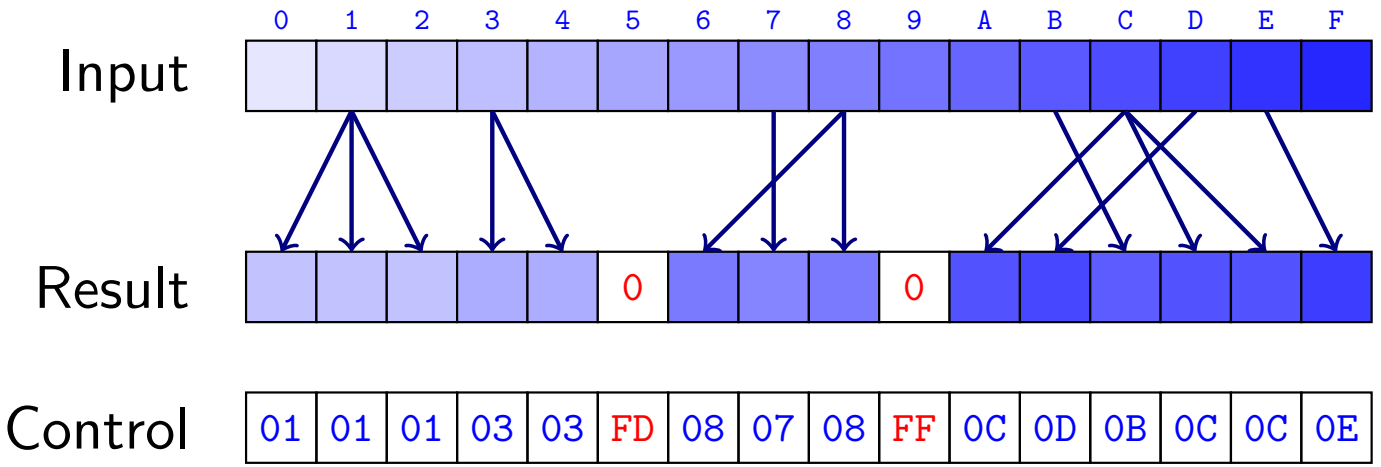

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- More powerful on AltiVec

Composite Fields

- AES uses inversion over $\mathbb{F}_{2^8}$
  - Too complicated to compute directly
- Decompose $\mathbb{F}_{2^8}$ as $\mathbb{F}_{2^4}[t]/(t^2 + t + \zeta)$
  - 16 elements – just right for vector permutes!
- Choice of basis is important!
  - We chose $(t,\ \bar{t} := t + 1)$

Computing the S-box

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$x^{254} \approx \frac{1}{x}$

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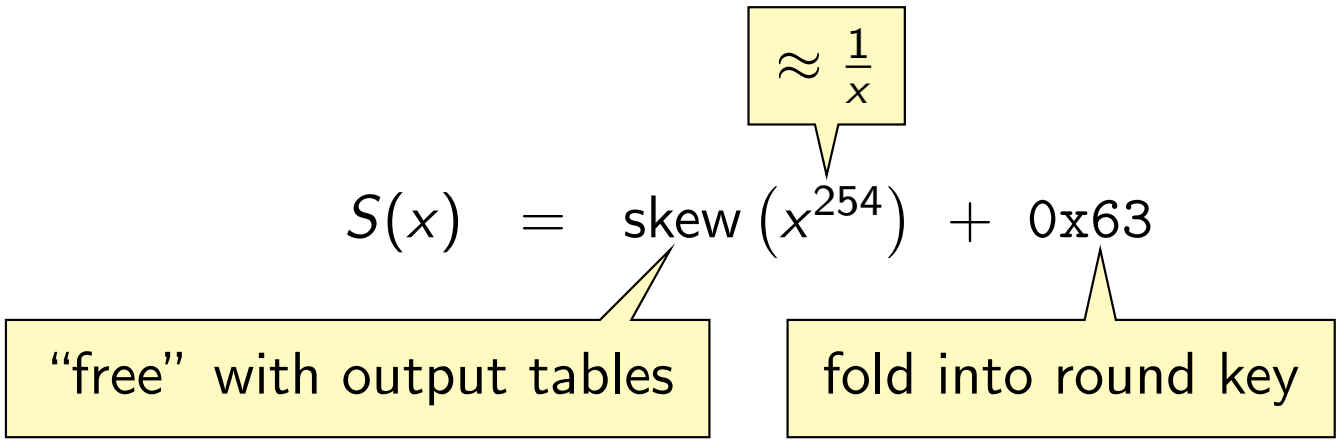

Computing $\frac{1}{xt+y\bar{t}}$ — Classical Inversion

- Clear the denominator:

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- Needs log tables!
  - Not enough space on x86

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- Multiply without multiplication:

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$$\frac{xy \ + \ \zeta(x^2+y^2)}{(1+\zeta)x \ + \ \zeta y} \ = \ \frac{1}{\frac{1}{x} \ + \ \frac{1}{\zeta(x+y)}} \ + \ y$$

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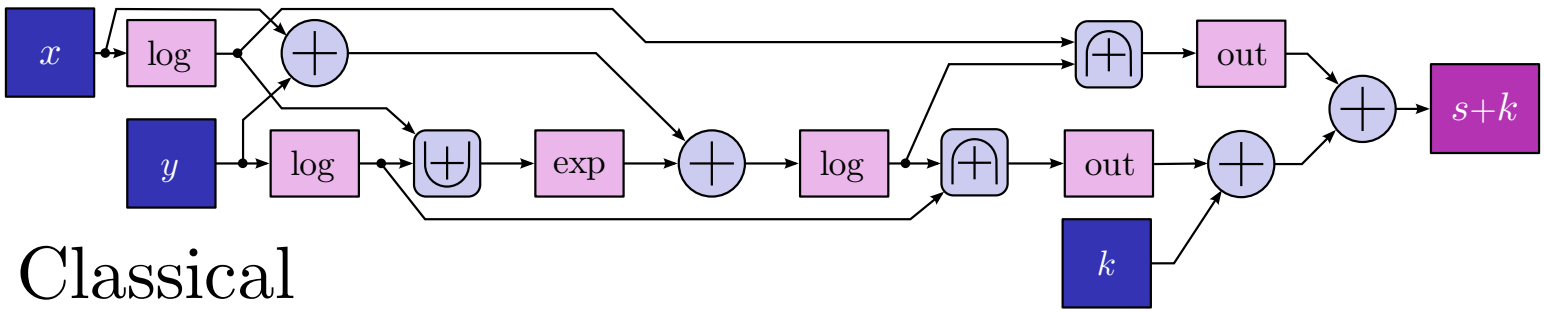
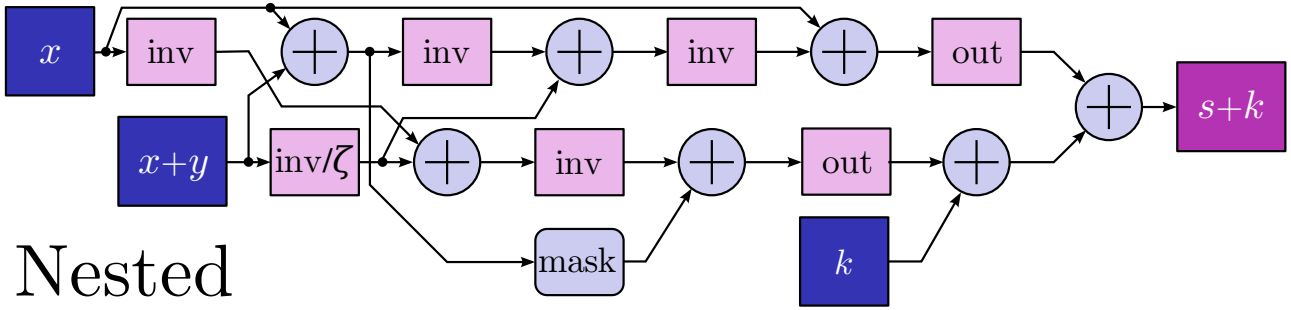
- Division by zero a problem
  - Use "∞ bit"

Computing $\frac{1}{xt+y\bar{t}}$ — Comparison



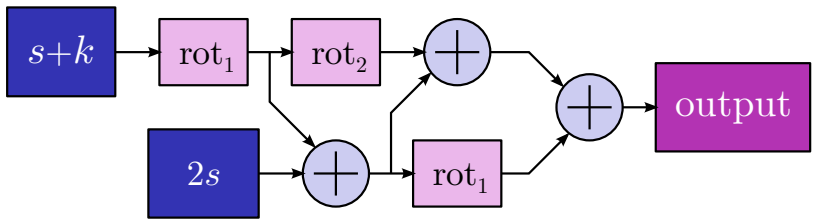
Classical



Nested

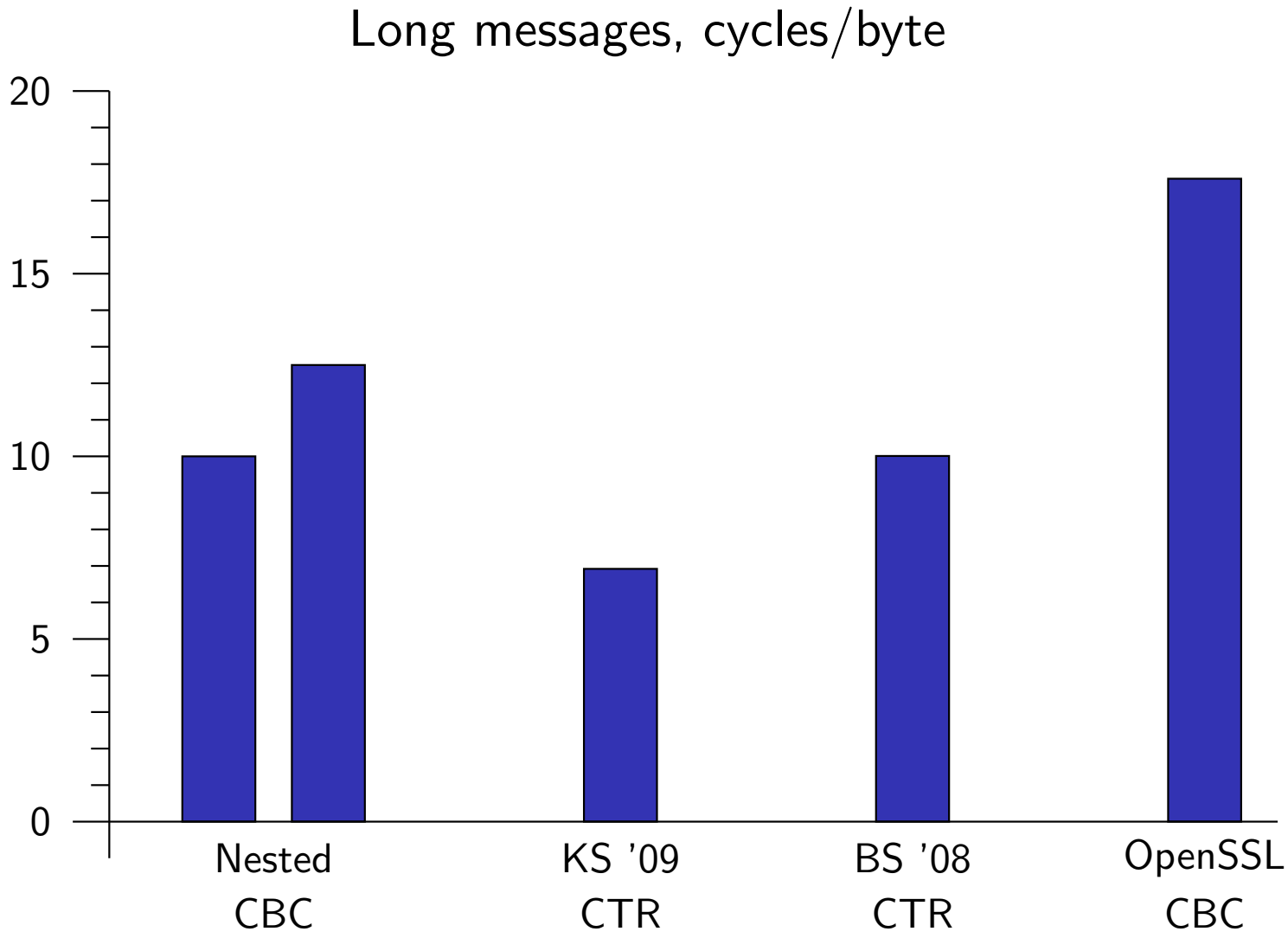
The Rest of the Cipher

- Don't compute ShiftRows
  - Fold into MixColumns permutations
- AddRoundKey before MixColumns
  - Modified key schedule
- MixColumns from $s + k$ and $2s$

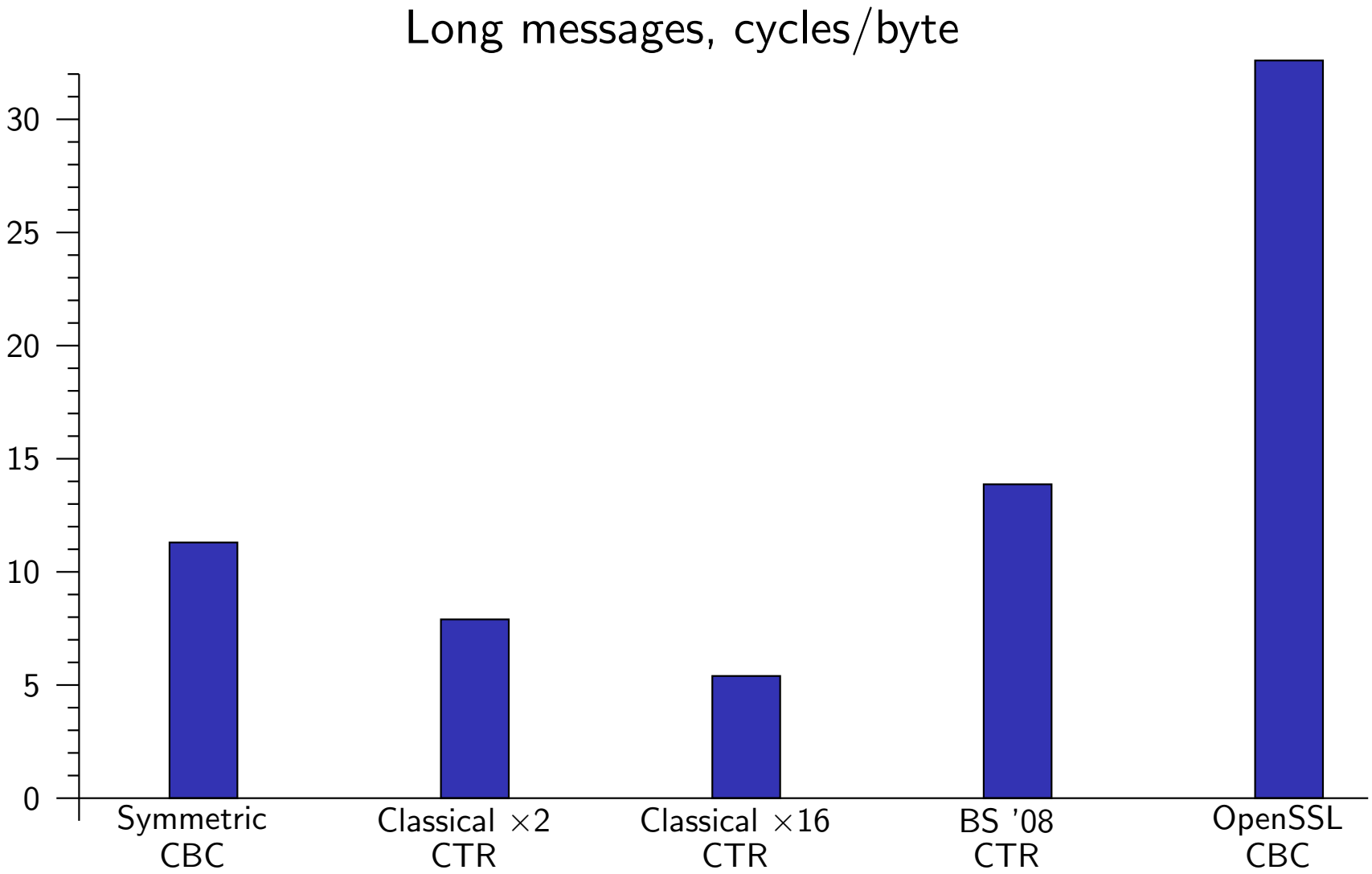


- Fold output basis shift into S-box

Performance – Nehalem



Performance – PowerPC G4e



Future Work

- Optimize more carefully for Intel
  - Up to 20% in microarchitectural tweaks
  - Up to 17% in CTR-mode caching
  - Byte-slicing?
- Implement other primitives
  - Camellia, LEX, Fugue, ...
- Package and distribute!

Fin

Questions?