Improved Key Recovery Attacks on Reduced-Round AES in the Single-Key Setting

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joint work with Patrick Derbez *and* Pierre-Alain Fouque

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Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128						
AES-192						
AES-256						

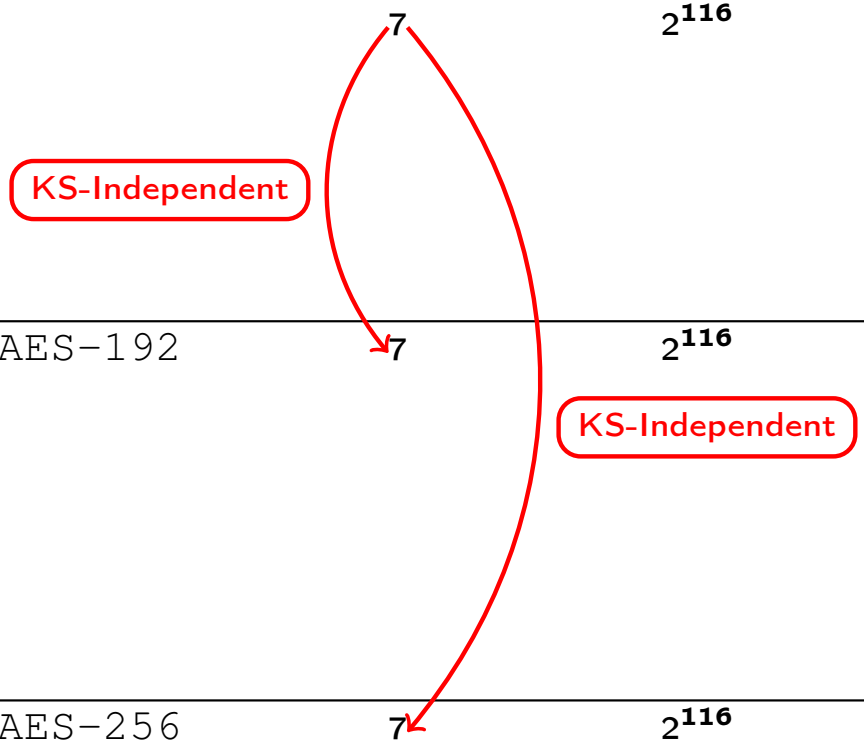
CP: Chosen-plaintext

Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
AES-192						
AES-256						

CP: Chosen-plaintext ID: Impossible Differential

[LDKK08] — J. Lu, O. Dunkelman, N. Keller, J. Kim @ Indocrypt 2008

Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]



CP: Chosen-plaintext ID: Impossible Differential MitM: Meet-in-the-Middle

[DKS10] — O. Dunkelman, N. Keller, A. Shamir @ Asiacrypt 2010

Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
Extension →	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
Extension →	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]

CP: Chosen-plaintext ID: Impossible Differential MitM: Meet-in-the-Middle

[DKS10] — O. Dunkelman, N. Keller, A. Shamir @ Asiacrypt 2010

Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
Improved ID	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	$2^{106.2}$	$2^{110.2}$	$2^{90.2}$	ID	[MDRMH10]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]

CP: Chosen-plaintext ID: Impossible Differential MitM: Meet-in-the-Middle

[MDRMH10] — H. Mala, M. Dakhilalian, V. Rijmen, M. Modarres-Hashemi @ Indocrypt 2010

Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	$2^{106.2}$	$2^{110.2}$	$2^{90.2}$	ID	[MDRMH10]
	8	2^{88}	$2^{125.3}$	2^{8}	Bicliques	[BKR11]
	10 (full)	2^{88}	$2^{126.2}$	2^{8}	Bicliques	[BKR11]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
	9	2^{80}	$2^{188.8}$	2^{8}	Bicliques	[BKR11]
	12 (full)	2^{80}	$2^{189.4}$	2^{8}	Bicliques	[BKR11]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]
	9	2^{120}	$2^{251.9}$	2^{8}	Bicliques	[BKR11]
	14 (full)	2^{40}	$2^{254.4}$	2^{8}	Bicliques	[BKR11]

CP: Chosen-plaintext ID: Impossible Differential MitM: Meet-in-the-Middle

[BKR11] — A. Bogdanov, D. Khovratovich, C. Rechberger @ Asiacrypt 2011

Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
Memory improvement	7	$2^{106.2}$	$2^{110.2}$	$2^{90.2}$	ID	[MDRMH10]
	7	2^{105}	2^{99}	2^{90}	MitM	New!
	8	2^{88}	$2^{125.3}$	2^{8}	Bicliques	[BKR11]
	10 (full)	2^{88}	$2^{126.2}$	2^{8}	Bicliques	[BKR11]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
	9	2^{80}	$2^{188.8}$	2^{8}	Bicliques	[BKR11]
	12 (full)	2^{80}	$2^{189.4}$	2^{8}	Bicliques	[BKR11]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]
	9	2^{120}	$2^{251.9}$	2^{8}	Bicliques	[BKR11]
	14 (full)	2^{40}	$2^{254.4}$	2^{8}	Bicliques	[BKR11]

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Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	$2^{106.2}$	$2^{110.2}$	$2^{90.2}$	ID	[MDRMH10]
Tradeoffs	7	2^{105}	2^{99}	2^{90}	MitM	New!
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{88}	$2^{125.3}$	2^{8}	Bicliques	[BKR11]
	10 (full)	2^{88}	$2^{126.2}$	2^{8}	Bicliques	[BKR11]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
	9	2^{80}	$2^{188.8}$	2^{8}	Bicliques	[BKR11]
	12 (full)	2^{80}	$2^{189.4}$	2^{8}	Bicliques	[BKR11]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]
	9	2^{120}	$2^{251.9}$	2^{8}	Bicliques	[BKR11]
	14 (full)	2^{40}	$2^{254.4}$	2^{8}	Bicliques	[BKR11]

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Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	$2^{106.2}$	$2^{110.2}$	$2^{90.2}$	ID	[MDRMH10]
	7	2^{105}	2^{99}	2^{90}	MitM	New!
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{88}	$2^{125.3}$	2^{8}	Bicliques	[BKR11]
KS-Independent	10 (full)	2^{88}	$2^{126.2}$	2^{8}	Bicliques	[BKR11]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
KS-Independent						
	9	2^{80}	$2^{188.8}$	2^{8}	Bicliques	[BKR11]
	12 (full)	2^{80}	$2^{189.4}$	2^{8}	Bicliques	[BKR11]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{98}	2^{96}	MitM	New!
	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]
	9	2^{120}	$2^{251.9}$	2^{8}	Bicliques	[BKR11]
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Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	$2^{106.2}$	$2^{110.2}$	$2^{90.2}$	ID	[MDRMH10]
	7	2^{105}	2^{99}	2^{90}	MitM	New!
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{88}	$2^{125.3}$	2^{8}	Bicliques	[BKR11]
Extension	10 (full)	2^{88}	$2^{126.2}$	2^{8}	Bicliques	[BKR11]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
	8	2^{113}	2^{172}	2^{82}	MitM	New!
Extension	9	2^{80}	$2^{188.8}$	2^{8}	Bicliques	[BKR11]
	12 (full)	2^{80}	$2^{189.4}$	2^{8}	Bicliques	[BKR11]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{98}	2^{96}	MitM	New!
	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]
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Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
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	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	$2^{106.2}$	$2^{110.2}$	$2^{90.2}$	ID	[MDRMH10]
	7	2^{105}	2^{99}	2^{90}	MitM	New!
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{88}	$2^{125.3}$	2^{8}	Bicliques	[BKR11]
	10 (full)	2^{88}	$2^{126.2}$	2^{8}	Bicliques	[BKR11]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
Tradeoffs	8	2^{113}	2^{172}	2^{82}	MitM	New!
	8	2^{107}	2^{172}	2^{96}	MitM	New!
	9	2^{80}	$2^{188.8}$	2^{8}	Bicliques	[BKR11]
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AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
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Tradeoffs	8	2^{113}	2^{196}	2^{82}	MitM	New!
	8	2^{107}	2^{196}	2^{96}	MitM	New!
	9	2^{120}	$2^{251.9}$	2^{8}	Bicliques	[BKR11]
	14 (full)	2^{40}	$2^{254.4}$	2^{8}	Bicliques	[BKR11]

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AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
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	7	2^{105}	2^{99}	2^{90}	MitM	New!
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{88}	$2^{125.3}$	2^{8}	Bicliques	[BKR11]
	10 (full)	2^{88}	$2^{126.2}$	2^{8}	Bicliques	[BKR11]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
	8	2^{113}	2^{172}	2^{82}	MitM	New!
	8	2^{107}	2^{172}	2^{96}	MitM	New!
	9	2^{80}	$2^{188.8}$	2^{8}	Bicliques	[BKR11]
	12 (full)	2^{80}	$2^{189.4}$	2^{8}	Bicliques	[BKR11]
AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{98}	2^{96}	MitM	New!
	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]
	8	2^{113}	2^{196}	2^{82}	MitM	New!
	8	2^{107}	2^{196}	2^{96}	MitM	New!
	9	2^{120}	$2^{251.9}$	2^{8}	Bicliques	[BKR11]
	9	2^{120}	2^{203}	2^{203}	MitM	New!
	14 (full)	2^{40}	$2^{254.4}$	2^{8}	Bicliques	[BKR11]

Extension & Tradeoffs

CP: Chosen-plaintext ID: Impossible Differential MitM: Meet-in-the-Middle

Cipher	Rounds	Data (CP)	Time	Memory	Technique	Reference
AES-128	7	$2^{112.2}$	$2^{117.2}$	$2^{112.2}$	ID	[LDKK08]
	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	$2^{106.2}$	$2^{110.2}$	$2^{90.2}$	ID	[MDRMH10]
	7	2^{105}	2^{99}	2^{90}	MitM	New!
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{88}	$2^{125.3}$	2^{8}	Bicliques	[BKR11]
	10 (full)	2^{88}	$2^{126.2}$	2^{8}	Bicliques	[BKR11]
AES-192	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{99}	2^{96}	MitM	New!
	8	2^{113}	2^{172}	2^{129}	MitM	[DKS10]
	8	2^{113}	2^{172}	2^{82}	MitM	New!
	8	2^{107}	2^{172}	2^{96}	MitM	New!
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AES-256	7	2^{116}	2^{116}	2^{116}	MitM	[DKS10]
	7	2^{99}	2^{98}	2^{96}	MitM	New!
	8	2^{113}	2^{196}	2^{129}	MitM	[DKS10]
	8	2^{113}	2^{196}	2^{82}	MitM	New!
	8	2^{107}	2^{196}	2^{96}	MitM	New!
	9	2^{120}	$2^{251.9}$	2^{8}	Bicliques	[BKR11]
	9	2^{120}	2^{203}	2^{203}	MitM	New!
	14 (full)	2^{40}	$2^{254.4}$	2^{8}	Bicliques	[BKR11]

CP: Chosen-plaintext ID: Impossible Differential MitM: Meet-in-the-Middle

Soon on the ePrint.

Thanks for listening!

Andrey Bogdanov, Dmitry Khovratovich, and Christian Rechberger.

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