Card Brand Mixup Attack: Bypassing the PIN in non-Visa cards by Using Them for Visa Transactions

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Outline

EMV standard

- EMV is the protocol standard for **smartcard payments**
- Founded by **E**uropay, **M**astercard, and **V**isa,
  and later Amex, JCB, Discover, and UnionPay joined the consortium too
- **9+ billion** EMV cards in circulation worldwide

EMV security

Cardholder protection

Low-value purchases do not require a PIN

High-value purchases **should** be protected by PIN

Credits: https://pngtree.com/so/

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We'll show that they are **not**

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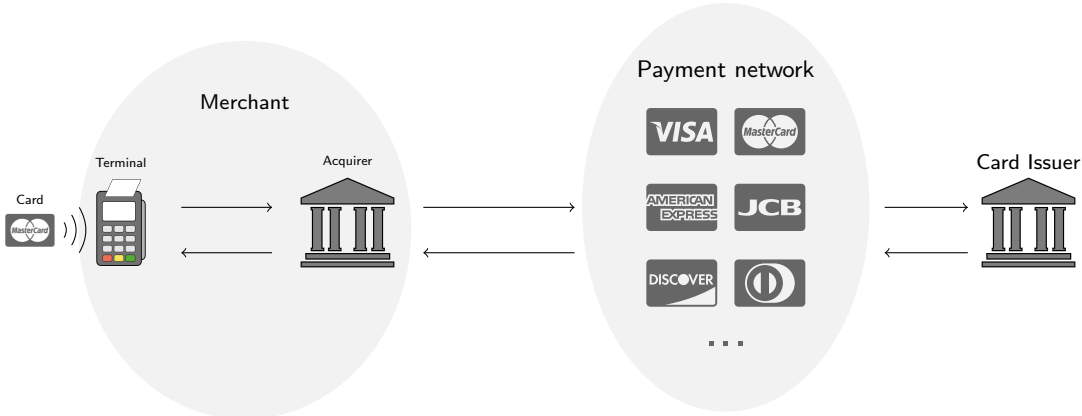
Online authorization and routing



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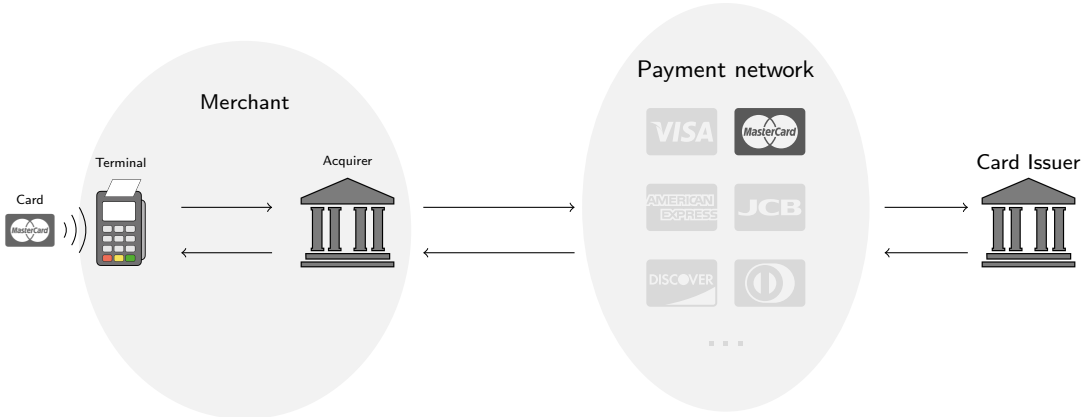
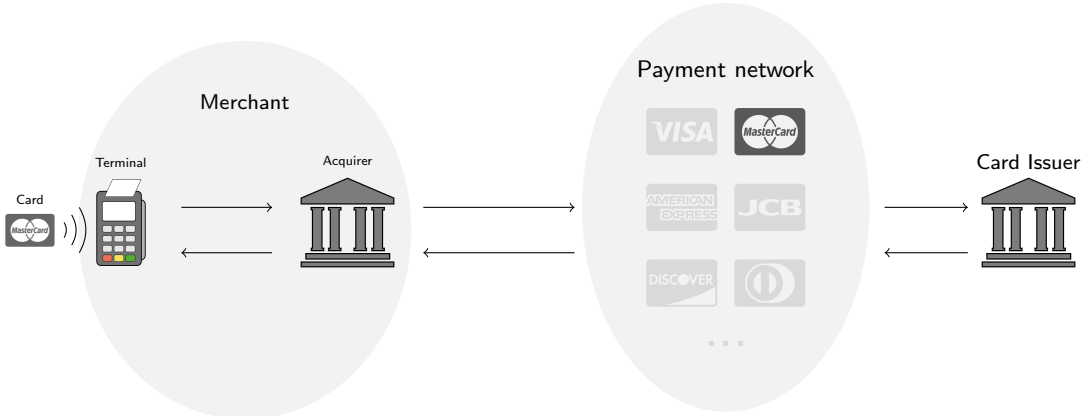


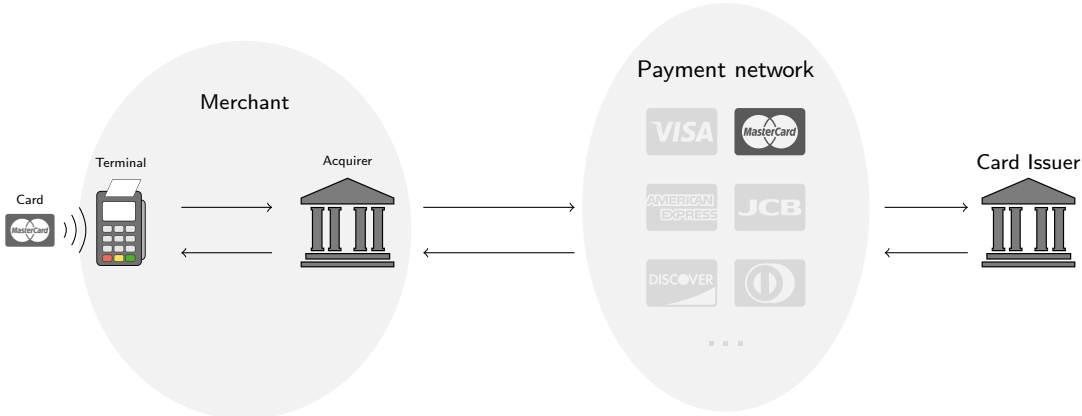
What card data does the merchant use to determine the payment network?

Online authorization and routing



What card data does the merchant use to determine the payment network?
The *Application Identifier (***AID***)* or the *Primary Account Number (***PAN***)*?

Online authorization and routing



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The *Application Identifier* (**AID**) or the *Primary Account Number* (**PAN**)?

Why multiple choices? Do they always indicate the same payment network?

Contributions

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  - Develop an EMV model with PAN-based routing
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- **Mechanized the attack and showed it is effective and easy to carry out**
  - Bypassed the PIN for a transaction of over **USD 400** with a Maestro card
- **Disclosed issues to vendor and proposed verified fixes**
  - Disclosure process led to Mastercard deploy countermeasures at network level

Outline

Analysis results for EMV with AID-based routing

Basin et al. *"The EMV Standard: Break, Fix, Verify."* IEEE S&P 2021

Target Model	exec.	issuer accepts	auth. to terminal	auth. to issuer
Visa_EMV_Low	✓	✓	×	×
Visa_EMV_High	✓	✓	×	×
Visa_DDA_Low	✓	×	×	✓
Visa_DDA_High	✓	✓	✓	✓
Mastercard_SDA_OnlinePIN_Low	✓	×	×	✓
Mastercard_SDA_OnlinePIN_High	✓	✓	✓	✓
Mastercard_SDA_NoPIN_Low	✓	×	×	✓
Mastercard_SDA_NoPIN_High	–	–	–	–
Mastercard_DDA_OnlinePIN_Low	✓	×	×	✓
Mastercard_DDA_OnlinePIN_High	✓	✓	✓	✓
Mastercard_DDA_NoPIN_Low	✓	×	×	✓
Mastercard_DDA_NoPIN_High	–	–	–	–
Mastercard_CDA_OnlinePIN_Low	✓	✓	✓	✓
Mastercard_CDA_OnlinePIN_High	✓	✓	✓	✓
Mastercard_CDA_NoPIN_Low	✓	✓	✓	✓
Mastercard_CDA_NoPIN_High	–	–	–	–

✓: property verified ×: property falsified –: not applicable

- Issuer **agrees** with terminal on all the data for every transaction with a Mastercard card

Analysis results for EMV with PAN-based routing

Target Model	exec.	issuer accepts	auth. to terminal	auth. to issuer
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Mastercard_SDA_OnlinePIN_High	✓	✓	✓	×
Mastercard_SDA_NoPIN_Low	✓	×	×	×
Mastercard_SDA_NoPIN_High	×	–	–	–
Mastercard_DDA_OnlinePIN_Low	✓	×	×	×
Mastercard_DDA_OnlinePIN_High	✓	✓	✓	×
Mastercard_DDA_NoPIN_Low	✓	×	×	×
Mastercard_DDA_NoPIN_High	×	–	–	–
Mastercard_CDA_OnlinePIN_Low	✓	✓	✓	×
Mastercard_CDA_OnlinePIN_High	✓	✓	✓	×
Mastercard_CDA_NoPIN_Low	✓	✓	✓	×
Mastercard_CDA_NoPIN_High	×	–	–	–

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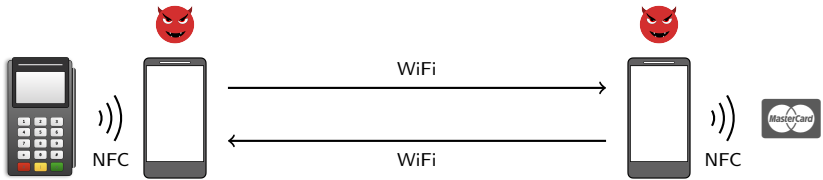
- Attacker induces **disagreement** on the card brand: issuer knows the card is a Mastercard but terminal thinks it's a Visa

Weaponizing: PIN bypass attack

Man-in-the-middle attack built on top of a **relay attack** architecture:



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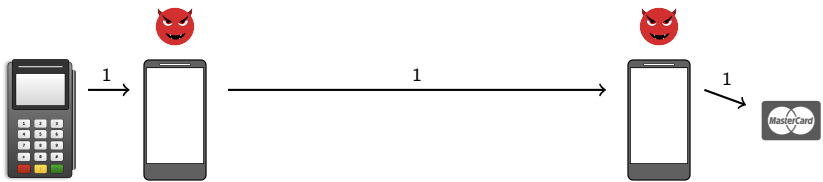

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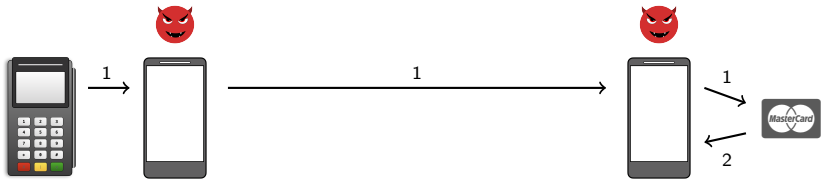

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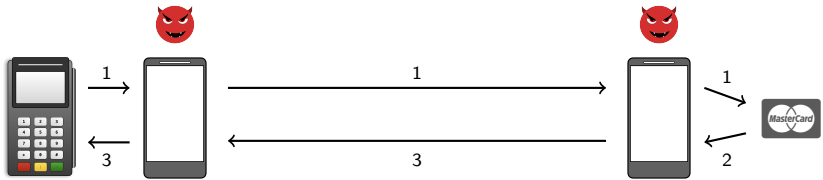

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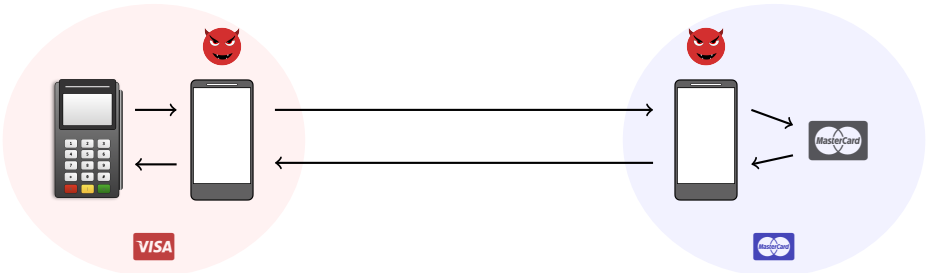
4. Transaction continues in two simultaneous sessions:
   - Terminal & Attacker running the Visa protocol
   - Attacker & Card running the Mastercard protocol



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4. Transaction continues in two simultaneous sessions:
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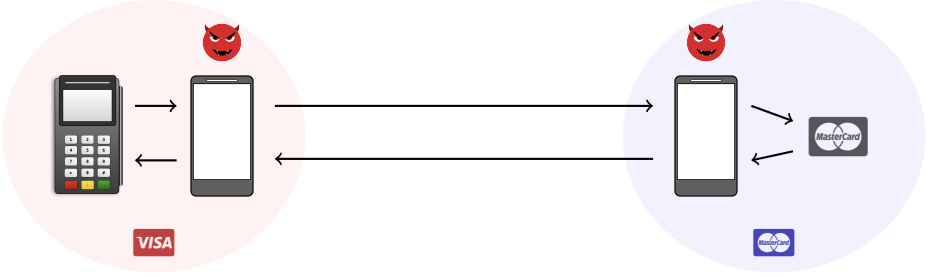
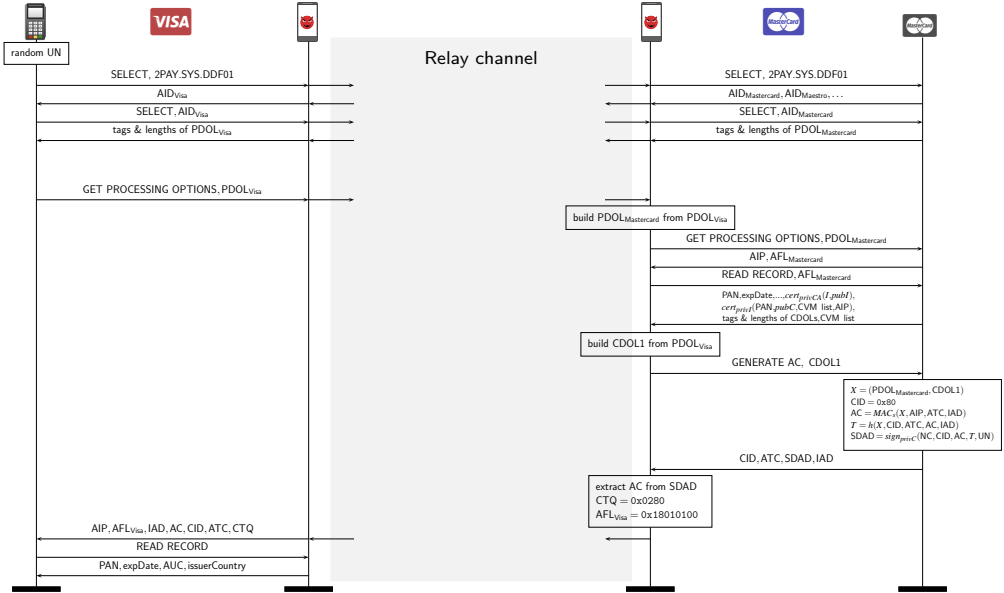
   - Attacker & Card running the Mastercard protocol
5. Attacker applies PIN bypass on Visa [see our S&P paper]



The attack in technical detail



Demo

Available at:

- https://youtu.be/8d7UgIiMRBU
- https://emvrace.github.io

Countermeasures

- We verified that our countermeasure[1] to the PIN bypass on Visa **does prevent** our Mastercard-Visa brand mixup

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- We also proposed and machine-checked new **intra-kernel countermeasures**
- Mastercard implemented their own defenses at **network level**, which we experimentally confirmed as effective against our attack

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Outline

Conclusion

- **Systems must be verified as a whole and not by parts separately**
  Separate system parts may be secure but composition may be insecure
- **Ambiguity and redundancy should be avoided in system specification**
  Critical mechanisms (e.g. routing) of the system should be unambiguously specified
- **Formal automated verification is a necessity**
  We (humans) cannot cover the full execution space that complex systems have

Webpage of this work: `https://emvrace.github.io`