EMV Payment Security

A Brief Overview

Card-based Payments Environment

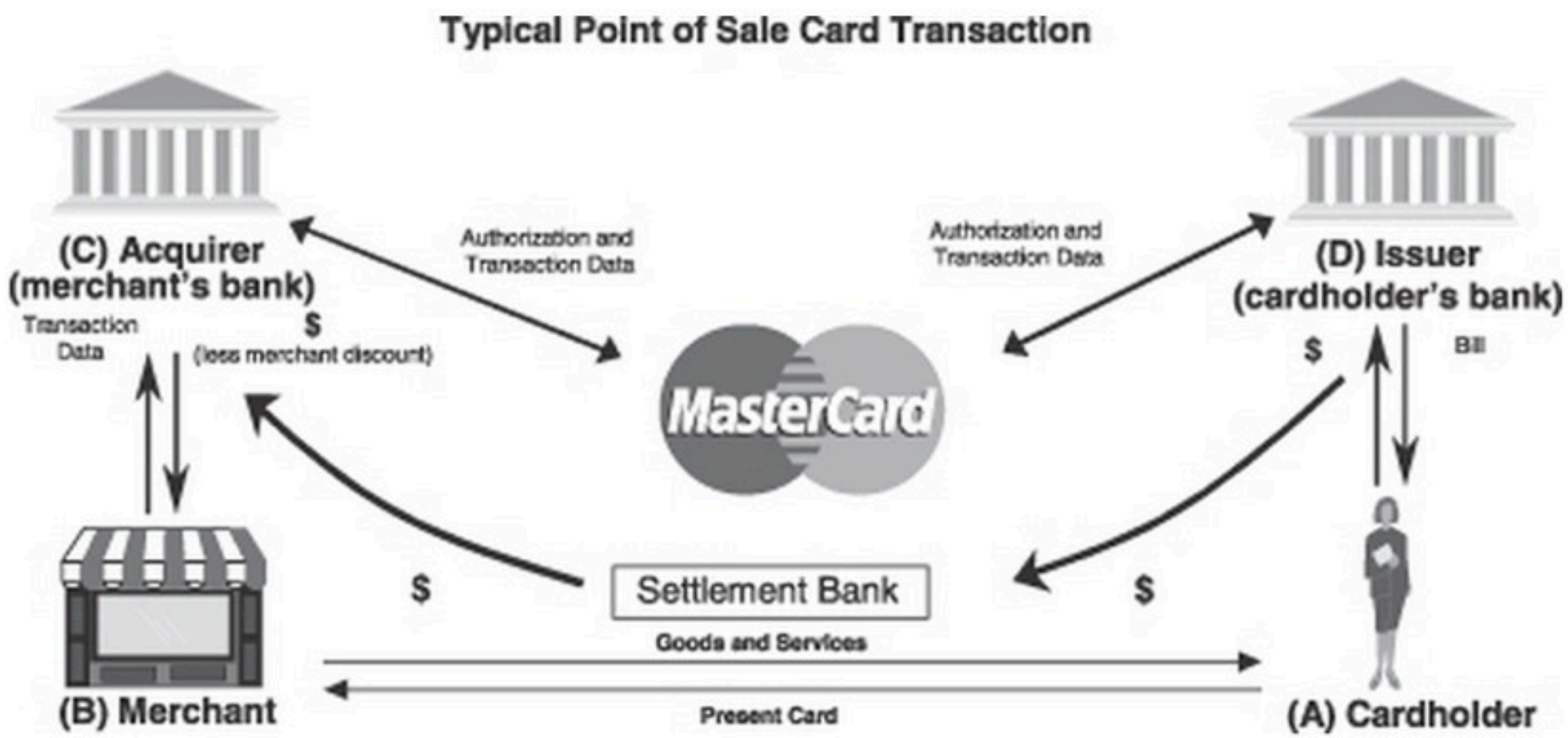

Image from http://www.sec.gov/Archives/edgar/data/1141391/000119312508034694/d10k.htm

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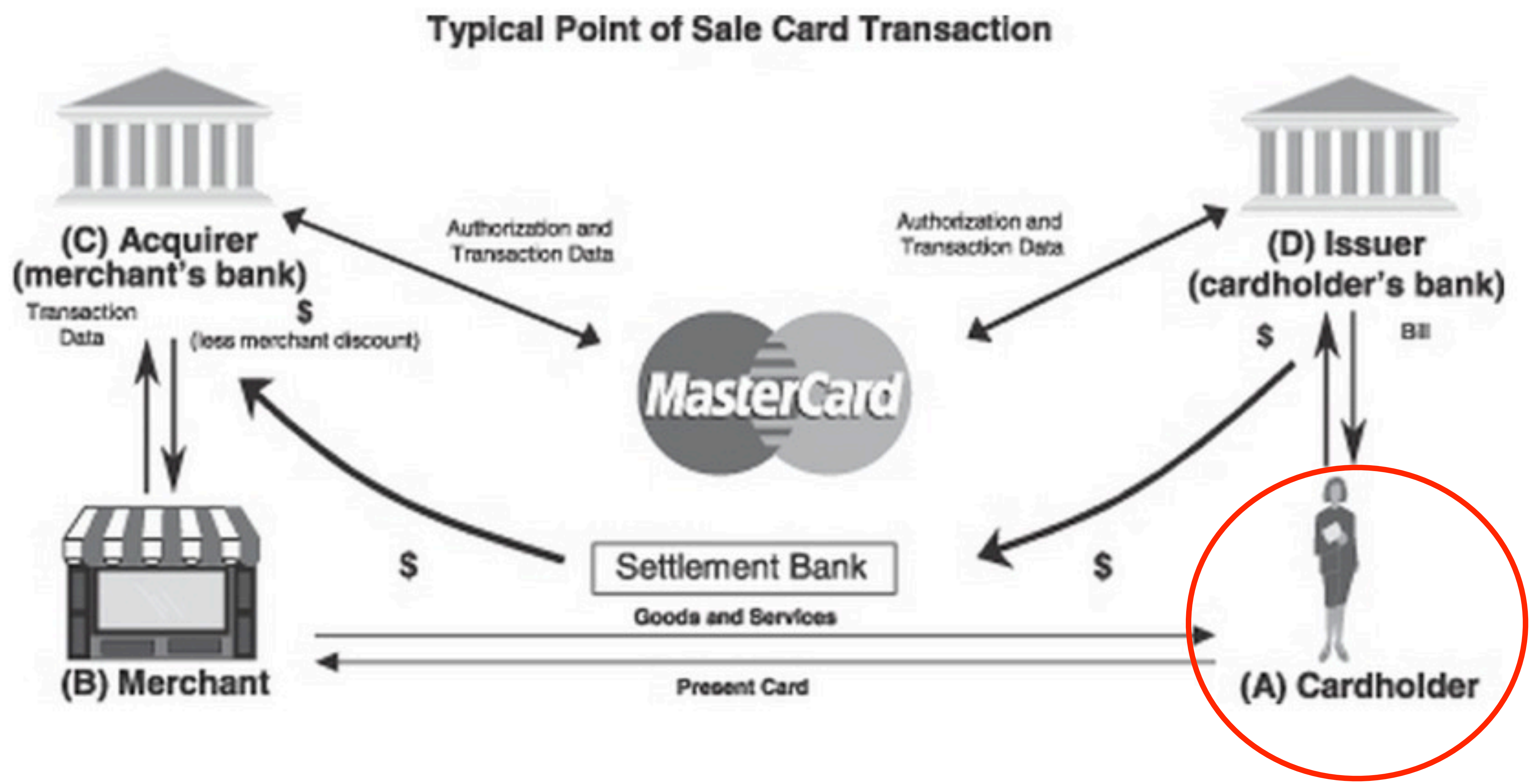

Cardholder Goals

- Receive goods, services
- Keep personal payment credentials secure

Image from http://www.sec.gov/Archives/edgar/data/1141391/000119312508034694/d10k.htm

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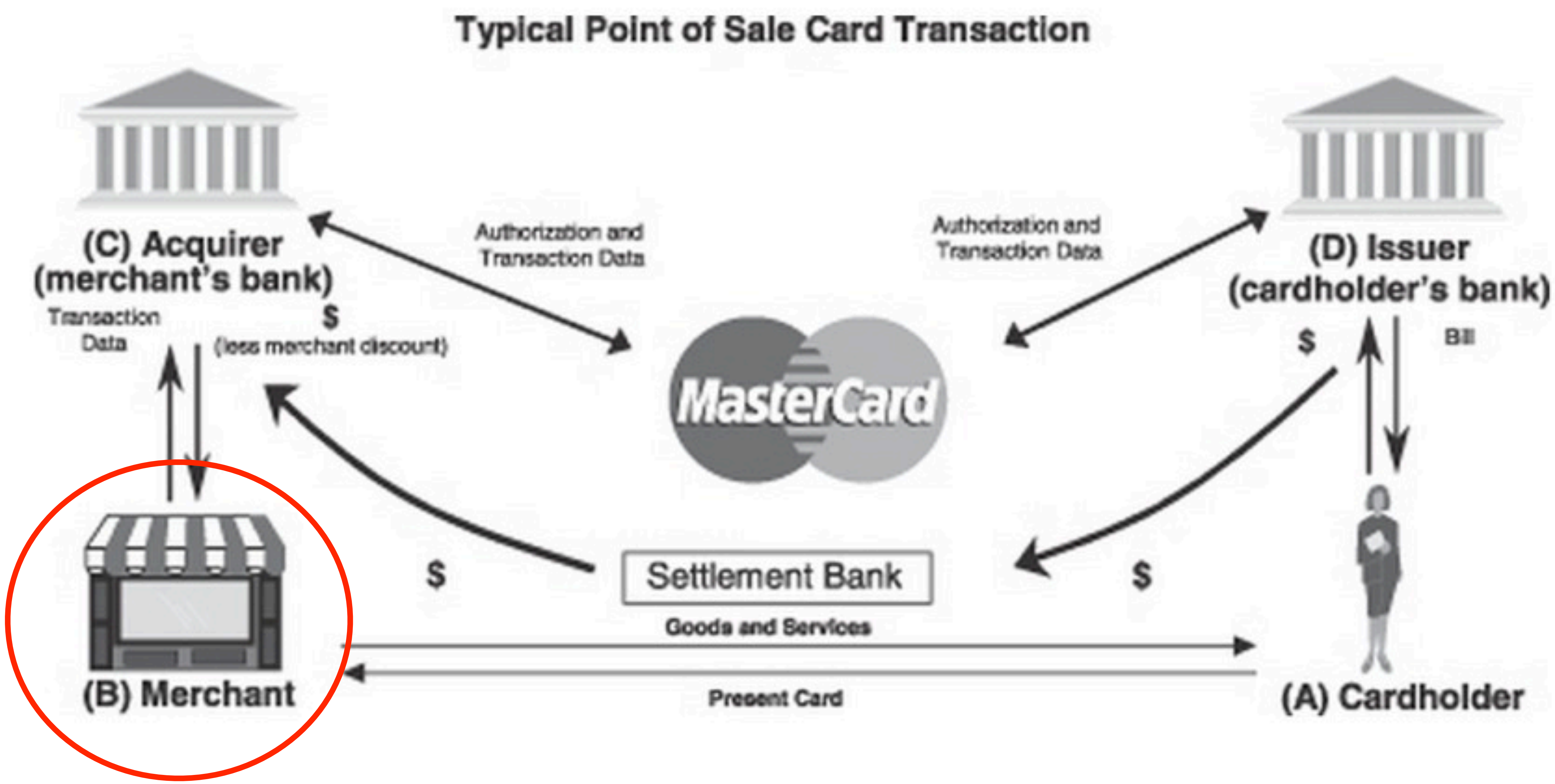

Merchant Goals

- Profit from the sale of goods, services
- Rest assured that regardless of the form of customer payment, will receive $

Image from http://www.sec.gov/Archives/edgar/data/1141391/000119312508034694/d10k.htm

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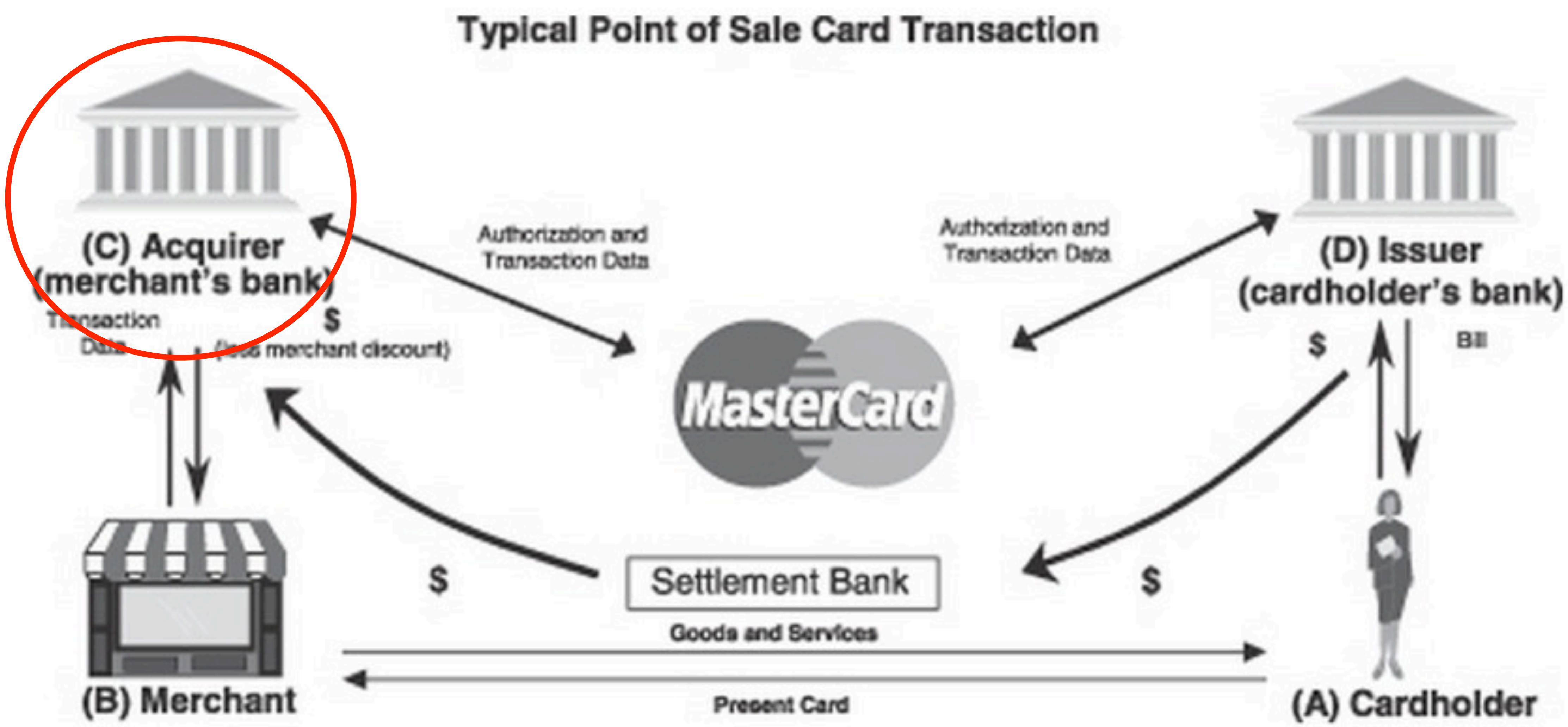
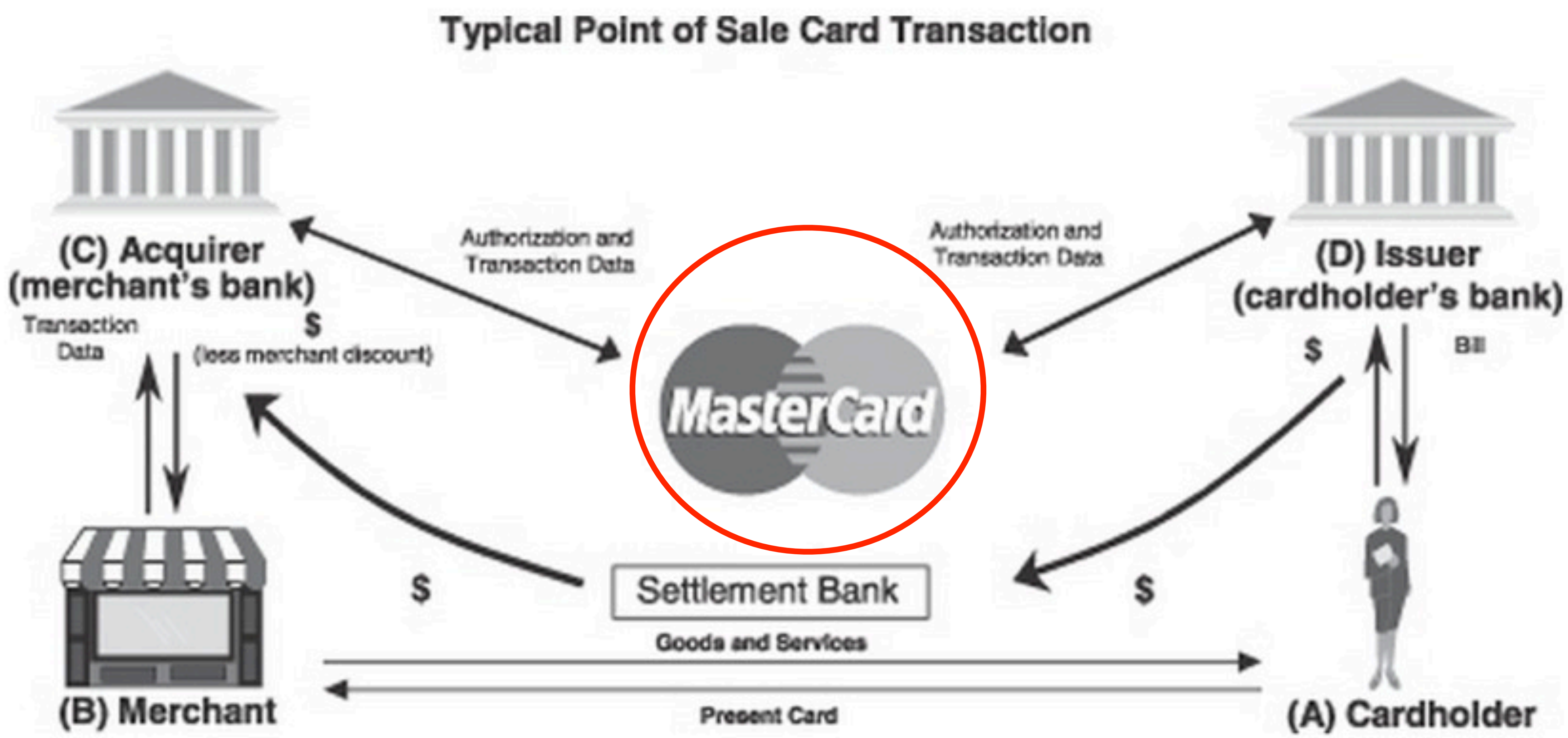


Acquirer Goals

- Profit from offering payment processing services to merchants
- Limit fraud losses

Image from http://www.sec.gov/Archives/edgar/data/1141391/000119312508034694/d10k.htm

Card-based Payments Environment

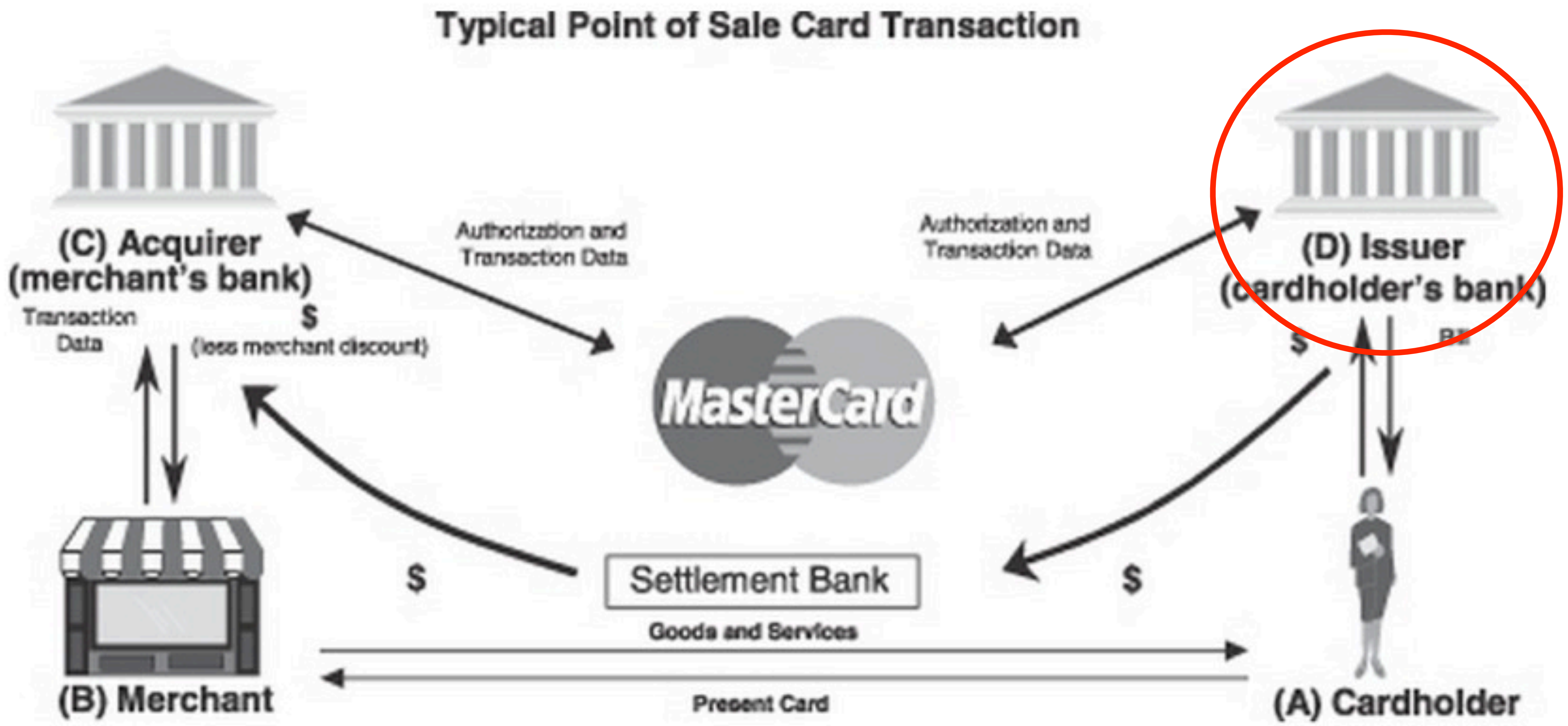


Card Association / Payment Network Goals

- Profit from movement of money everywhere (interchange fees)
- Limit fraud losses

Image from http://www.sec.gov/Archives/edgar/data/1141391/000119312508034694/d10k.htm

Card-based Payments Environment

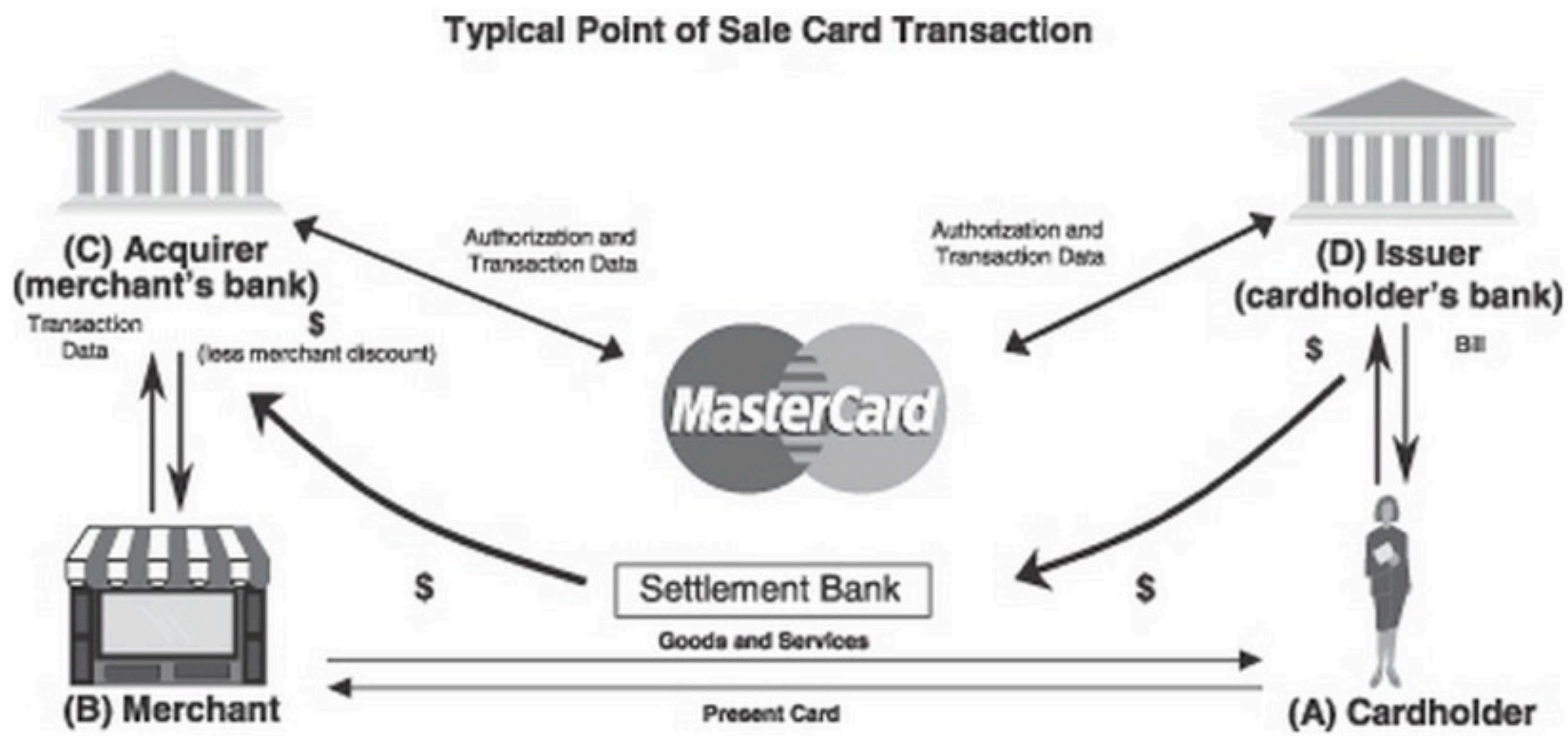


Issuer Goals

- Profit from offering a variety of buyer-side banking services to individuals, corporations
- Limit fraud losses

Image from http://www.sec.gov/Archives/edgar/data/1141391/000119312508034694/d10k.htm

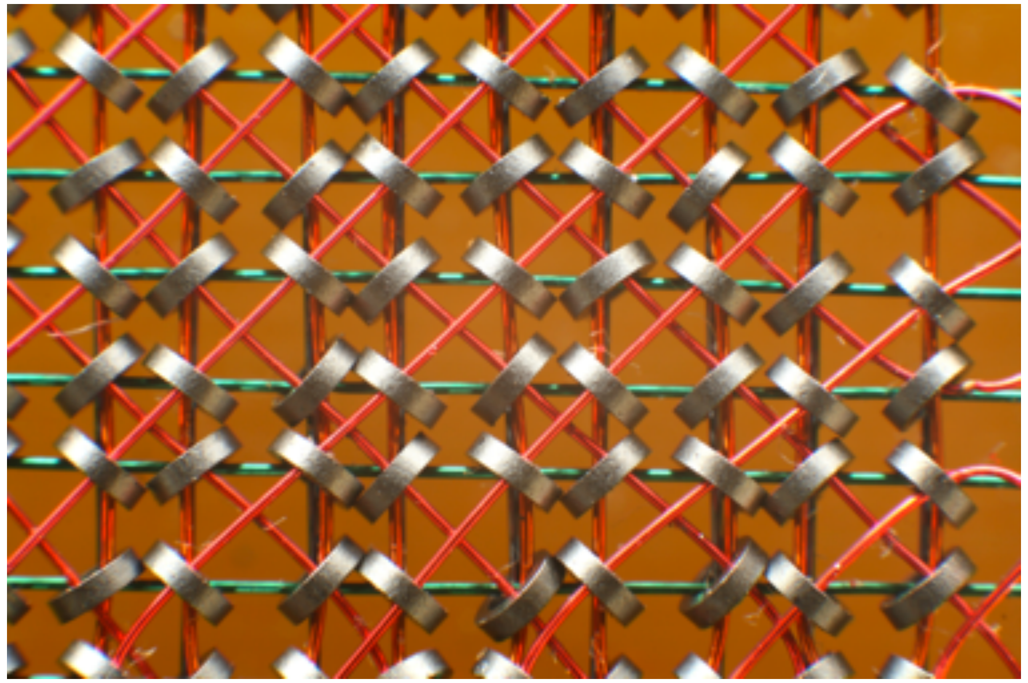
Card-based Payments Environment



Fraudster Goals

- Profit

Image from http://www.sec.gov/Archives/edgar/data/1141391/000119312508034694/d10k.htm and http://pbskidsbookwrombunch.wikia.com/wiki/File:Hamburglar.gif



More than one type of card...

In the U.S., magnetic-stripe readers by default

Plaintext account data stored magnetically on the card

Most MSR information also displayed on the card

CVV2 = 2FA for magnetic stripe “card not present” txns

Rest of world largely uses “EMV” chip cards

Based on the Europay Mastercard Visa (EMV) consortium, ISO 7816 physical definitions

International standards govern terminal, card security

Payment Card Industry (PCI), EMV, Common Criteria (CC)

Images from http://upload.wikimedia.org/wikipedia/commons/0/04/KL_Kernspeicher_Makro_1.jpg and http://www.emvco.com/about_emv.aspx

It's 1996: enter EMV and "liability shift"

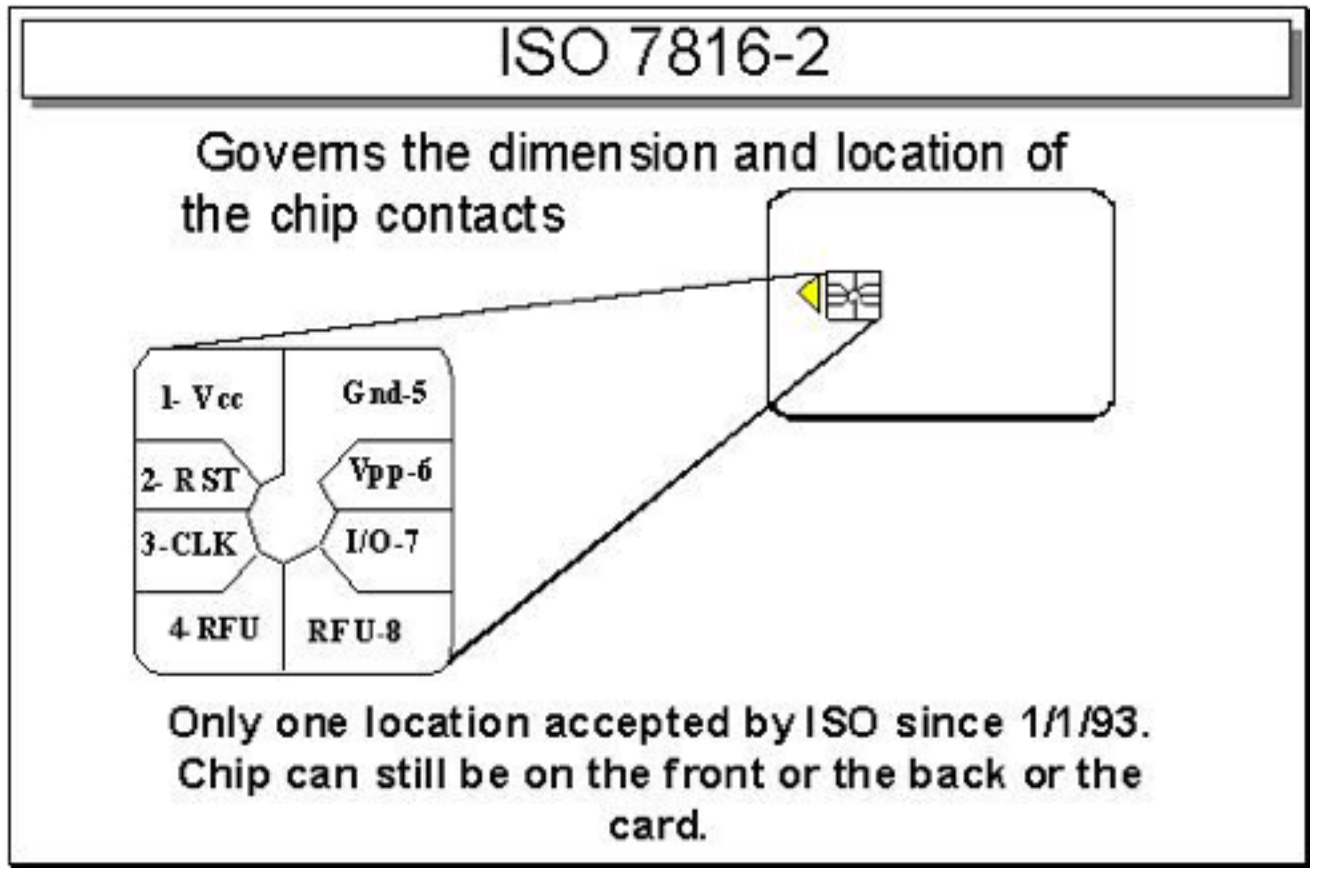


Image from http://people.cs.uchicago.edu/~dinoj/smartcard/7816.html

What shifts where?

Financial responsibility for fraud losses shifts from issuers to whichever party (issuer or acquirer/merchant) failed to deploy an EMV solution

Industry arguments:

1: 'Unclonable' chip cards that can compute 'cryptograms' for card authenticity attestation

2: Personal Identification Number (PIN) for cardholder verification

3: Issuers can configure chip card transaction parameters

Now at scale:

~1 billion active EMV cards, ~15 million terminals

References: [1]

How prevalent is EMV?

And where?

FIGURE 3: WORLDWIDE EMV DEPLOYMENT AND ADOPTION AS OF Q1 2011

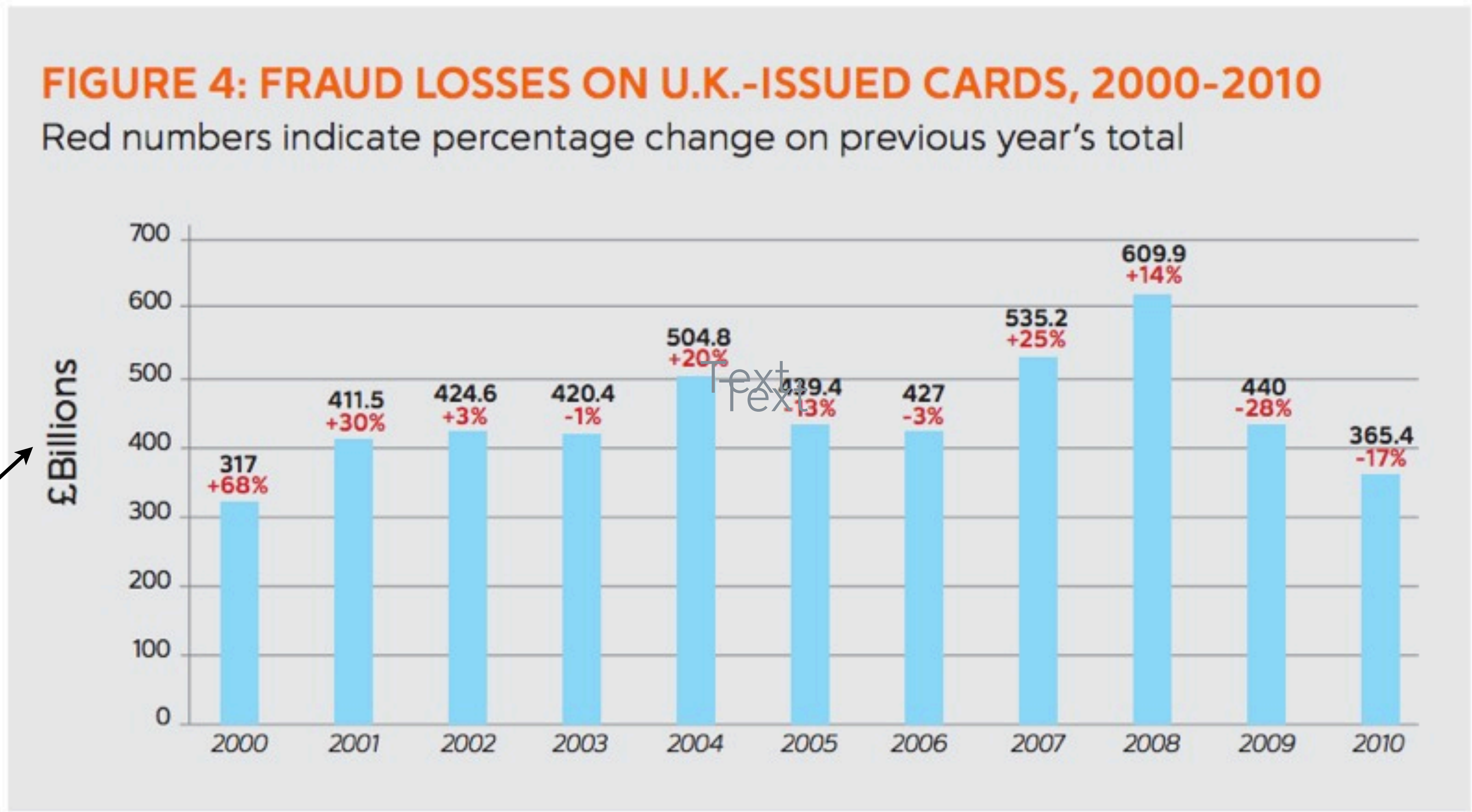
Region	EMV Cards	Adoption Rate	EMV Terminals	Adoption Rate
Canada, Latin America and the Caribbean	207,715,356	31.2%	3,900,00	76.5%
Asia Pacific	336,602,681	27.9%	3,480,000	43.0%
Africa and the Middle East	233,003,747	17.6%	345,000	60.7%
Europe Zone 1 (SEPA countries)	645,472,323	73.9%	10,5000,000	89.0%
Europe Zone 2	27,516,286	12.7%	513,600	65.4%
United States	Not reported	Not reported	Not reported	Not reported
Totals	**1,240,310,393**	**40.1%**	**18,738,600**	**71.1%**

Note: Figures reported in Q1 2011 and represent the latest statistics from American Express, JCB, MasterCard and Visa, as reported by their member financial institutions globally. Figures do not include data from the United States.

Source: EMVCo, LLC

Images from http://www.firstdata.com/downloads/thought-leadership/EMV_US.pdf

What about fraud rates?



Source: Financial Fraud Action U.K.

(they meant **millions**, not billions)

Images from http://www.firstdata.com/downloads/thought-leadership/EMV_US.pdf

What properties to verify during a transaction?

Authenticity of payment card
Attestation that card is legitimate

Presence of payment card
More on this later

Cardholder presence, intent
Attestation that account owner intends to conduct txn

Availability of funds
Confirmation that account funds or credit line sufficient

Managed risk
Assurance that behavior is approved by issuer

What makes verification difficult?

Cost

Merchants must purchase terminals
Issuers must provide millions of cards
These are large expenditures

Power and performance

Not just terminals that need to run crypto - cards too

Size

Mobile Point-of-Sale systems increasingly common, impose additional requirements on designers

User experience

Anti-fraud mechanisms can degrade usability

Network distribution and access

Cards, terminals widely, globally distributed, long roll-out periods
Attackers can easily obtain terminals and cards for vulnerability discovery, often have physical access in exploit scenarios

EMV Transactions and Cryptography

Offline Data Authentication:

Static, Dynamic, or Combined Data Authentication (SDA, DDA, CDA)

Cardholder Verification:

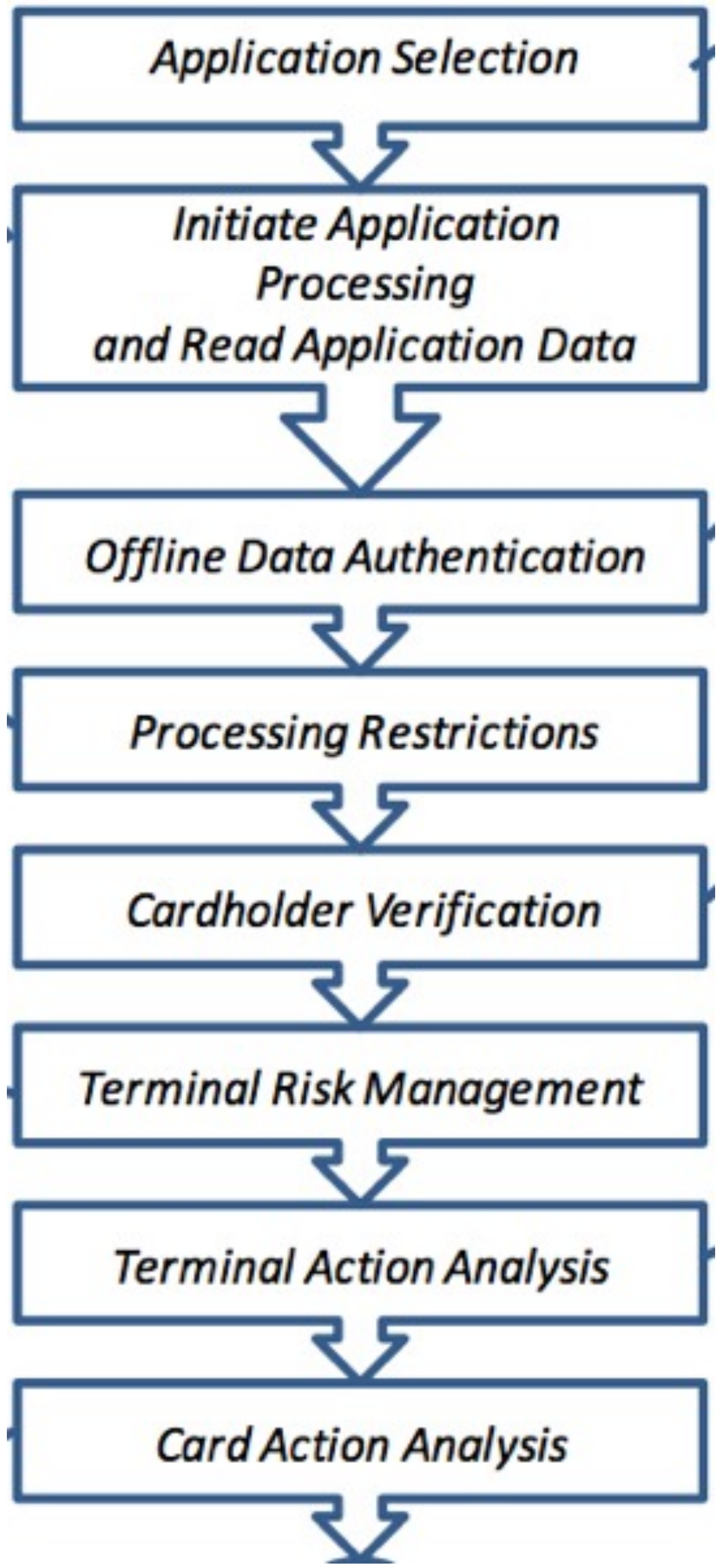
“Enciphered” PIN incorporated into online mode as well as one offline mode

Card Action Analysis:

Card signs transaction information to be sent to issuer, issuer responds with signed data

Application Cryptogram:

Card cryptographically certifies its decision on the transaction (both accept and decline)



$ Application Cryptogram $

Image from [1]

Verifying Card Authenticity

Static Data Authentication (SDA)

Card maintains list of Certificate Authority Public Keys

These CAPKs are used to authenticate cards' issuer certificates. Some are still 1024-bit RSA keys.

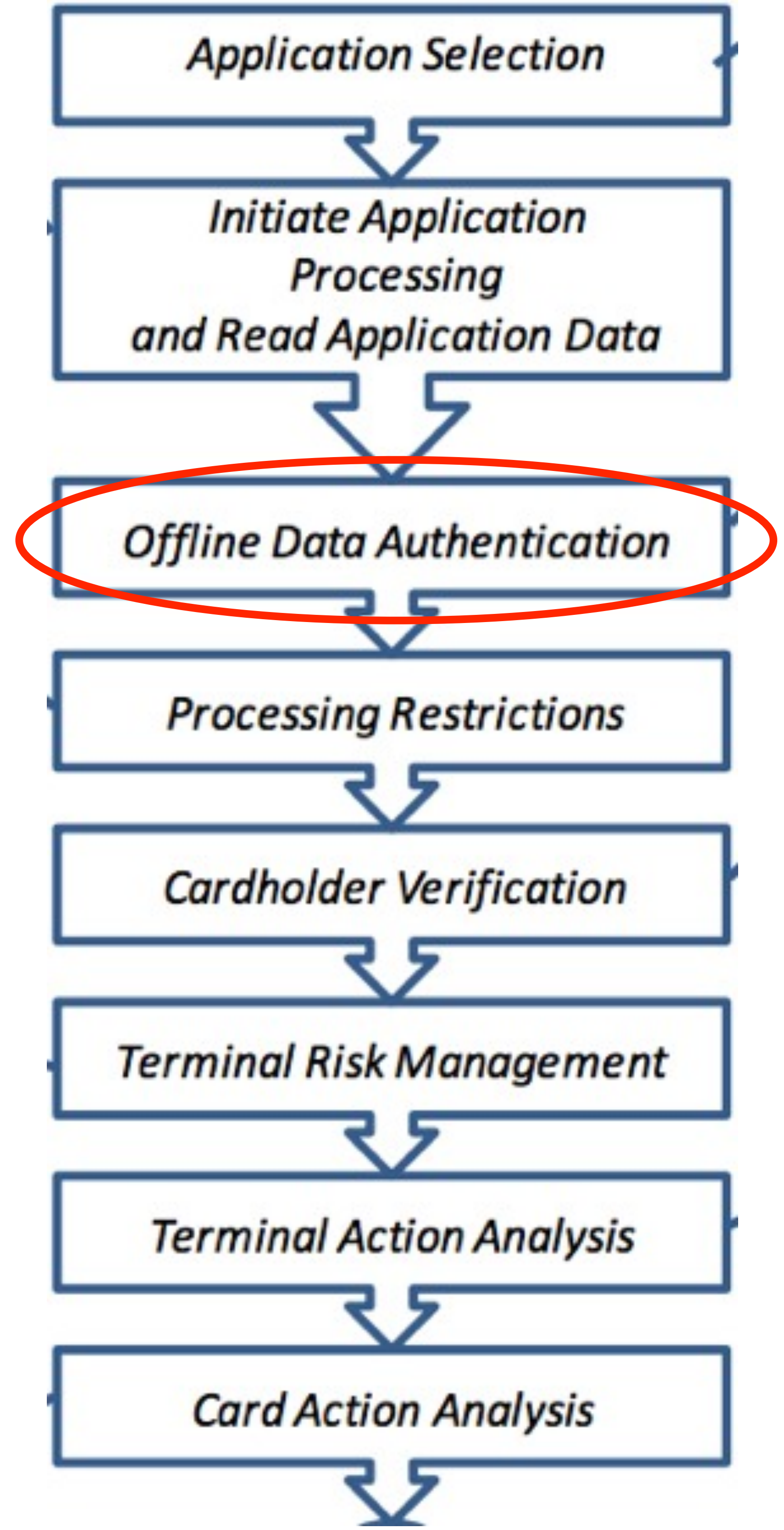
SDA provides a static verification mechanism

Terminal can verify:

- Card's issuer certificate is signed by an unrevoked, legitimate CAPK
- Card's static data blob is signed by the issuer

No replay protection

An attacker who observes this data once can "clone" the SDA capability over the card



$ Application Cryptogram $

Image from [1]

Verifying Card Authenticity

Dynamic Data Authentication (DDA)

This time in addition to issuer certificate, card-specific key verified

This certificate is signed by the issuer

Terminal chooses an ‘Unpredictable Number’ (UN)

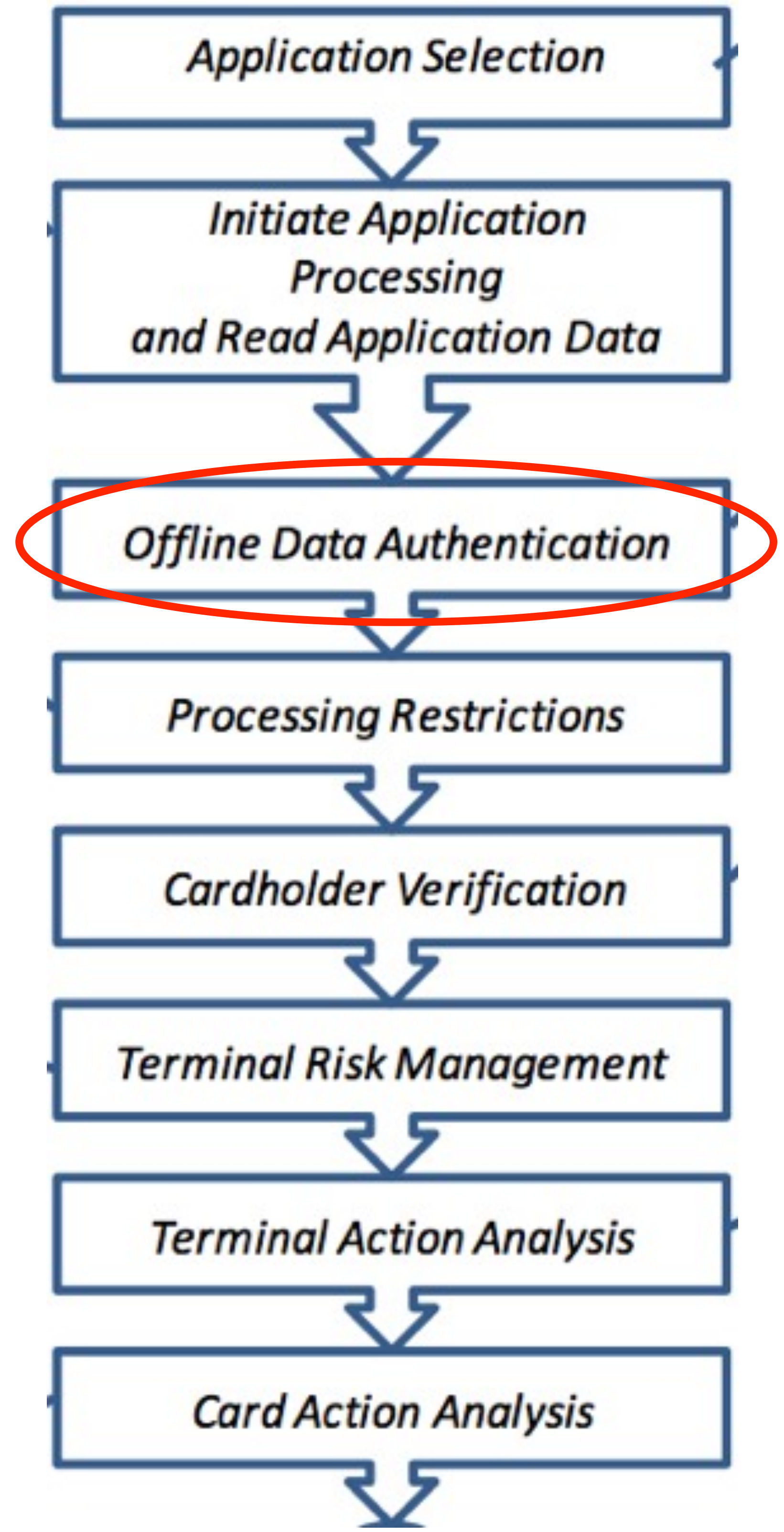
32 bits in length. This is added to other data in a Data Objects List (DOL), sent to the card

Card hashes data with SHA1, signs hash using private RSA key

Terminal verifies this to complete the authentication

Why a signature scheme like this?

Think about how to represent a long message..



$ Application Cryptogram $

Image from [1]

Cardholder Verification Methods

Offline Enciphered PIN (Card verifies PIN)

Card has separate PIN encipherment certificate

Verified through issuer-CA chain, as before

This time, card generates a random nonce

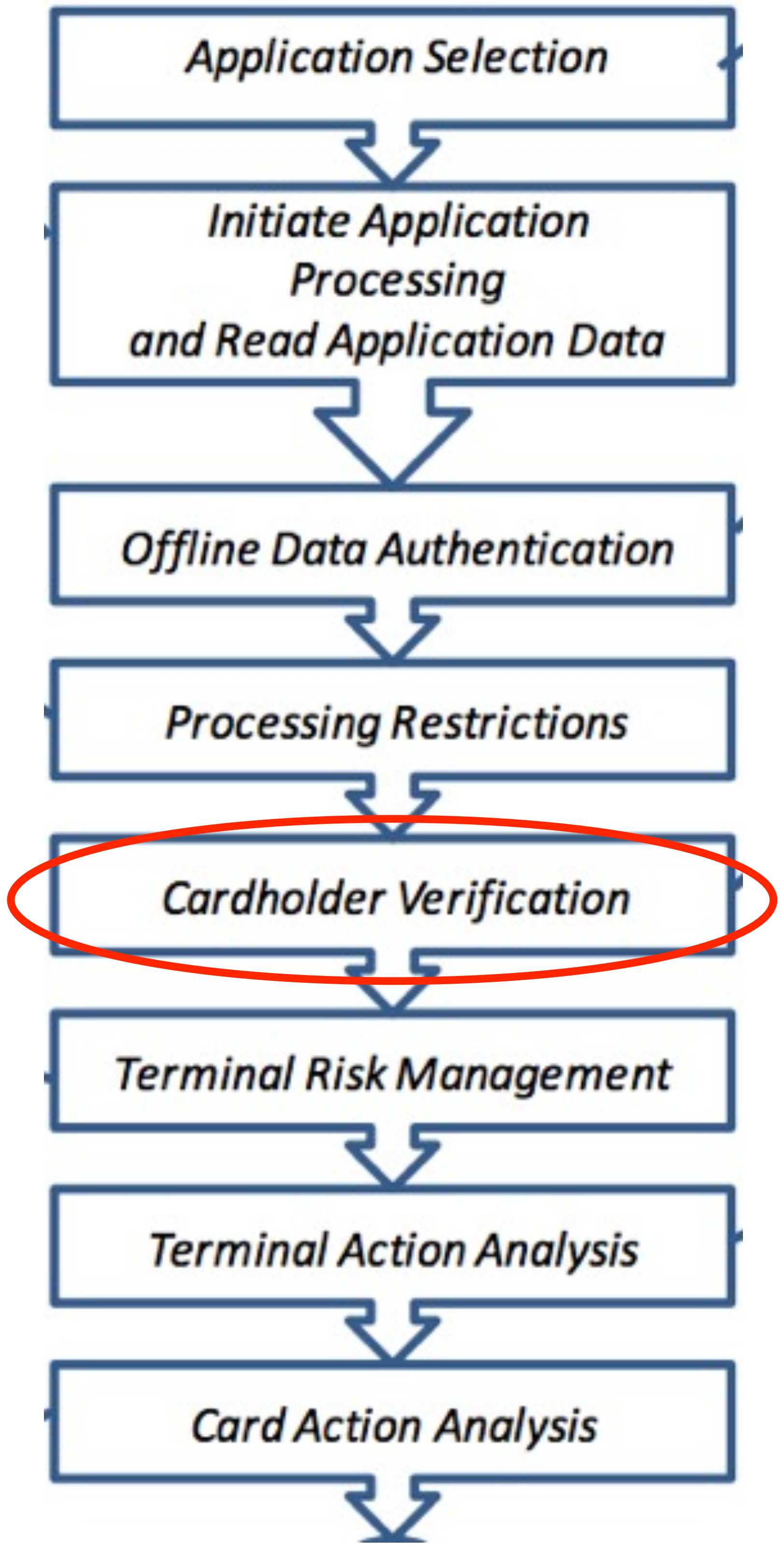
64 bits in length, sent to terminal

Terminal generates its own random, pads message, encrypts with card's RSA public key

Rest of the message is header, PIN, card's nonce

Card decrypts, checks nonce is the same

Then, can verify the PIN against internal storage



$ Application Cryptogram $

Image from [1]

Cardholder Verification Methods

Online Enciphered PIN (Issuer verifies PIN)

Terminal can send entered PIN to acquirer

Encrypted with 2-key Triple-DES, in ISO PIN block format

But it's not that simple

How does the terminal know the acquirer's TDES key?

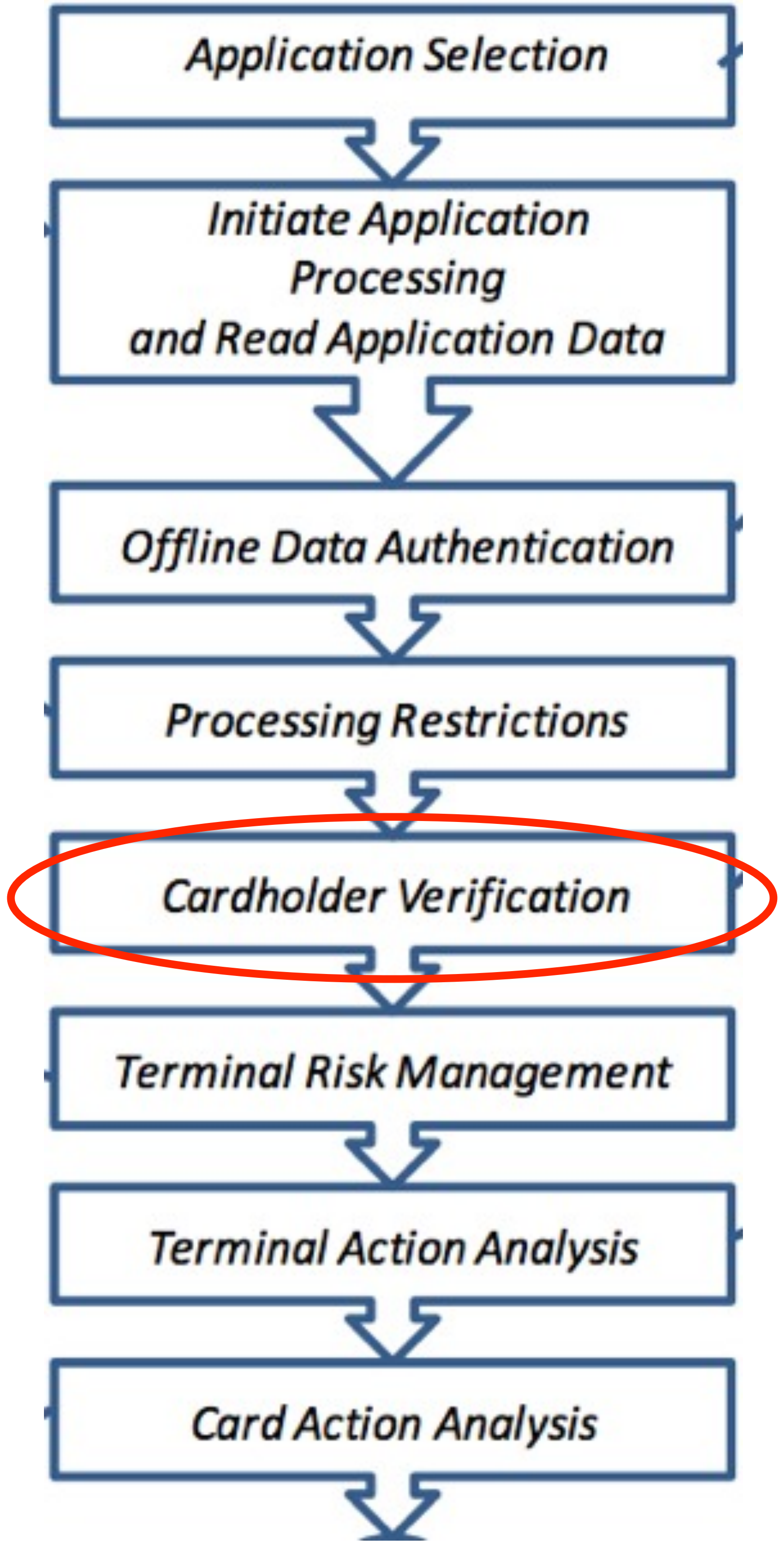
Could the terminal share a key with the issuer?

If not, how are keys established between acquirer and issuer?

Are the keys static?

Solution: extensive use of HSMs (e.g. 'payshield 9000')

Physically-secure, tamper-detecting module use for key storage and cryptographic operations



$ Application Cryptogram $

Image from [1]

Hardware Security Modules

And the difficulty of a flexible-yet-secure API

HSMs need to perform a wide range of functions

Cryptogram generation, PIN block translation, key export...

Key export example:

- card and issuer HSM currently share key K_i
- want to roll to K_{i+1}

APIs sometimes do terrible things in the name of flexibility [2]

IBM Common Cryptographic Architecture key export also allowed key **extraction** by a third party with access to API

Images from http://hasintech.com/?page=hsm&lang=en, http://nexteprocessing.com/emv-smart-cards/, http://newsbtc.com/tag/mtgox, https://www.chase.com/

Cashing Out

Acronym soup: ARQC, ARPC, TC ...

Authorization Request Cryptogram (ARQC)

Generated when online authorization required

Card computes TDES-based MAC on transaction data

Value	Source
Amount, Authorised (Numeric)	Terminal
Amount, Other (Numeric)	Terminal
Terminal Country Code	Terminal
Terminal Verification Results	Terminal
Transaction Currency Code	Terminal
Transaction Date	Terminal
Transaction Type	Terminal
Unpredictable Number	Terminal
Application Interchange Profile	ICC
Application Transaction Counter	ICC

Table 26: Recommended Minimum Set of Data Elements for Application Cryptogram Generation

Image from EMVCo's EMV Book 2

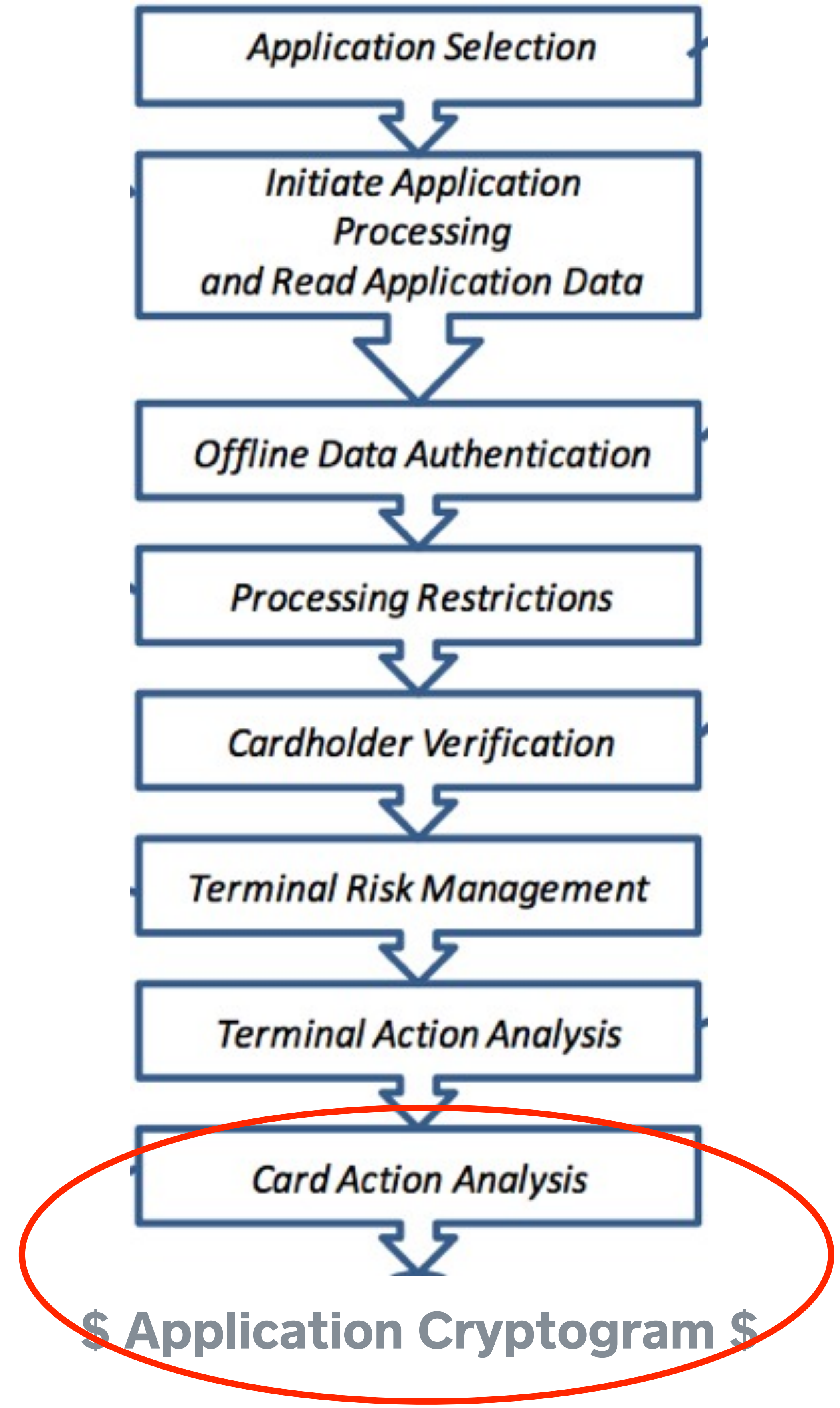


Image from [1]

Cashing Out

Acronym soup: ARQC, ARPC, TC ...

Authorization Response Cryptogram (ARPC)

Sent by issuer when online authorization requested

TDES-based MAC, but authentication data opaque to terminal

Transaction Certificate (TC)

Generated by card, effectively a card-signed (RSA) log of transaction

Needed by acquirer to collect $!

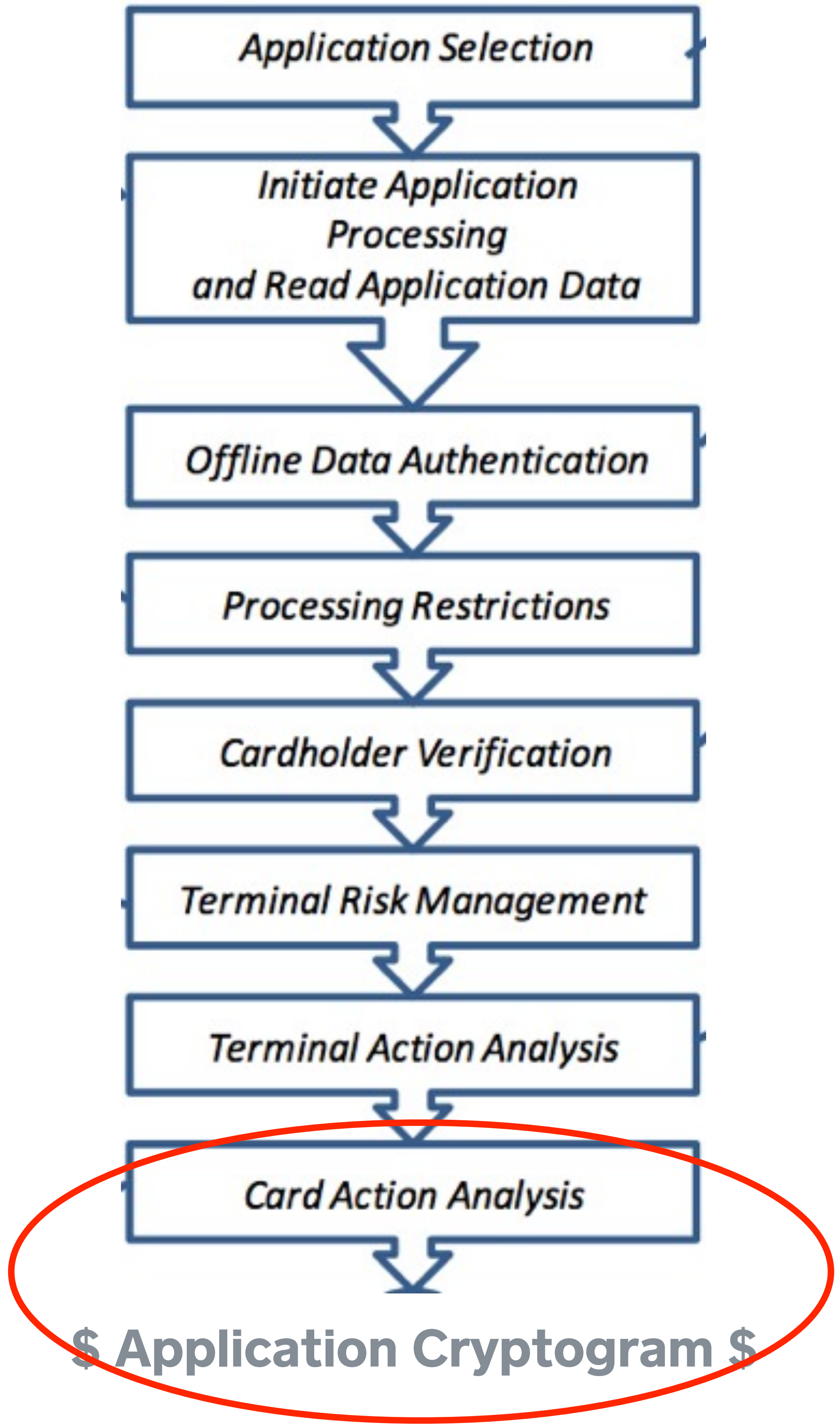


Image from [1]

Untrusted Intermediary

What happens if it's between ICC and terminal?

Why might a cardholder care?

How is the transaction amount communicated to the card?

Can cards authenticate terminals?

What are the challenges involved?

EMVCo discussing proposed ECC-based key-establishment between card and terminal [3]

Blinded Diffie-Hellman. Why the blinding factor?

Images from http://www.emvco.com/about_emv.aspx , http://pbskidsbookwrombunch.wikia.com/wiki/File:Hamburglar.gif , and http://www.cl.cam.ac.uk/research/security/banking/tamper/

Relay Attacks

Humans are usually the weakest link

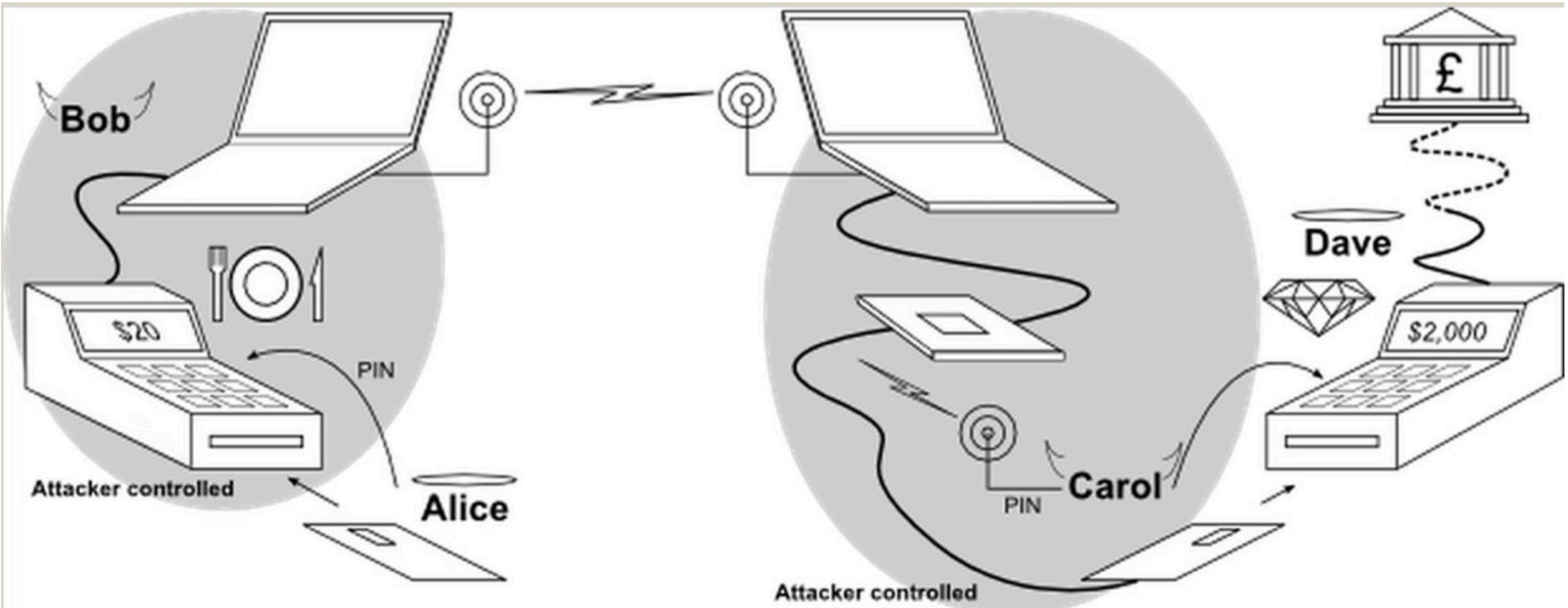


Image from [3]

Pre-play Attacks

What if a weak RNG is used to generate the Unpredictable Number?

What about a REALLY weak RNG?
Details in [5], let's discuss on whiteboard

securing $ with crypto, subject to real-world constraints

=

real-world problems

External References

[1] EMVCo. "A Guide to EMV" http://www.emvco.com/best_practices.aspx?id=217

[2] Adida et al. "Phish and Chips: Traditional and New Recipes for Attacking EMV." *Security Protocols Workshop,* Cambridge, England, March 2006.

[3] Saar Drimer and Steven J. Murdoch. "Chip and PIN (EMV) Relay Attacks." https://www.cl.cam.ac.uk/research/security/banking/relay/

[4] EMV Specifications. http://www.emvco.com/specifications.aspx?id=155

[5] Mike Bond; Omar Choudhary; Steven J. Murdoch; Sergei Skorobogatov; Ross Anderson. "Chip and Skim: Cloning EMV cards with the pre-play attack." 2012.