Peppercoin Micropayments

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Outline

- Micropayment examples
- Challenges
- Aggregation methods
- The "Peppercoin" method
  (In England a *peppercorn* is smallest amount that can be paid in a contract)

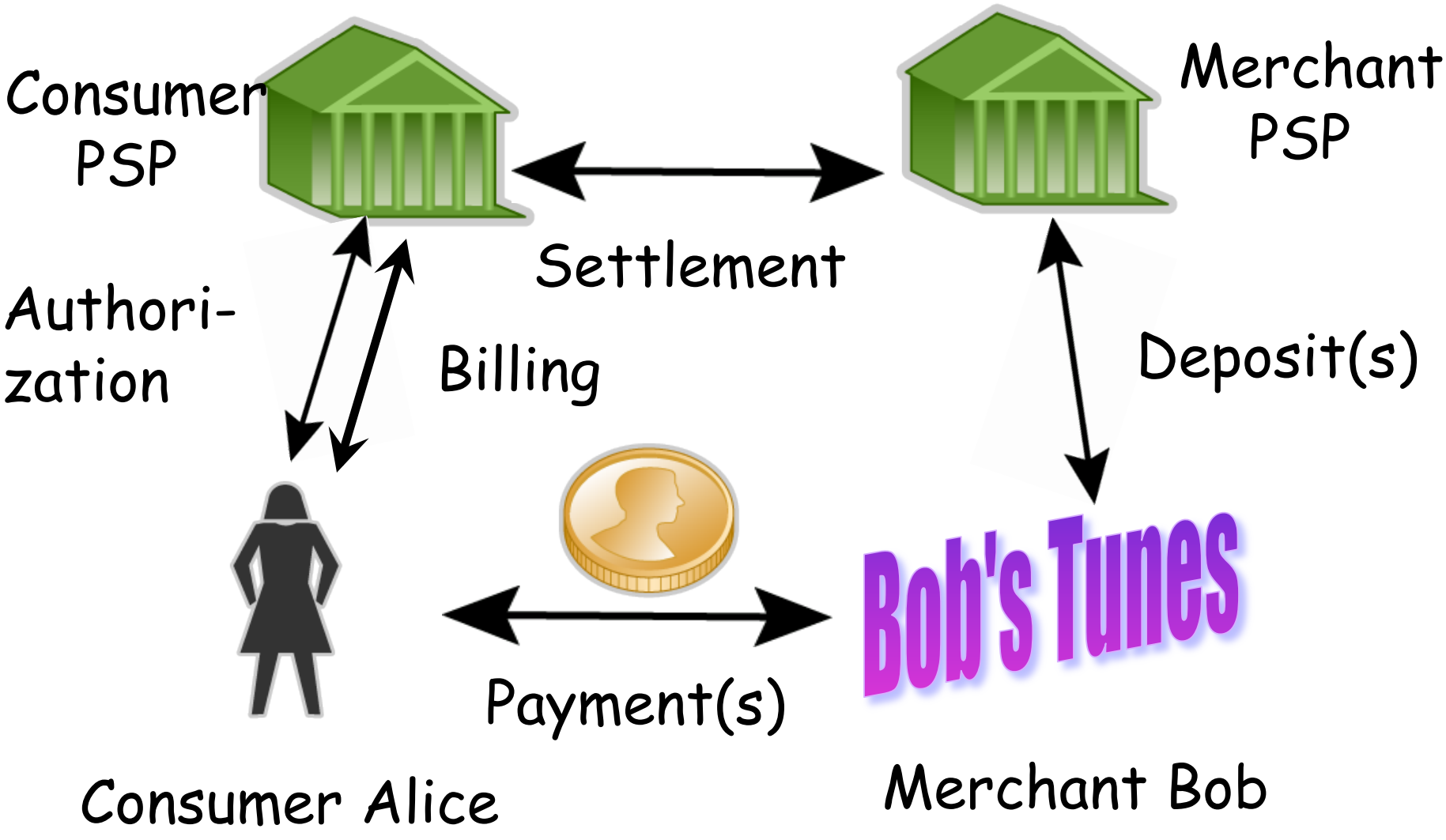
What is a "micropayment"?

- A payment in the range 0.1¢ to $10.
- A payment small enough that processing it is relatively costly. (Processing one credit-card payment costs about 25¢ …)
- *Processing cost* is the key issue for micropayment methods.

Lydians invented coins 640 B.C.

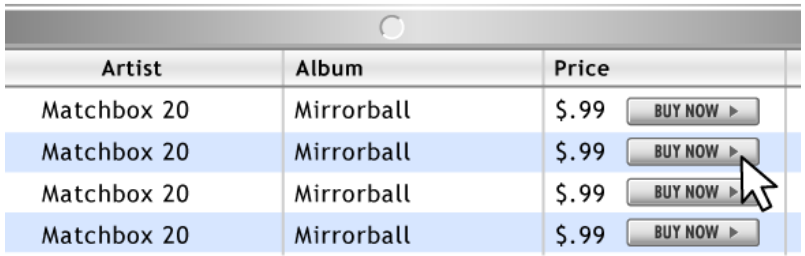
- Before 640 B.C.: ***gold bars, barter***
  small purchases difficult.
- After 640 B.C.: ***coins***
  small purchases easy.
- Before 2003: ***credit cards***
  small on-line purchases difficult.
- After 2003: …

Generic Payment Framework



How we'll make small payments

- Web download
  - Music (even streaming)



- Mobile phone
  - Map
  - Ringtones

- Physical POS
  - Vending machine

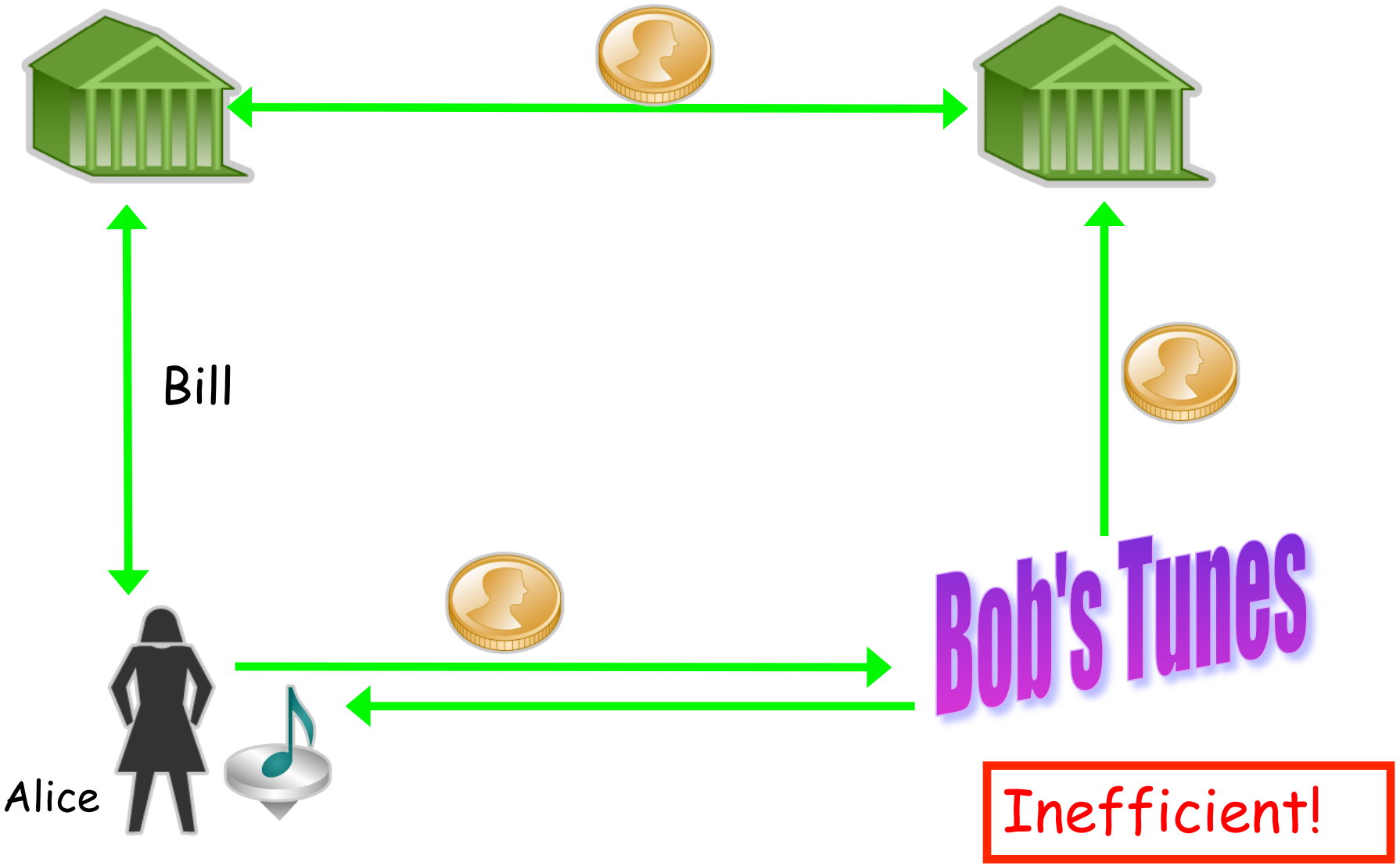
Challenges:

- Ease-of-use
- Low-Cost
- Extending existing payment framework
- Security
- … (many other issues, too)

Aggregation

- To reduce cost, ***micropayments*** must be aggregated into fewer ***macropayments***.
- Possible levels of aggregation:
  - **None**: Every payment deposited with PSP
  - **Merchant-level**: A consumer's payments are aggregated by merchant
  - **MicroPSP**: Monopoly service that disintermediates existing payment services; doesn't scale well
  - **Universal**: Payments aggregated across all users and merchants, even those supported by different cooperating PSPs

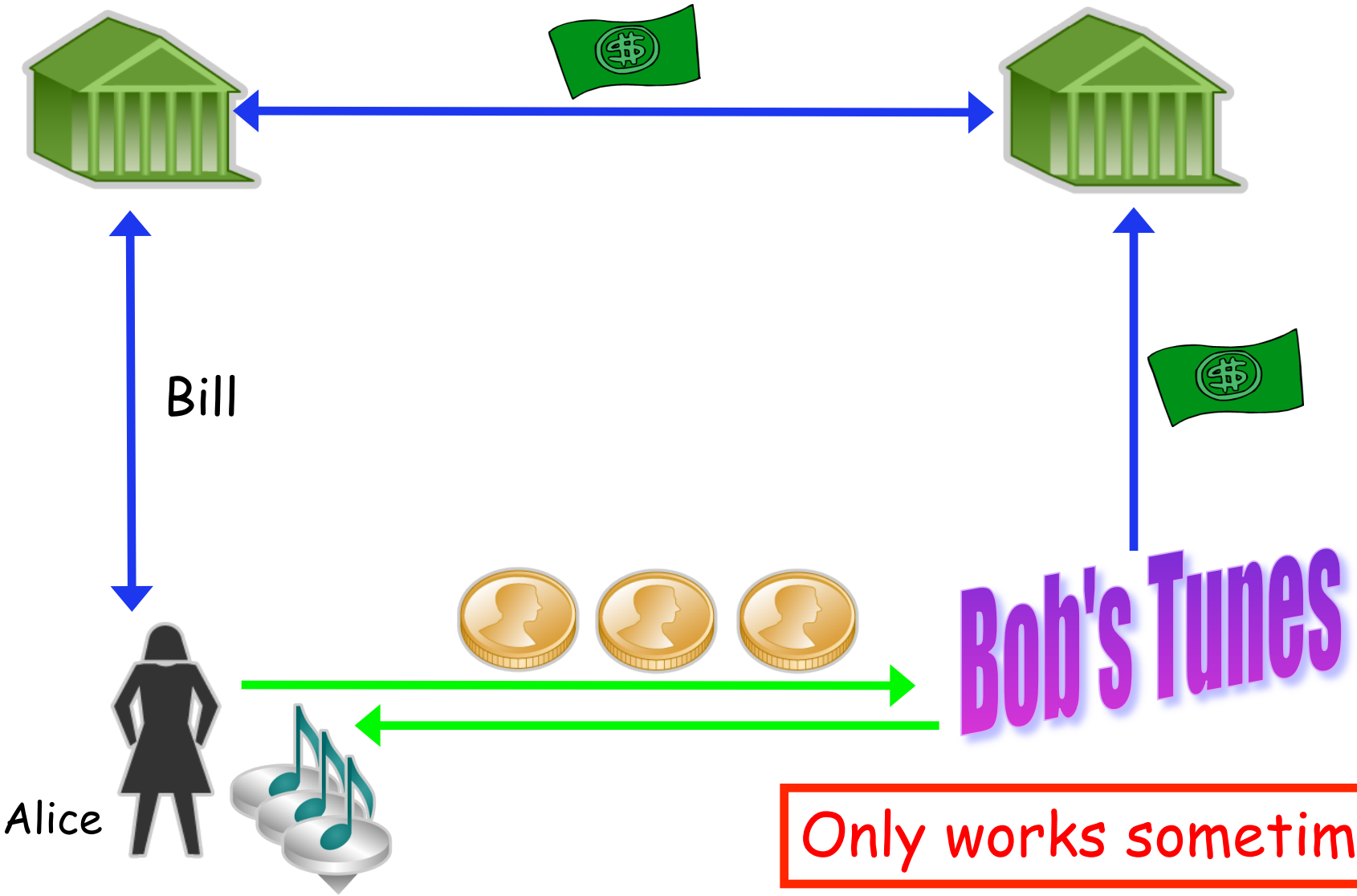
No Aggregation



Previous Work: Digital Cash

- Example: Chaum's digital coins
- Emphasis on *anonymity:*
  Withdrawals use blind signatures
- Problem of double-spending handled by having doubler-spenders revealed (e.g. Brand's protocol)
- No aggregation: every coin spent is returned to the PSP.

Merchant-Level Aggregation

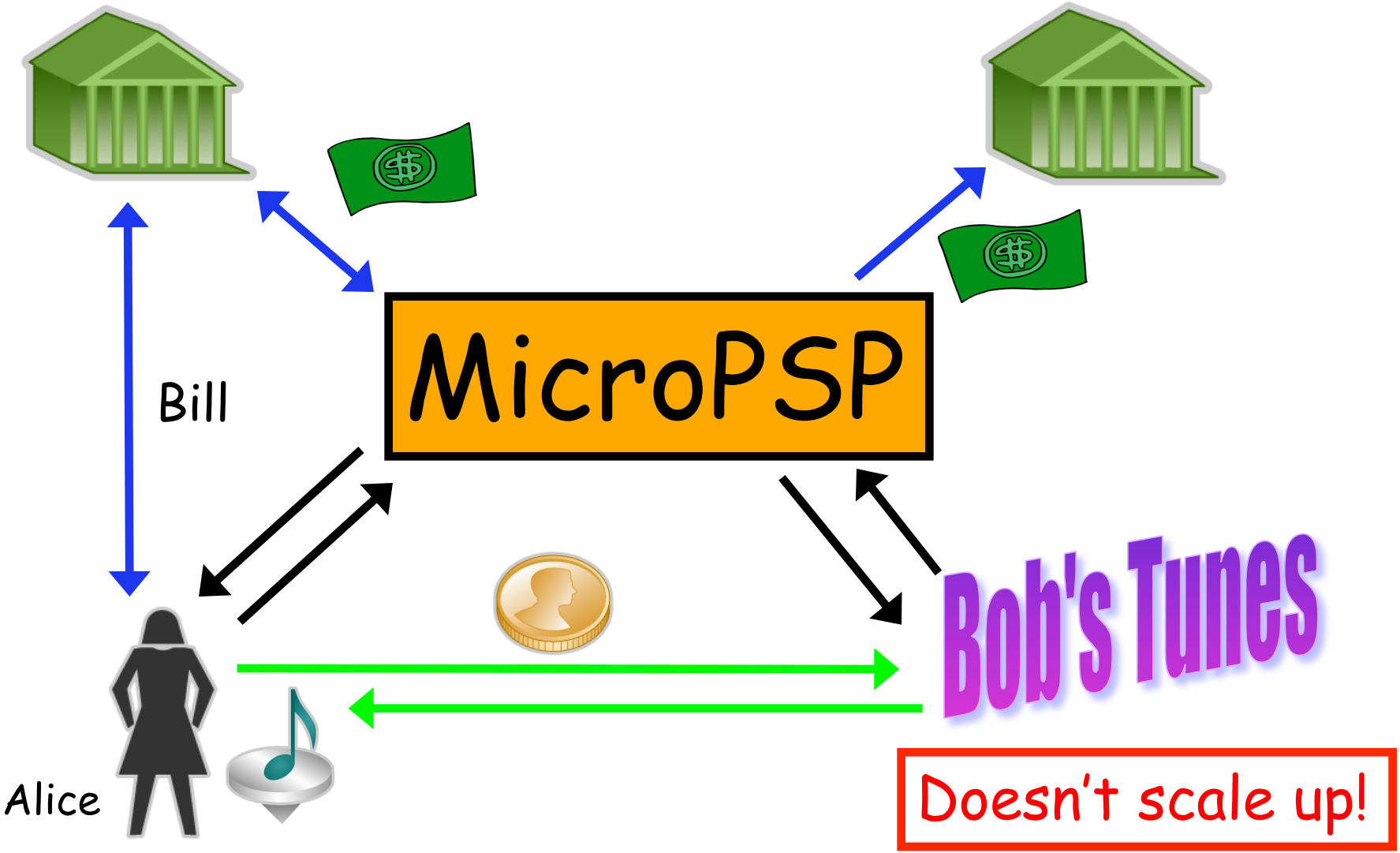


Previous Work: PayWord

- Rivest and Shamir '96
- Emphasis on reducing public-key operations by using per user/merchant hash-chains instead:

  $x_0 \leftarrow x_1 \leftarrow x_2 \leftarrow x_3 \leftarrow \ldots \leftarrow x_n$
- User signs x_0 over to merchant and releases next x_i for next payment
- Merchant-level aggregation only.

MicroPSP Aggregation



Universal Aggregation

- ***Universal aggregation*** dramatically reduces processing cost, independent of spending patterns.
- *Also called* ***many/many/many aggregation****:* Aggregates payments from
  - *Many* consumers
  - *Many* merchants
  - *Many* PSP's

  in any combination. No need to aggregate sales per consumer.

Universal Aggregation Idea

- Would merchant prefer:

  (a) twenty *50 cent payments*, or

  (b) *$0 for 19 payments, and $10 for one?*

  No difference to merchant, on average

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What if processing costs 20 cents per payment?

(a) nets only 30 cents per payment

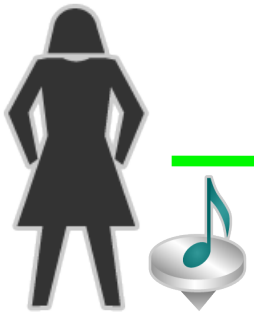
(b) nets 49 cents net per payment!

Merchant strongly prefers (b) !

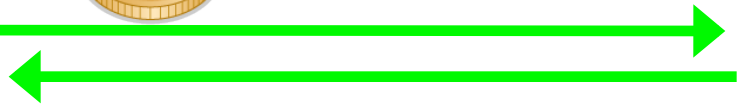
Peppercoin's Universal Aggregation

- One micropayment in 20 is "cryptographically selected" by merchant, and deposited for 20x its value, as a macropayment!
- Yet consumer pays *only* for what she has spent: each micropayment records cumulative amount she has spent at all merchants.

Peppercoin's Universal Aggregation



50 cents



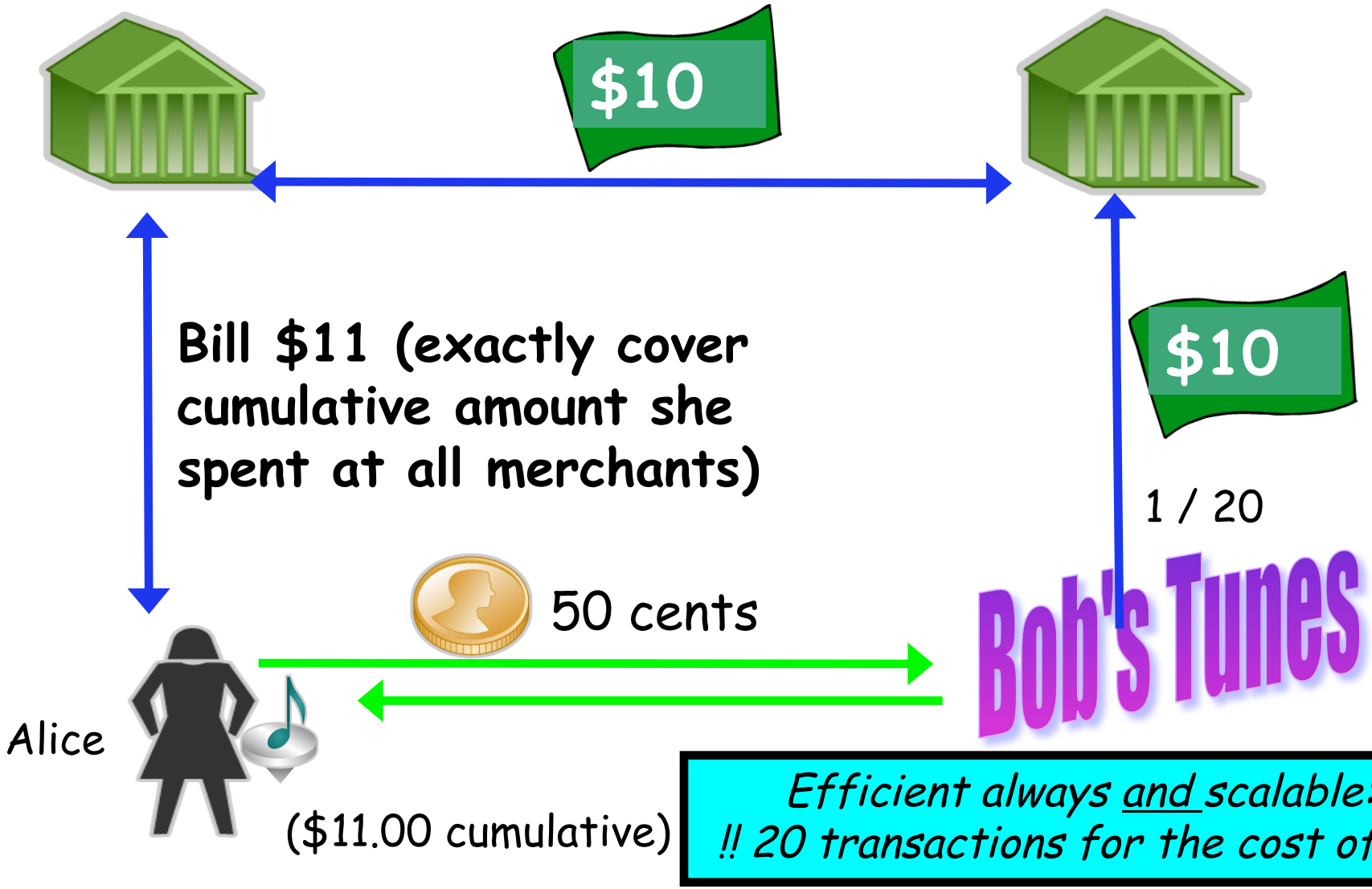
19 / 20

Log

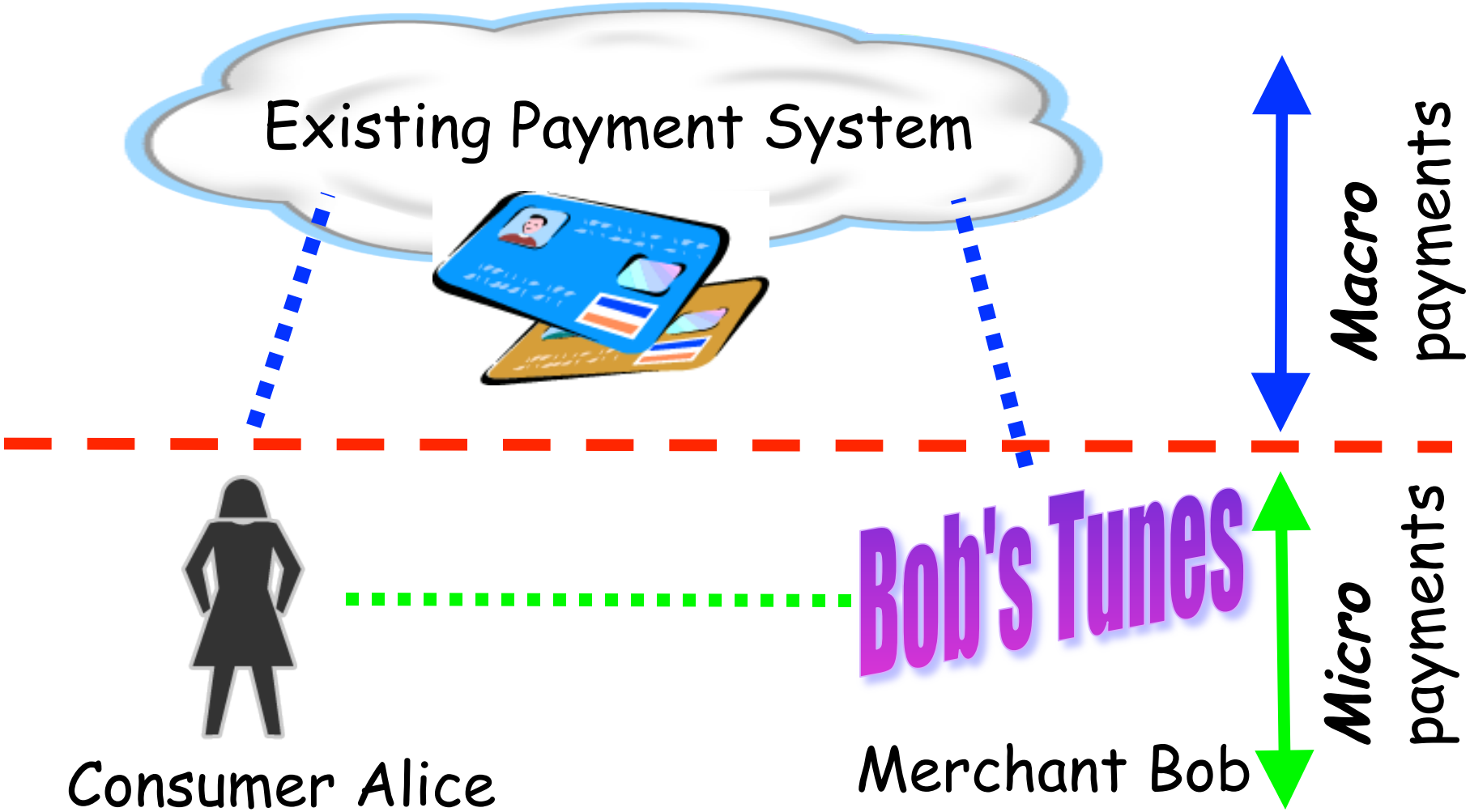
Alice ($8.50 cumulative)

Peppercoin's Universal Aggregation

Peppercoin's Universal Aggregation



Peppercoin Extends Existing Payment Systems to Micropayments

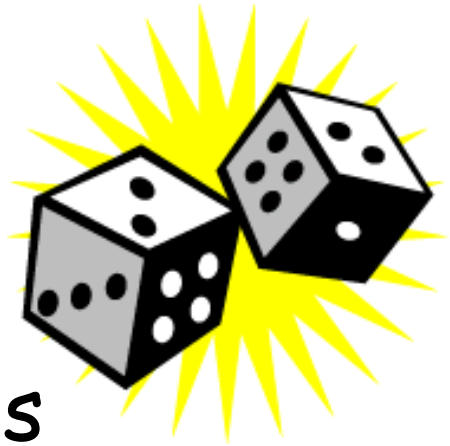


Dimensions to consider:

- Aggregation (*universal)*
- PSP on-line or off-line ? *(off-line)*
- Interactive vs. non-interactive *(non)*
  - (e.g. anti-spam payment in email)
- Computation Cost *(cheap)*
- User-fairness *(fair)*
- … (many other issues, too)

Previous Work: Lottery Tickets

- "Electronic Lottery Tickets as Micropayments" – Rivest FC '97 (similar to "Transactions using Bets" proposal by Wheeler '96)
- Payments are *probabilistic*
- First schemes to provide <u>universal aggregation:</u> payments aggregated across all user/merchant pairs.



"Lottery Tickets" Explained

- Assume micropayments are for ten cents.
- Merchant gives user y = hash(x) for random x.
- User writes check: "Pay Merchant $10 if two low-order digits of $hash^{-1}(y)$ are 75." (Signed by user, with cert from his PSP.)
- Merchant "wins" $10 with probability 1/100. Expected value of payment is 10 cents.
- Bank sees only 1 out of every 100 payments. (A plus for user privacy!)

Non-interactive

- Revised check:
  "Pay Merchant $10 if
  two low-order digits of
  the hash of Merchant's digital signature on this check are 75."
- Merchant's deterministic signature scheme unpredictable to user.
- Merchant can convince PSP to pay.

Computation Cost

- Digital signatures are still relatively expensive --- but *much cheaper than they used to be!*
- It now seems reasonable to base micropayments on digital signatures. (E.g. Java card in cell phone)
- User and merchant are anyways involved with each transaction; digital signatures add only a few milliseconds.
- On-line/Off-line signature can also help.

Optimization for less Signing

- "Pay Merchant $10 if the two low-order digits of the hash of Merchant's digital signature on *the date of* this check are 75."
- Merchant only signs once a day.

Variable-sized payments

- To make micropayment of size m:
  - Chance of "winning" becomes
    m / M
    where M is the macropayment size.
- For example, a $1 micropayment converts to a $10 macropayment with probability 1/10.
- A one-penny micropayment converts to a $10 macropayment with probability 1/1000.

Is revenue variance an issue?

- **Theorem.** If Peppercoin reduces merchant fees by R percent of transaction value, then merchant will be ahead (with probability 999,999/1,000,000) after only
$$(5 / R)^2$$
macropayments have been received.
- **Example:** micro = 0.10, macro = $10, otherfee = 0.03, peppercoinfee = 0.01, R = 0.20, $(5/R)^2 = 625$ or $6250 total value.

Fraud models

- Security is challenging to achieve given that PSP has only partial information, parties may collude, and payment schedules are decoupled.
- For example, consumer and merchant may try to collude to defraud PSP's.
- One effective countermeasure is to make macropayment to merchant only from revenues from that specific consumer (perhaps deferring payment if necessary).

Conclusion

- Peppercoin micropayments are
  - Easy to use
  - Low-cost even for small payments
  - Flexible
    (interface with existing payment systems)
  - Secure
- www.peppercoin.com

Thanks!

(The End)