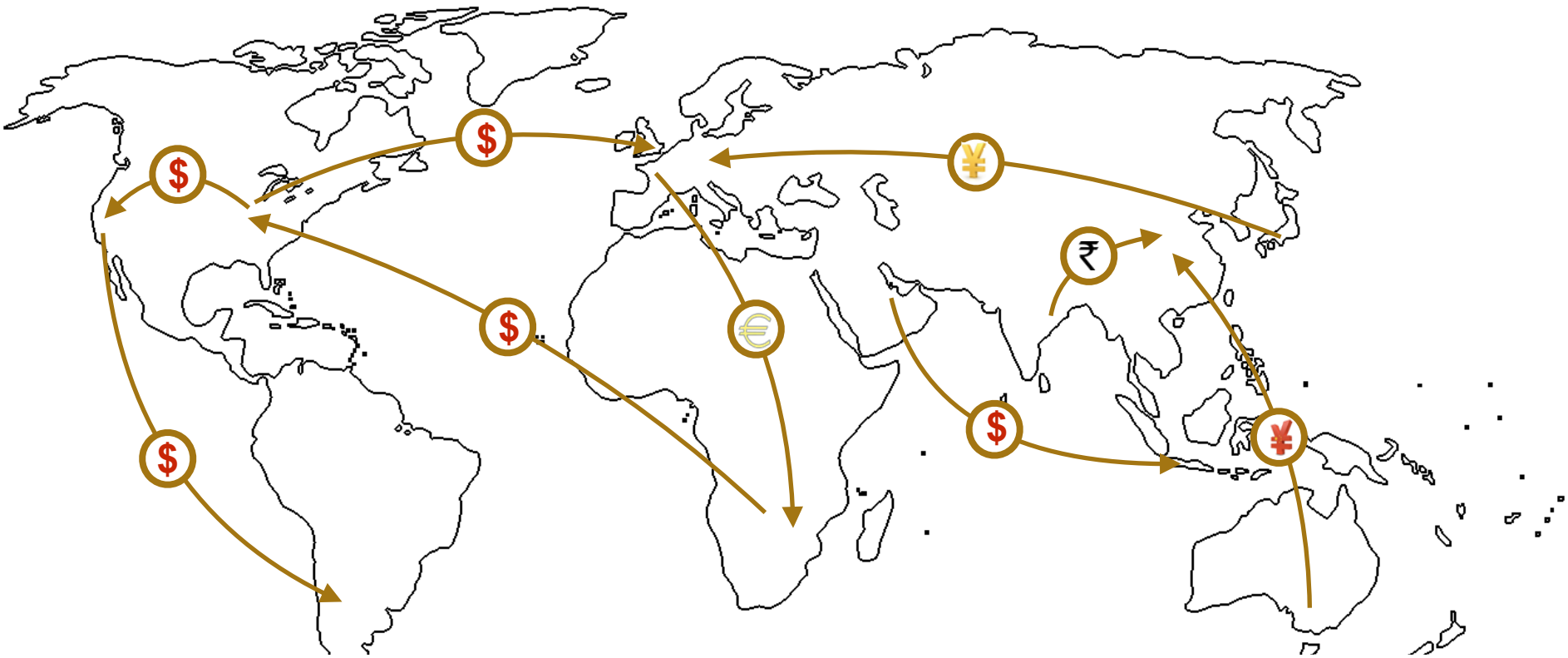
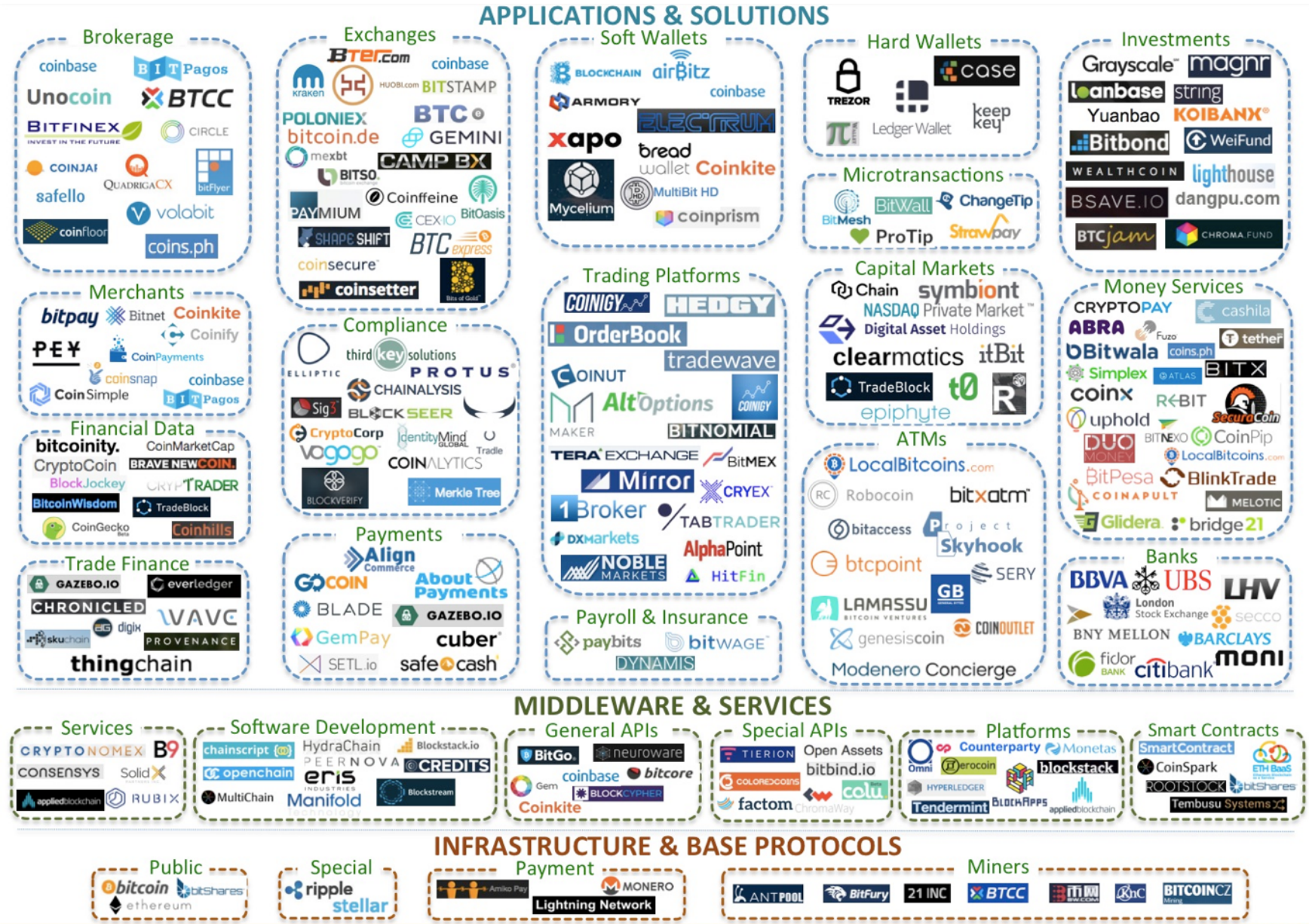
Distributed *IOweYou* Credit Networks



Aniket Kate
Purdue University

Blockchains can change a lot of things



Source: http://startupmanagement.org/blog

Issues with Global Blockchains

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  - If one controls more than half of the computation power in any permission-less cryptocurrency system, he/she can …

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- IOU (or Credit) Networks
  - Combining credit and social trust (still not permissioned)

This talk aims at leaving you with *more questions* than answers regarding credit networks ;)

Credit (or IOU settlement) Networks: Basics

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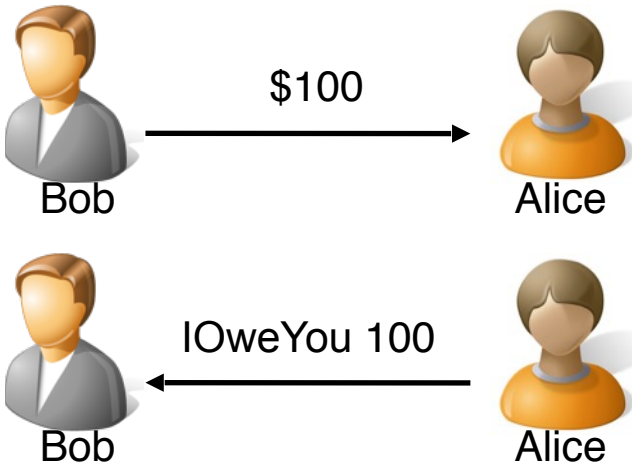
Transactions in the real world



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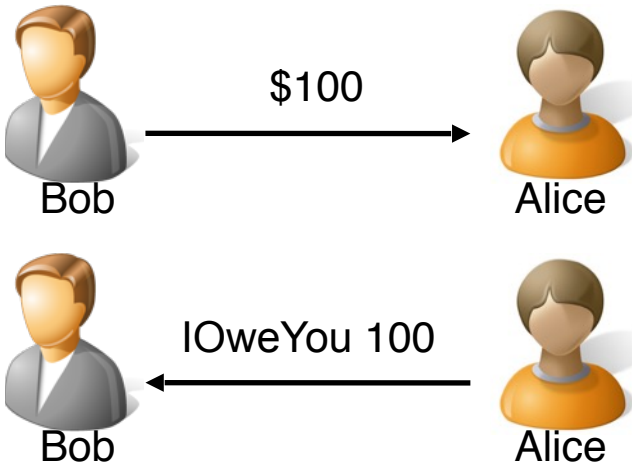
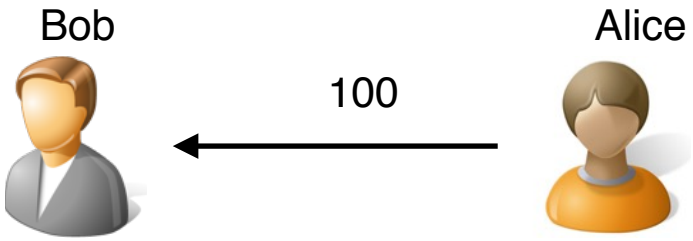


A credit network representation



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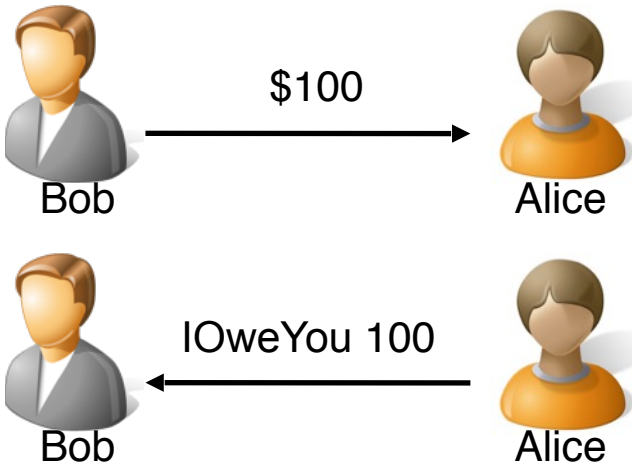
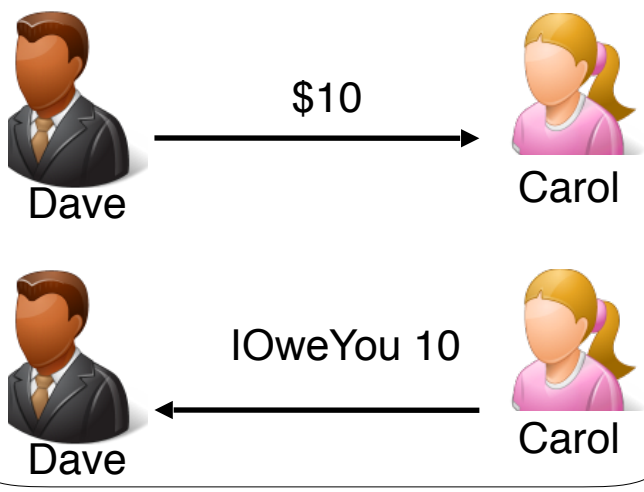


During a hike with Alice & Bob



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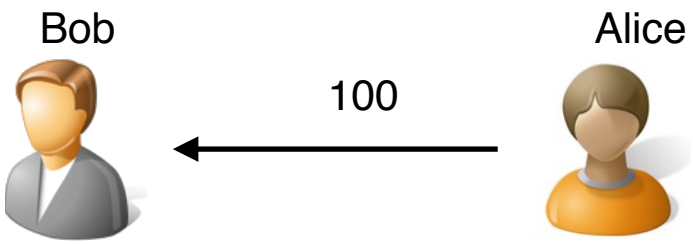

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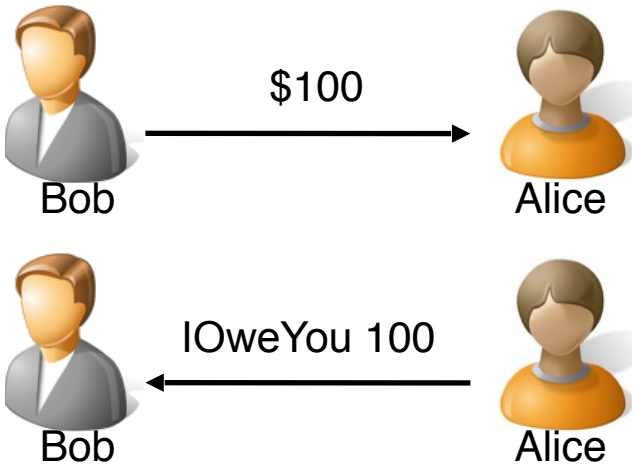

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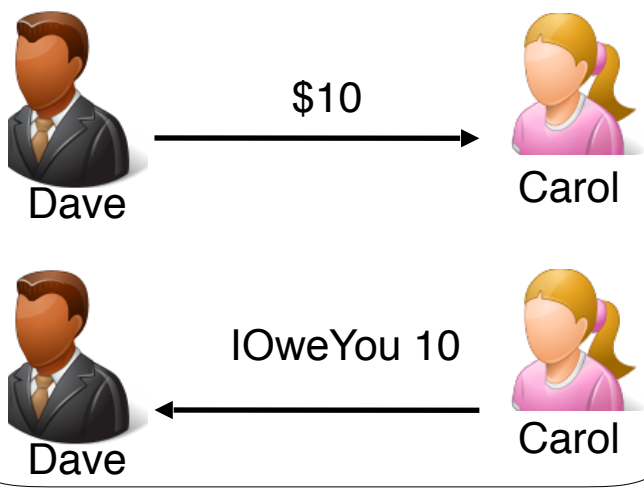

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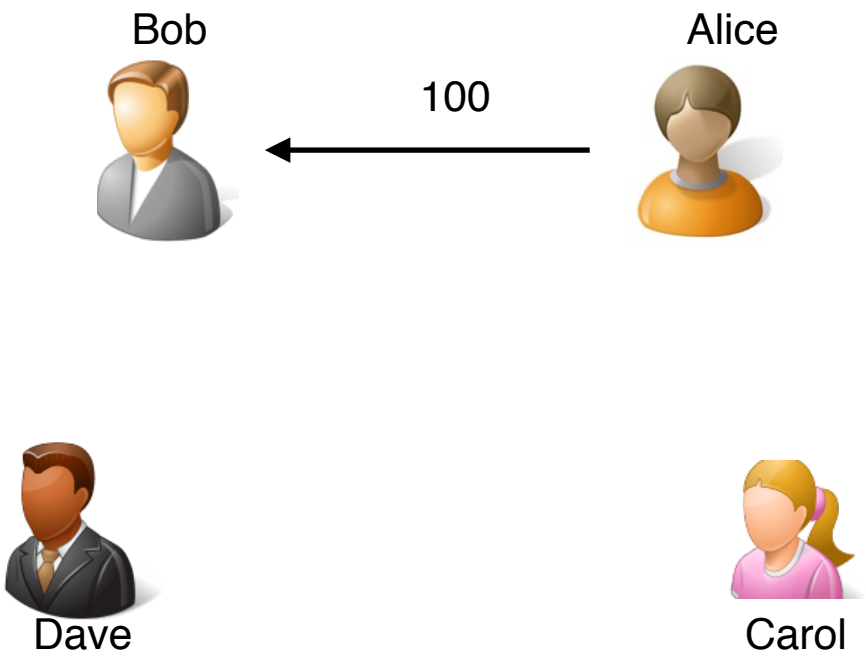

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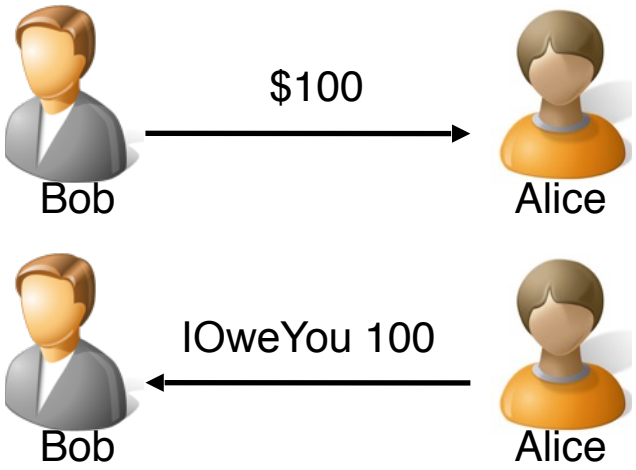

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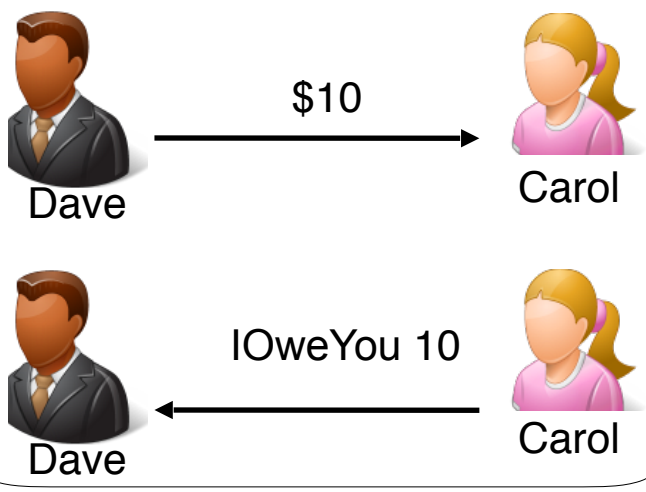

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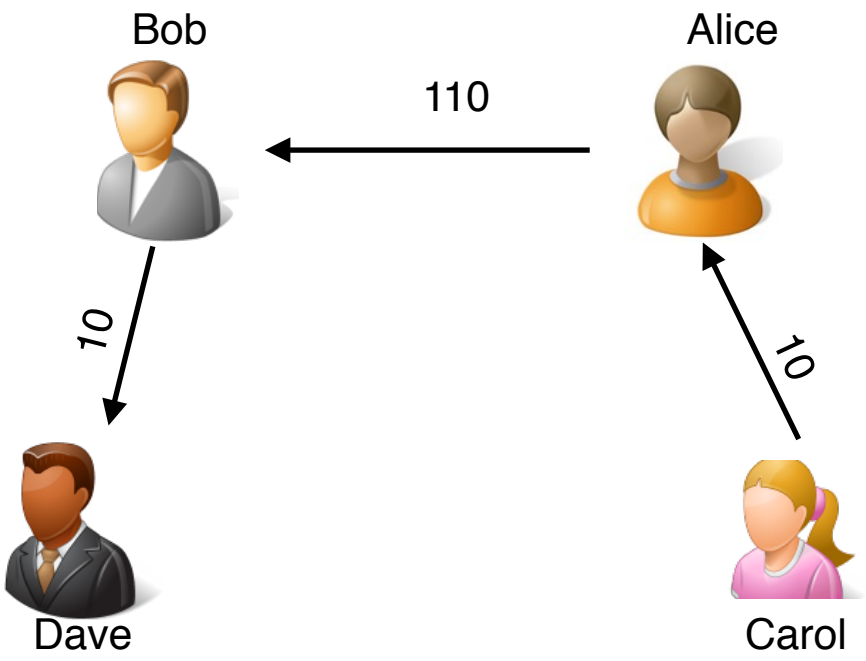
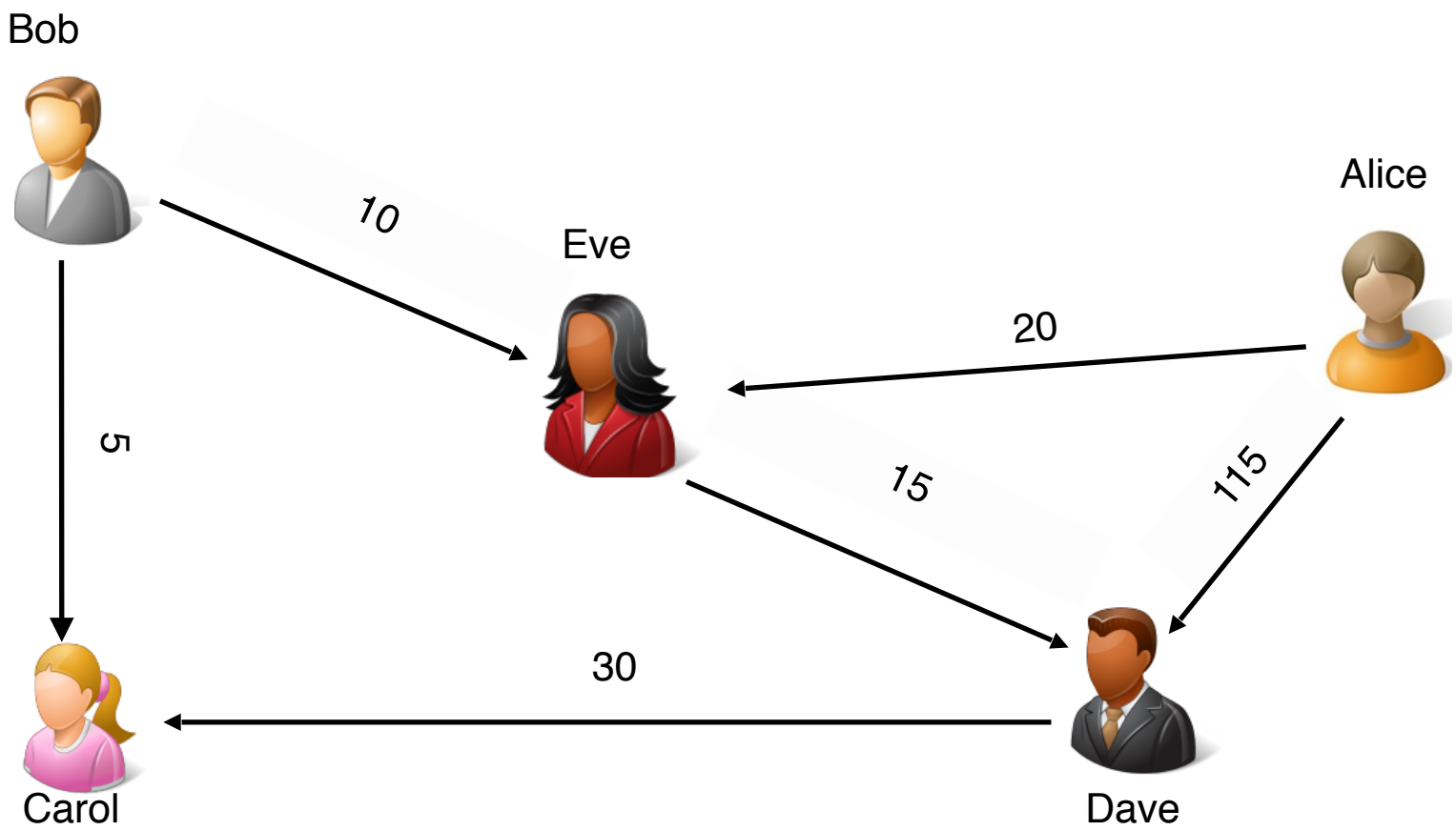


Payment (or credit) Network: an Example



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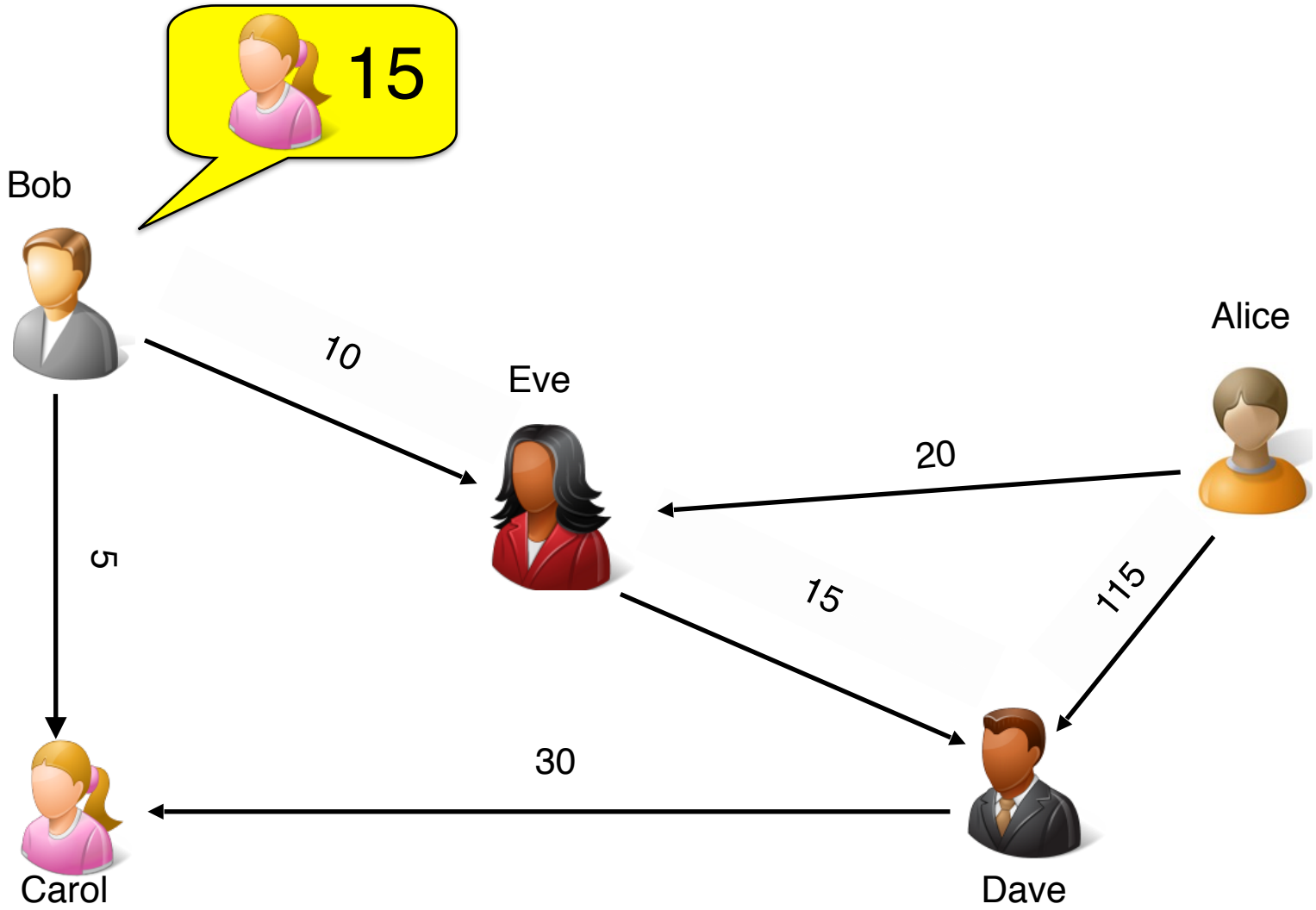
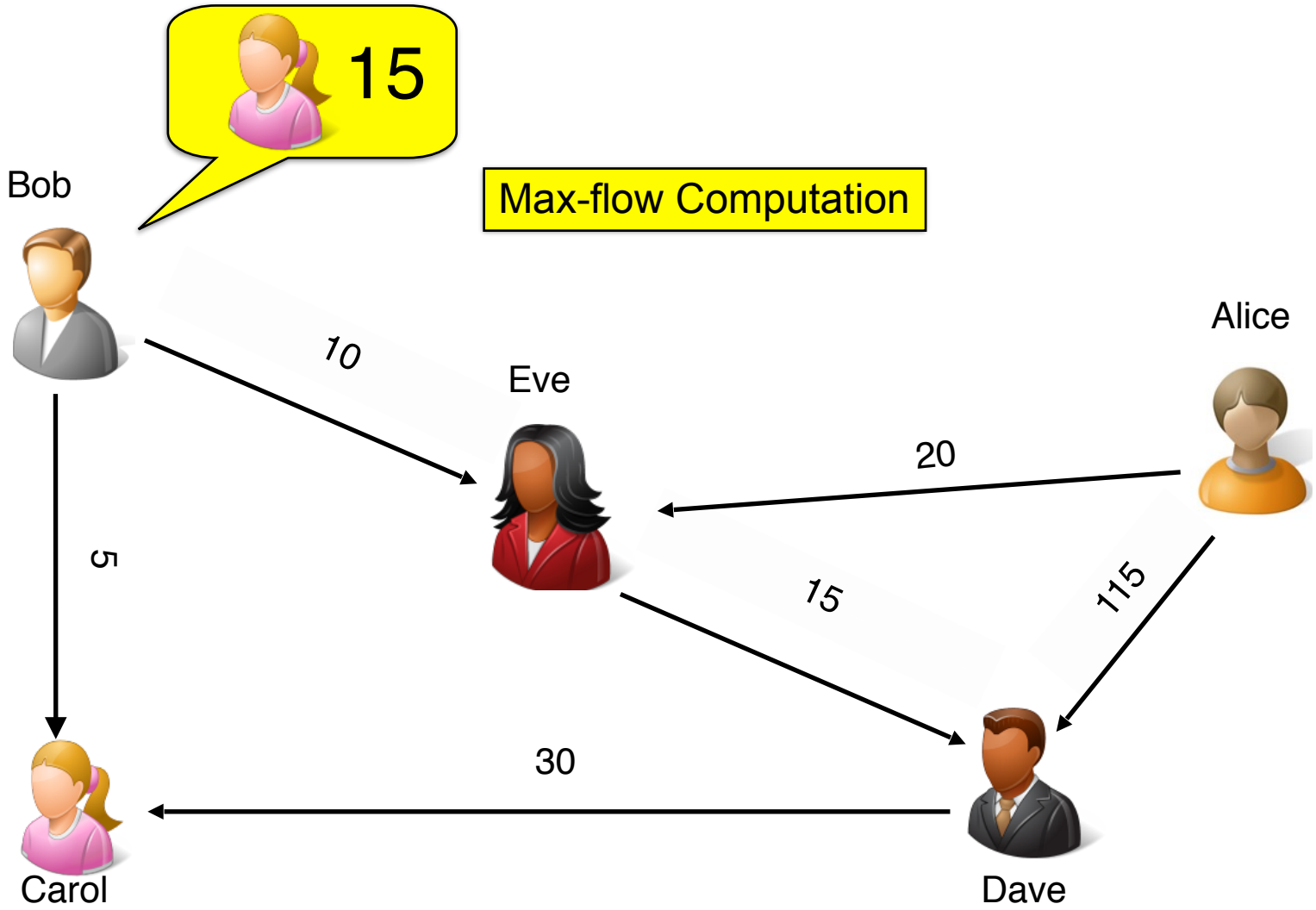


Payment (or credit) Network: an Example



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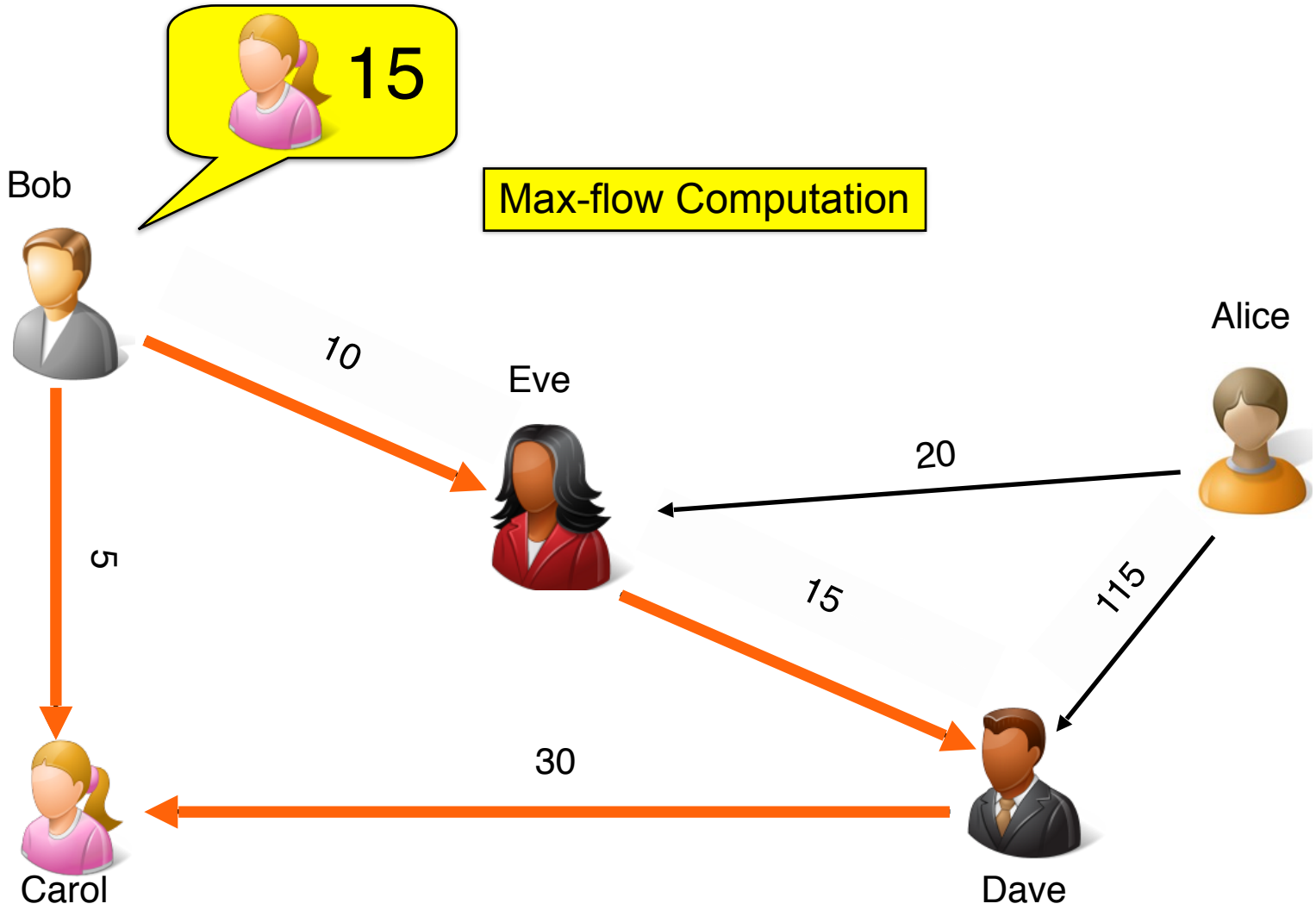

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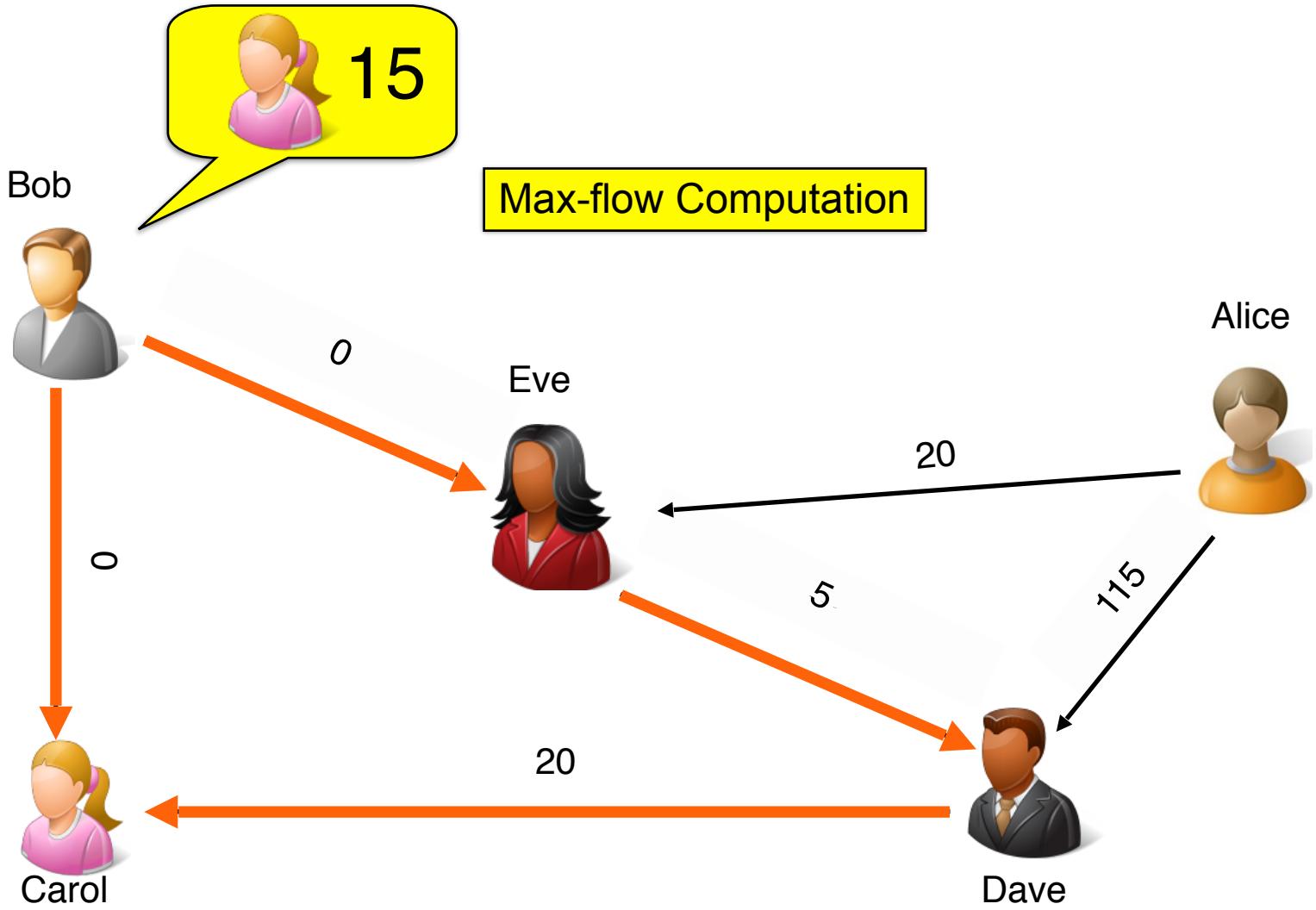

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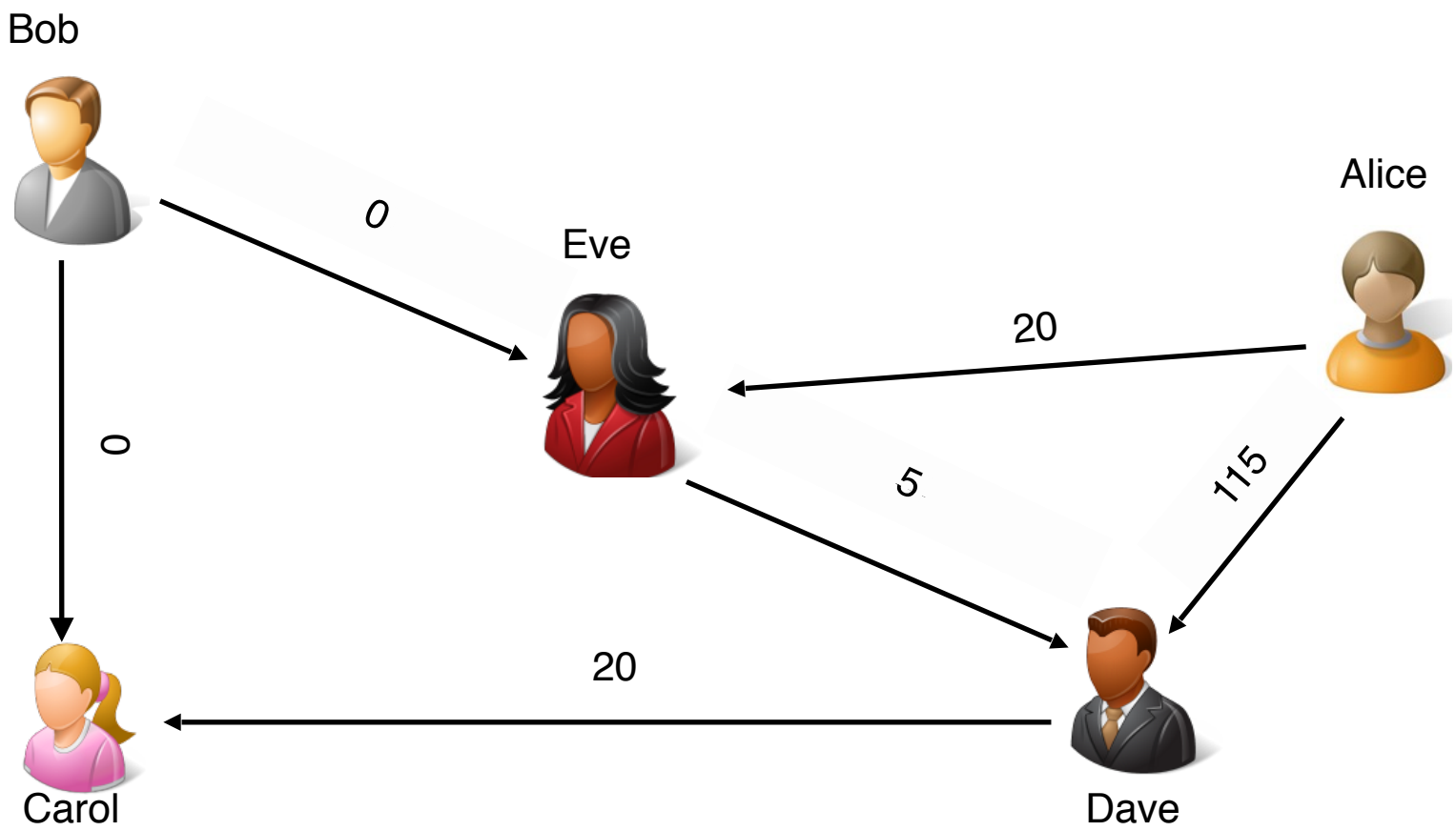

Why credit networks matter?

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- A flexible-yet-robust design for distributed (transitive) trust
  - through pairwise credit allocations
- Loss incurred due to misbehaving identities is bounded and (sometimes) localized

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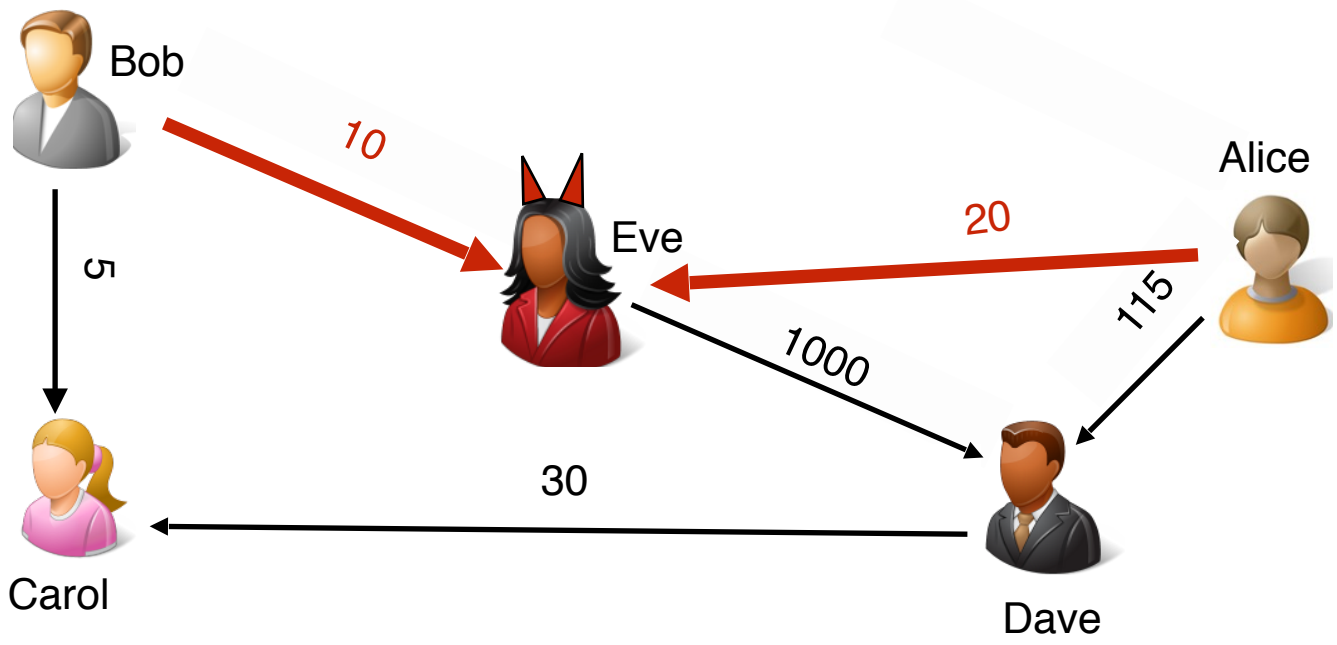
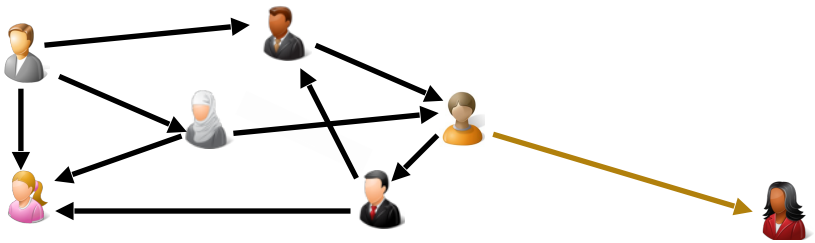


Building trust with credit networks

- Sybil-resistant applications



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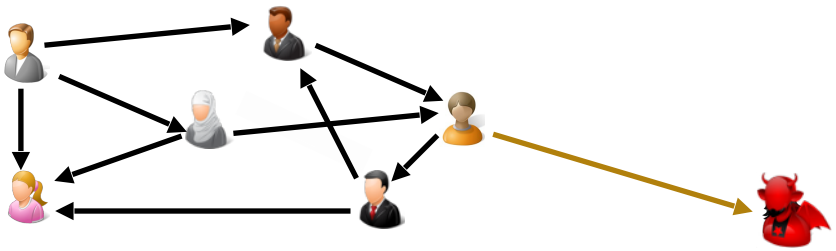

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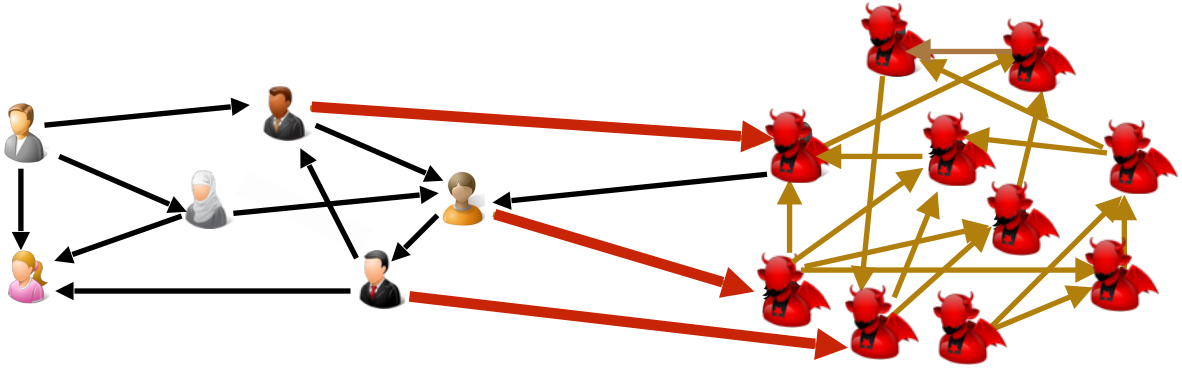

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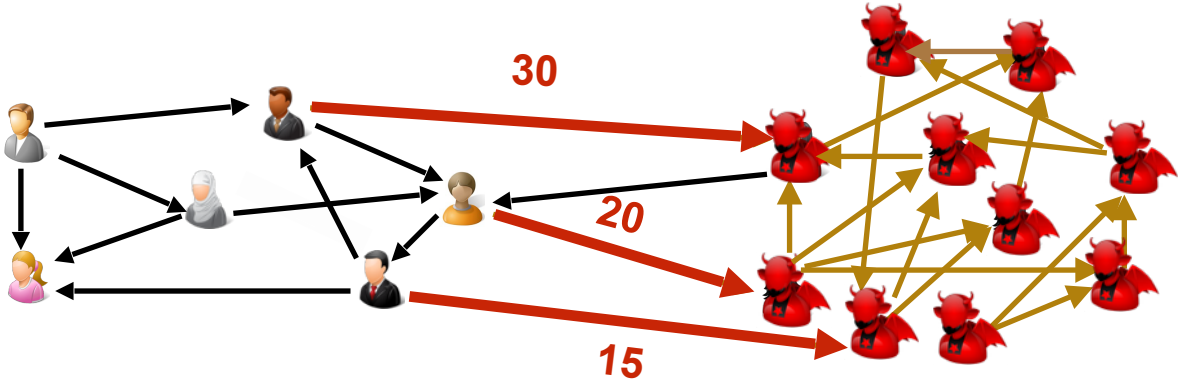

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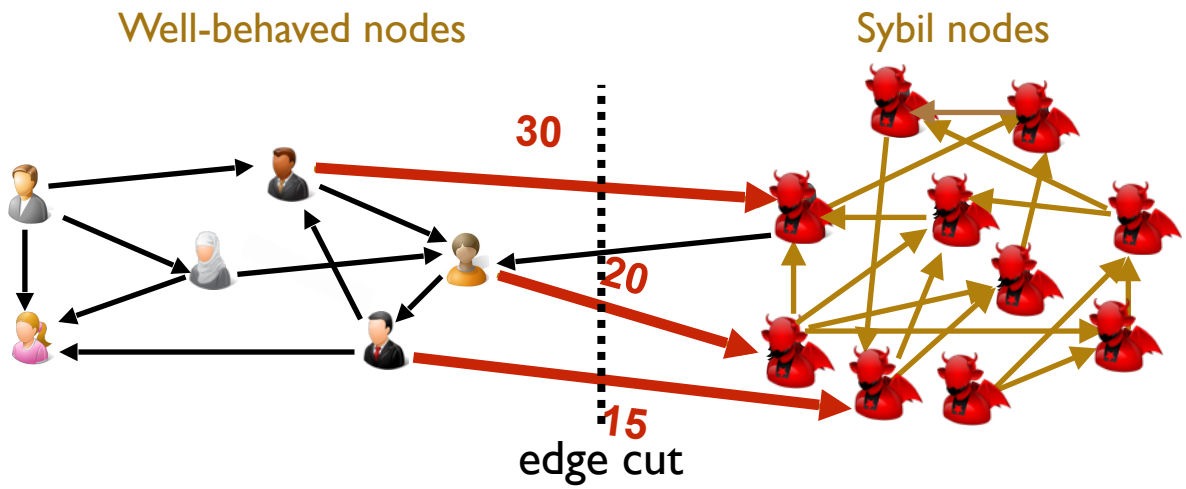

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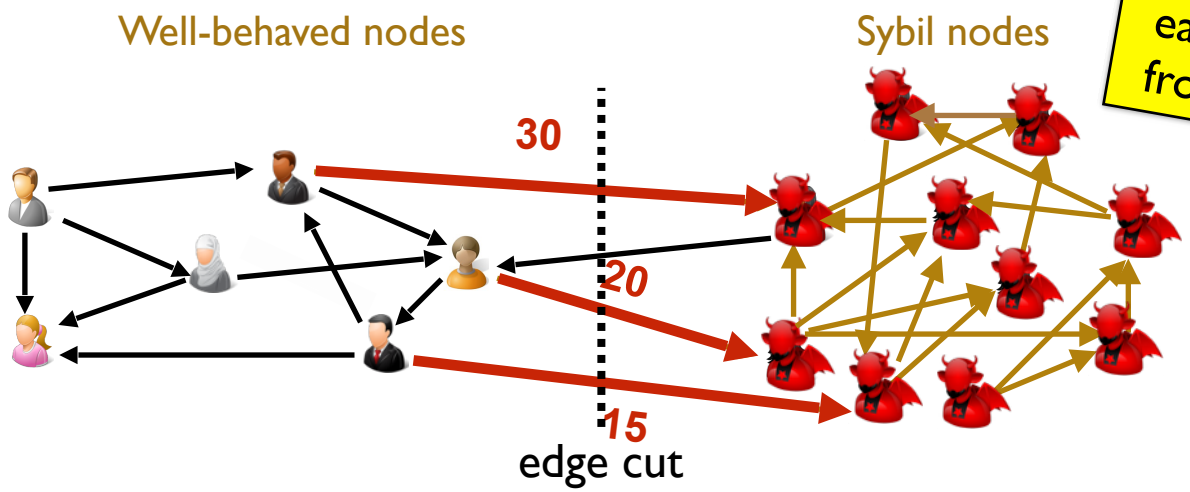

Introducing nodes is much easier than drawing trust from well-behaved nodes

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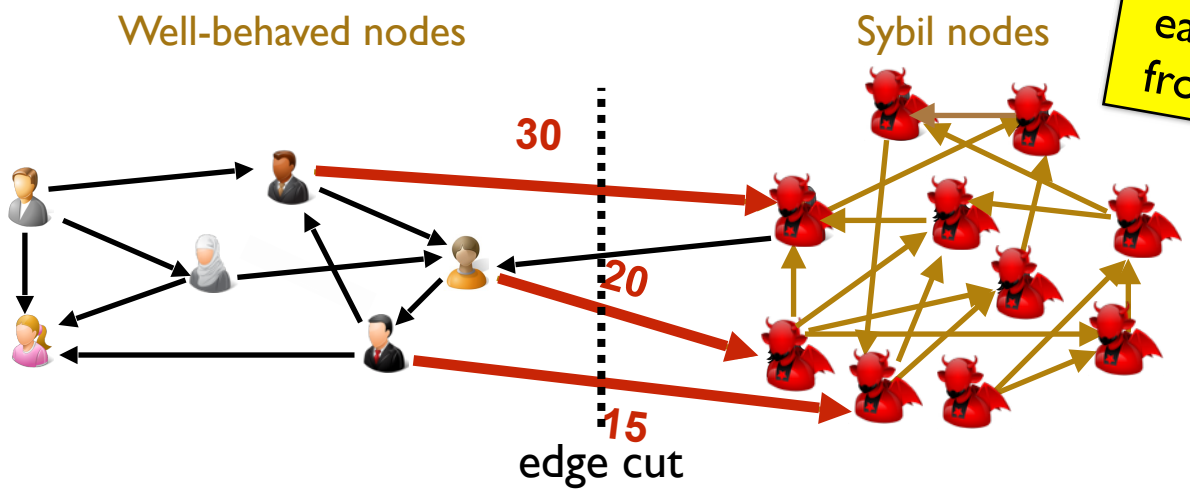

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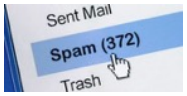

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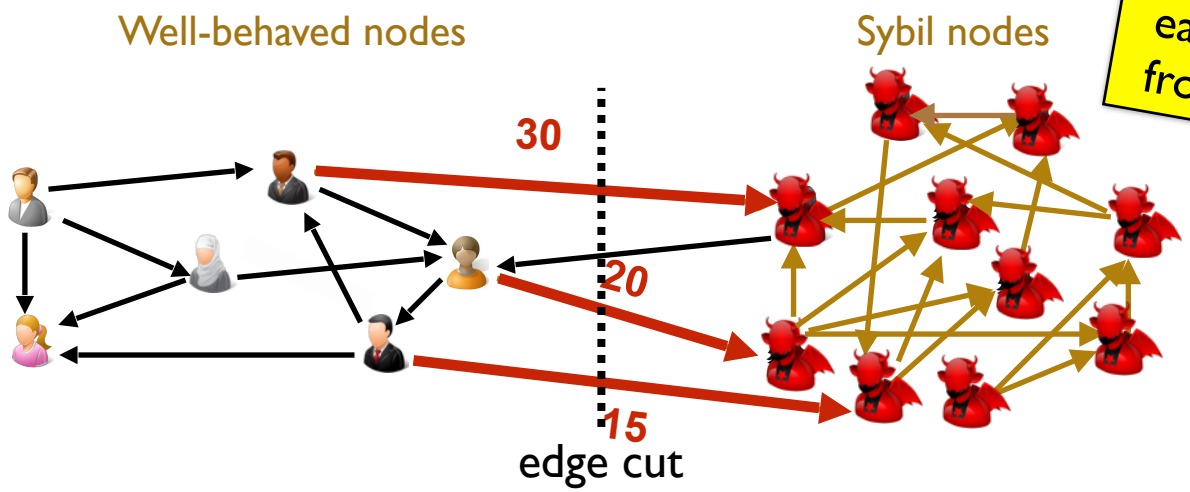

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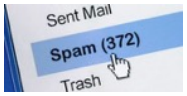

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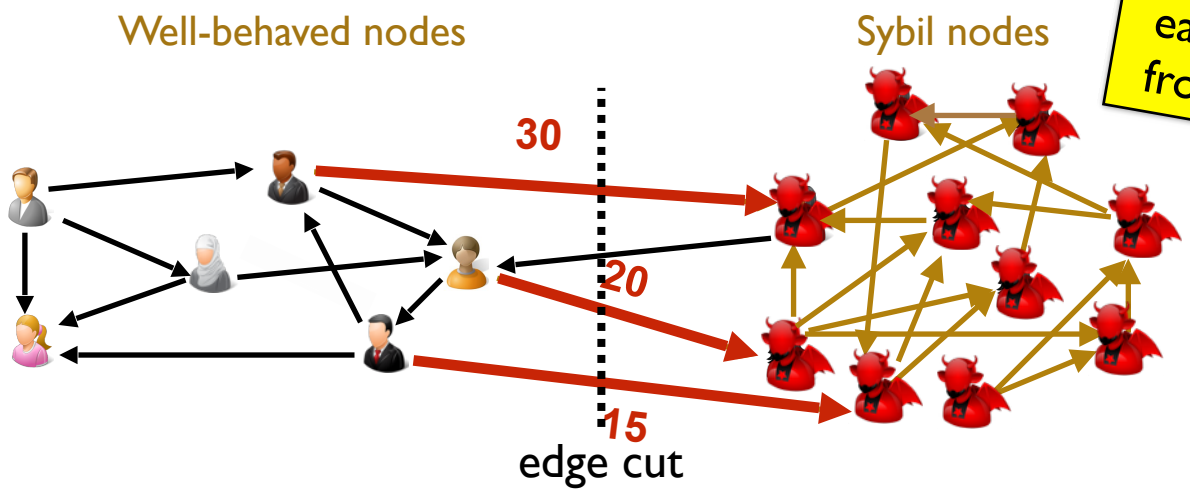

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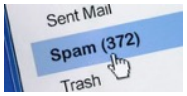

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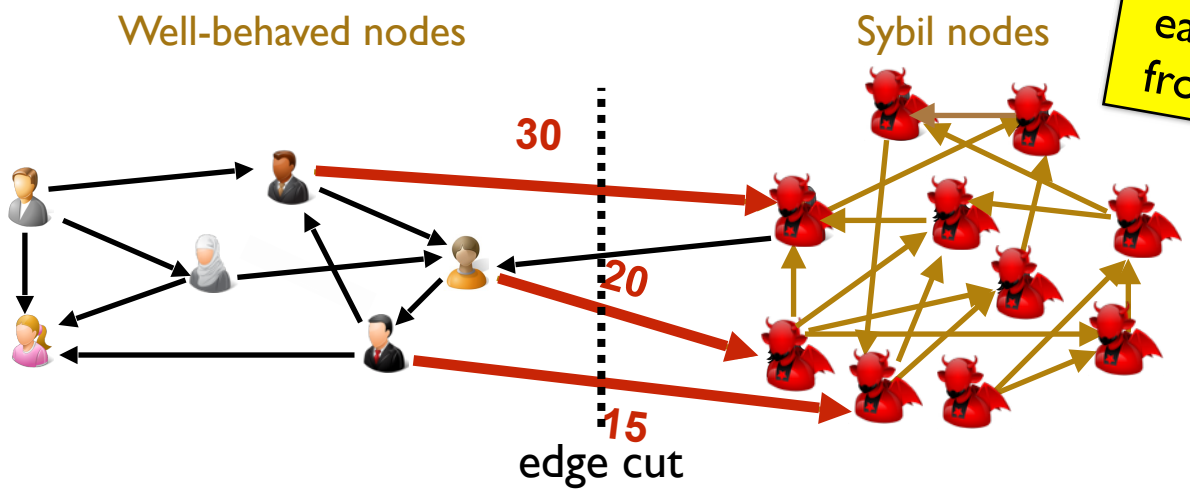

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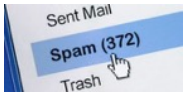
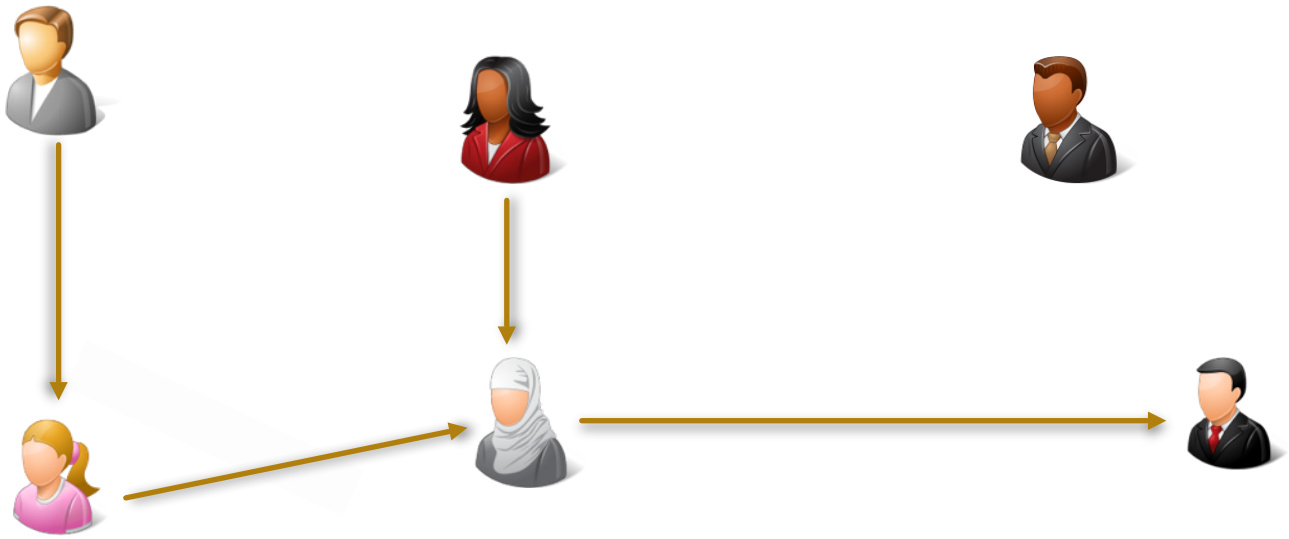


Ripple Credit (or Settlement) Network



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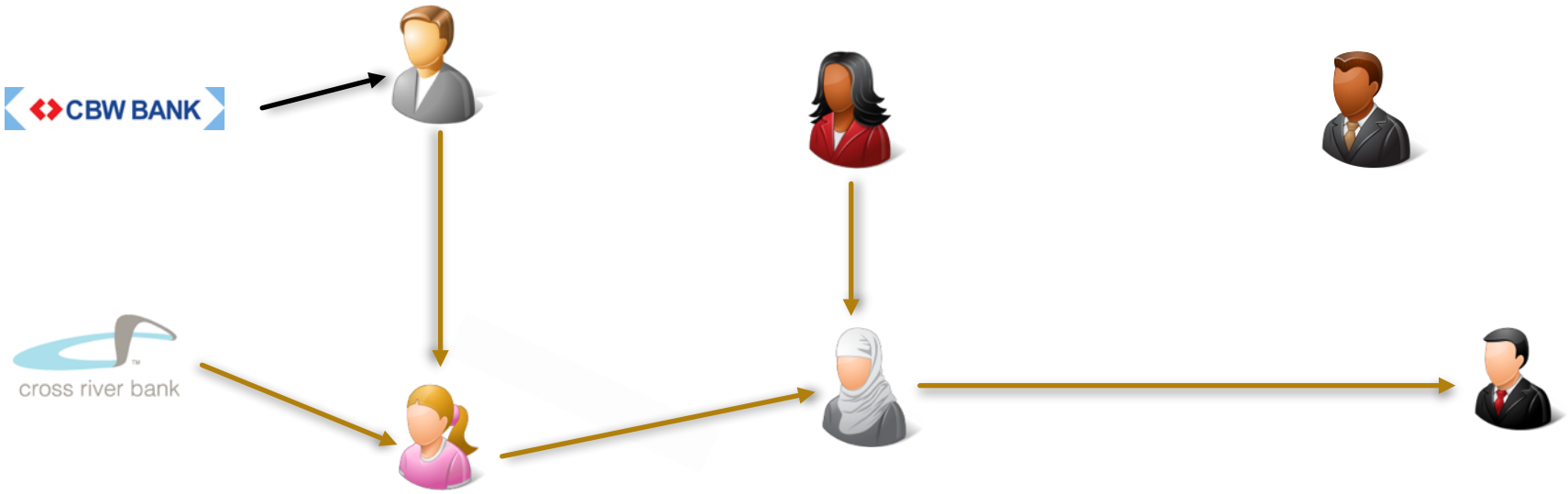

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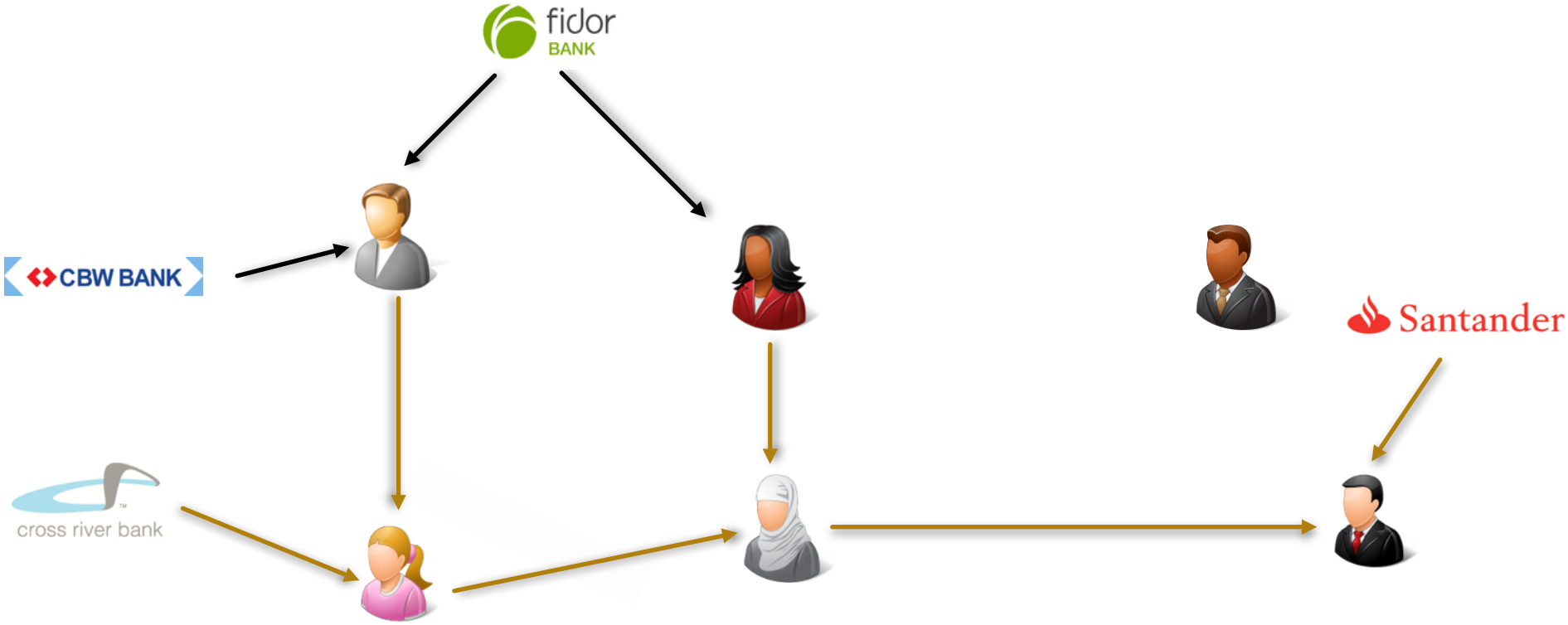

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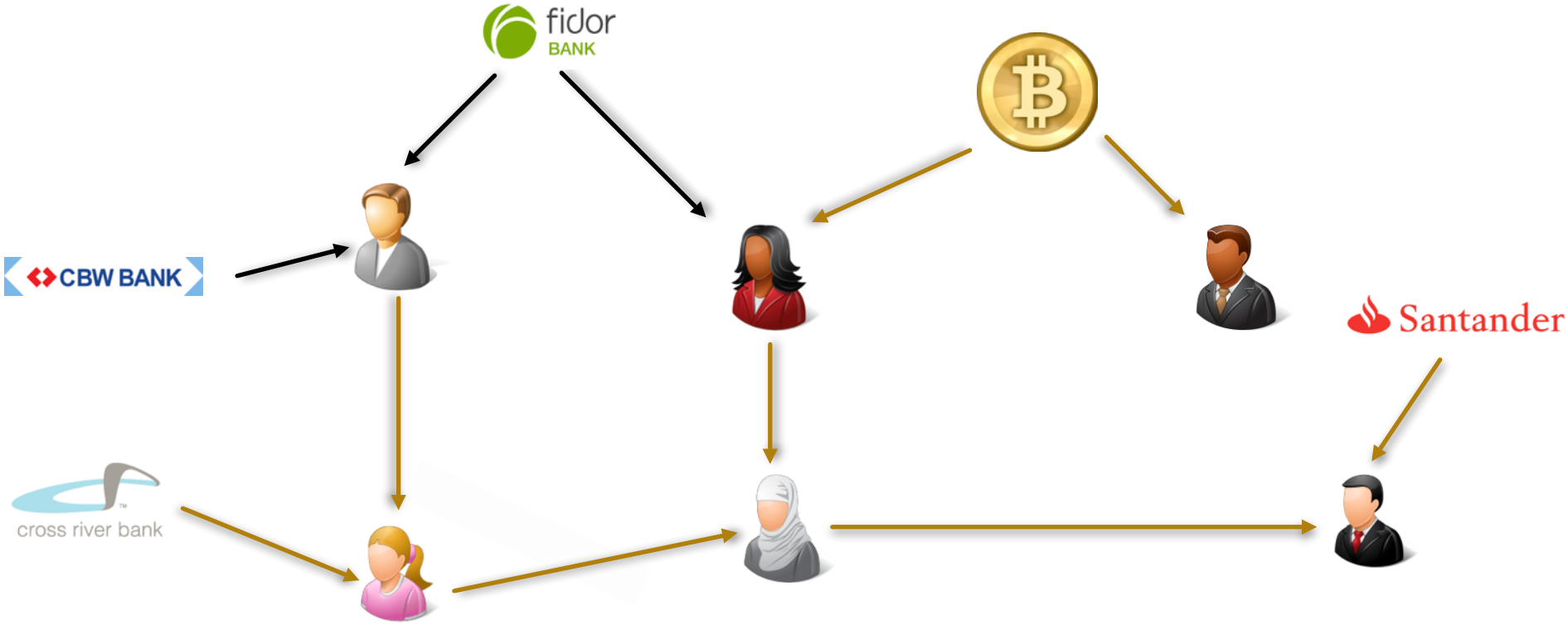

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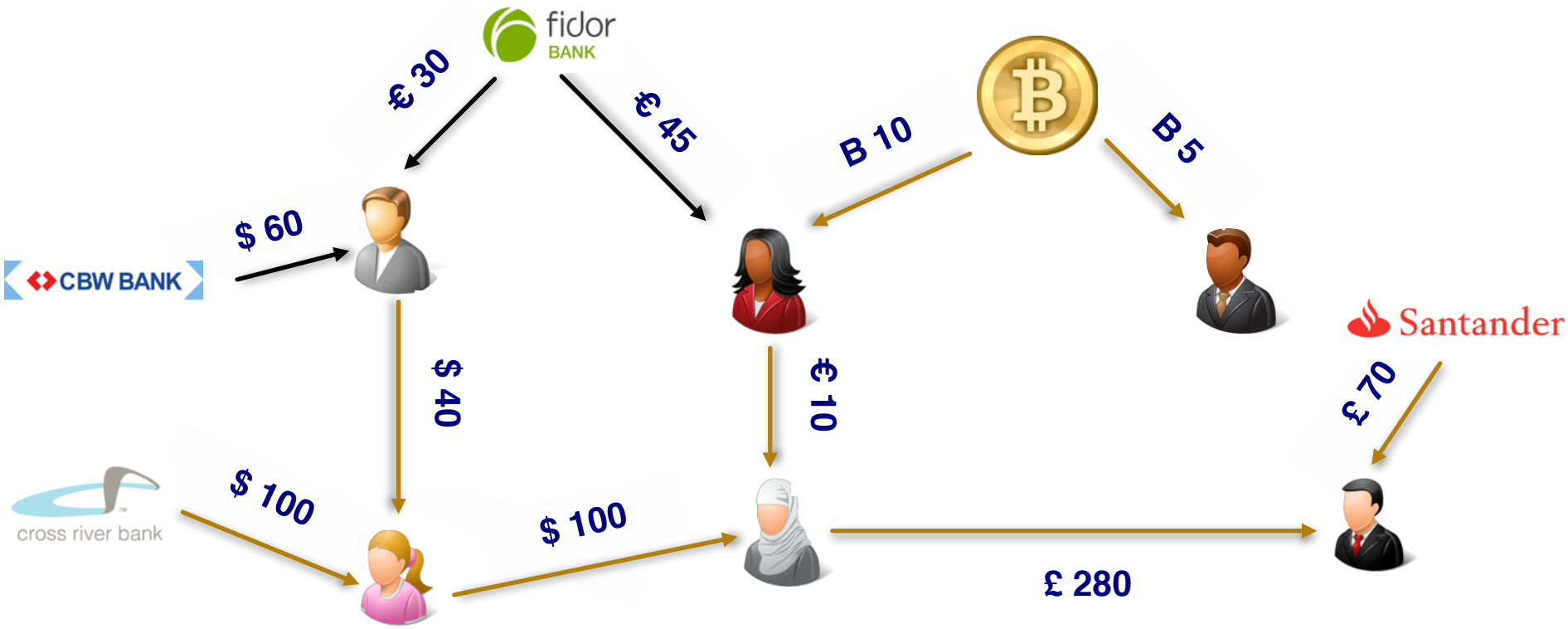

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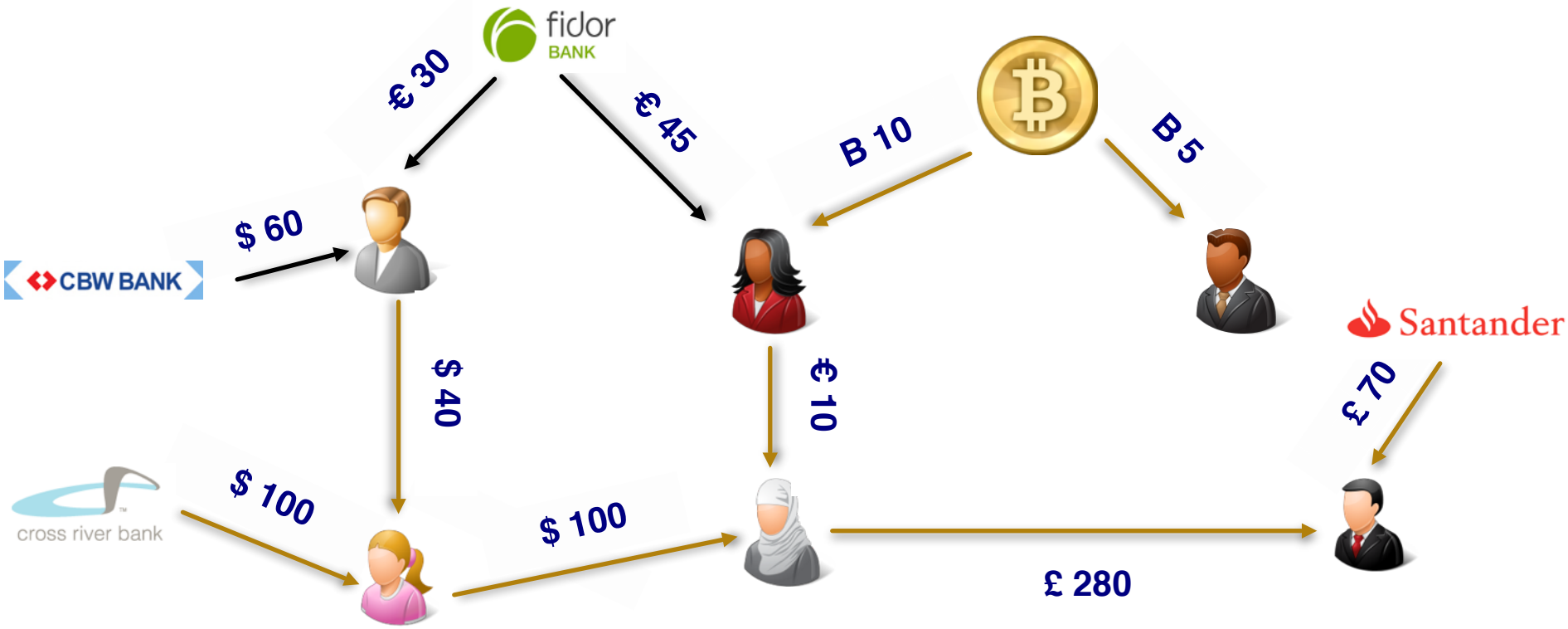

	Tx time	Worldwide, inter-currency tx	Integrity
BANK	~ 1 day	High fees	Bank only
ripple	~ 5 seconds	Tiny fees	Public verifiability

Ripple vs Bitcoin

We already have cryptocurrencies, then why do we need Ripple?

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Definition	Currency	Transaction network
Transfer of funds	Direct transactions between any two wallets	Transactions only via a path with enough credit
Scalability	Limited transaction rate (<100 tps)	Highly scalable

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Public verifiability of transactions

Attacks on privacy of Ripple links & transactions

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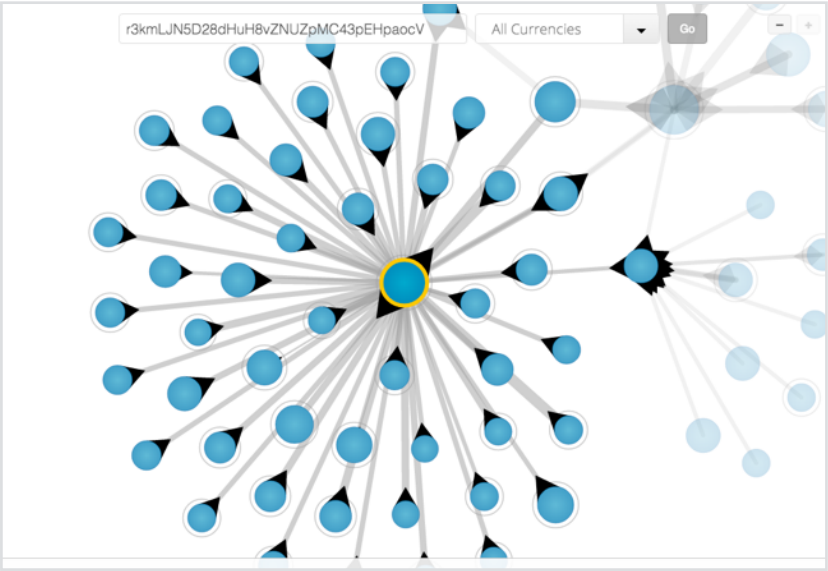
Transaction Details

Account	Destination	Amount
rwvctTPLKZqK59f1fXpDkQ…	rMnVZ9maUWp5cAvmqBECZM…	300/XRP
rLSBpSquSHKbbfvcKt1c54…	rKoDt7VL83AKJZewLxVZEs…	75/XRP
r428G9fSSmD4SYmnDra16B…	rBeToNo4AwHaNbRX2n4BNC…	0.0693402709148/CCK/rB…
rhD759dbJMrzMNL4QbvQe9…	r95pWKA1K55fy7EJWrqJ9b…	300/XRP
r42WJGvV9MJa4t5QcF8Cnx…	rBeToNo4AwHaNbRX2n4BNC…	0.0821058028231/CCK/rB…
rUnr1p7xkuSBxyAqHEopZ5…	r3H4rynDShFMRKWuJcadLY…	1129.916679154465/EUR/…
rw7UfGvzCeZwJxxUEeZHLG…	rBwgTdzzMHnouLk5DJD3xd…	100/XRP
rpVVzfSTUJX9CrKBSS2Z5W…	rDCgaaSBAWYfsxUYhCk1n2…	999.99/XRP

Credit Graph



Ripple provides pseudonymity to its users by employing public-key hashes as identities

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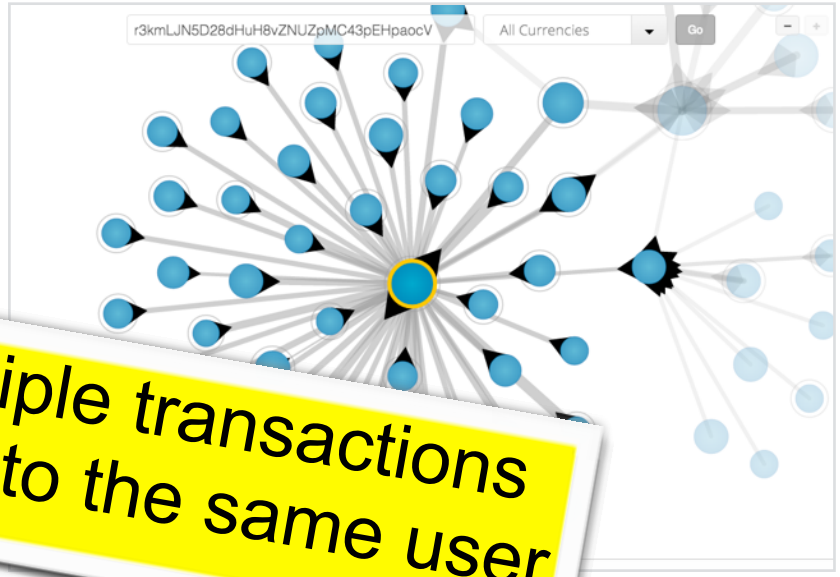
r428G9fSSmD4	rBeToNo4AwHaNbRX2n4BNC…	0.0693402709148/CCK/rB…
rhD759dbJMr		300/XRP
r42WJGvV9M		231/CCK/rB…
rUnr1p7xku		
rw7UfGvzC		
rpVVzfST		

Credit Graph



It is possible to link multiple transactions and identities belonging to the same user

Ripple provides pseudonymity to its users by employing public-key hashes as identities

Is privacy a real problem in Ripple?

Privacy Attacks: Innocent until Proven Guilty

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Privacy Attacks: Innocent until Proven Guilty

P. Moreno-Sanchez, M. B. Zafar, A. Kate:
Linking Wallets and Deanonymizing Transactions in the Ripple Network.
Privacy Enhancing Technologies Symposium (PETS) 2016.

Ripple Forum Discussion:
www.xrpchat.com/topic/1721-linking-wallets-and-deanonymizing-transactions-in-ripple/

Towards privacy-preserving transactions credit networks

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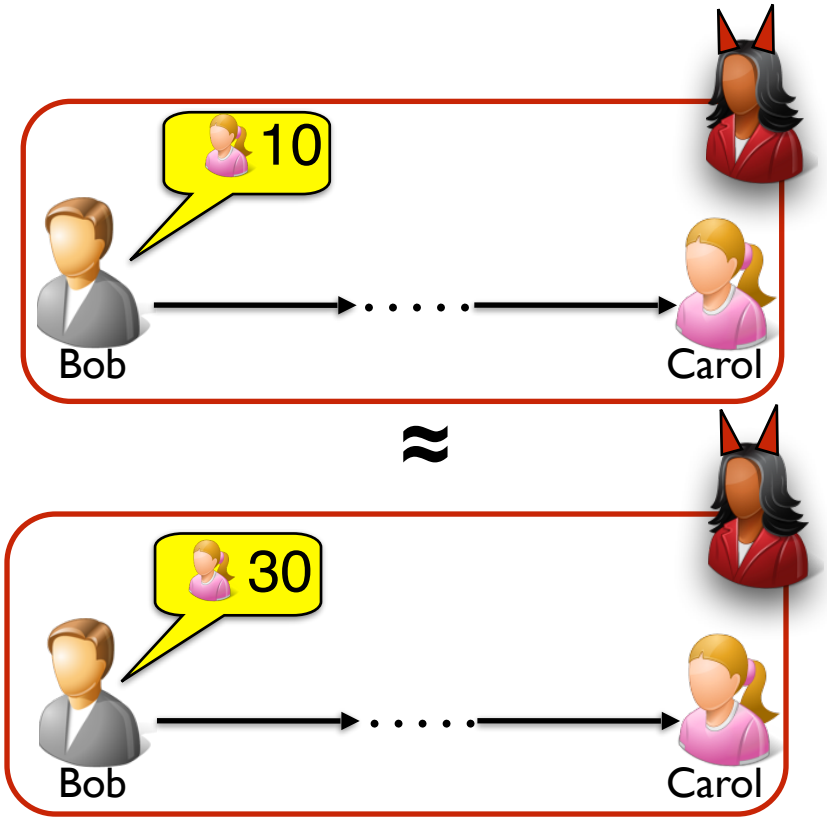
P. Moreno-Sanchez, A. Kate, M. Maffei, and K. Pecina:
Privacy Preserving Payments in Credit Networks.
NDSS 2015

Defining privacy for a credit network

Defining privacy for a credit network

Transaction value privacy



Defining privacy for a credit network

PURDUE UNIVERSITY

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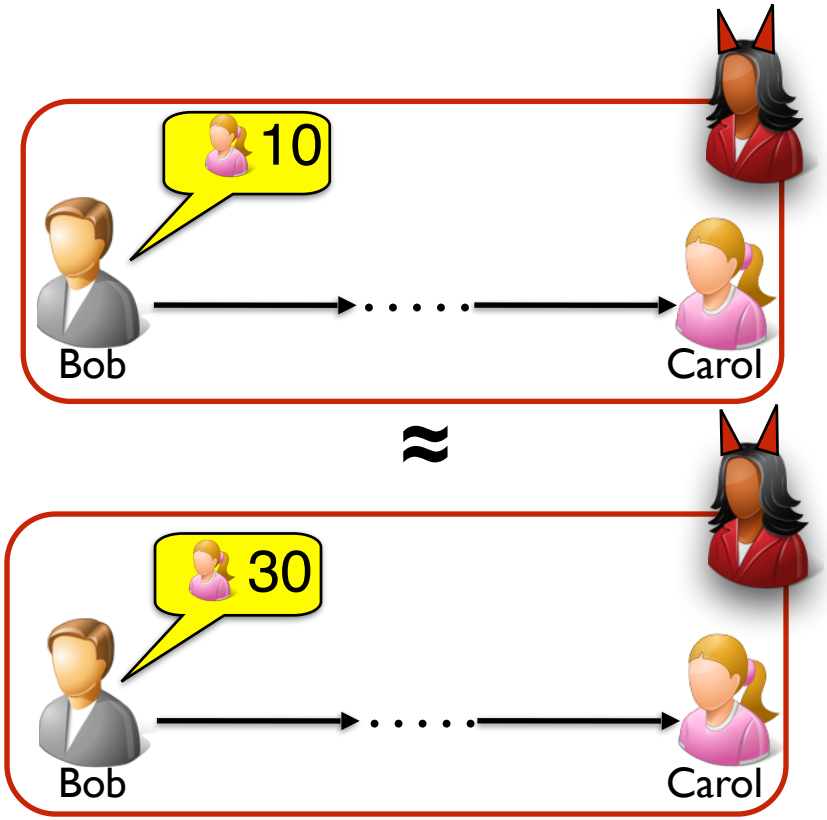
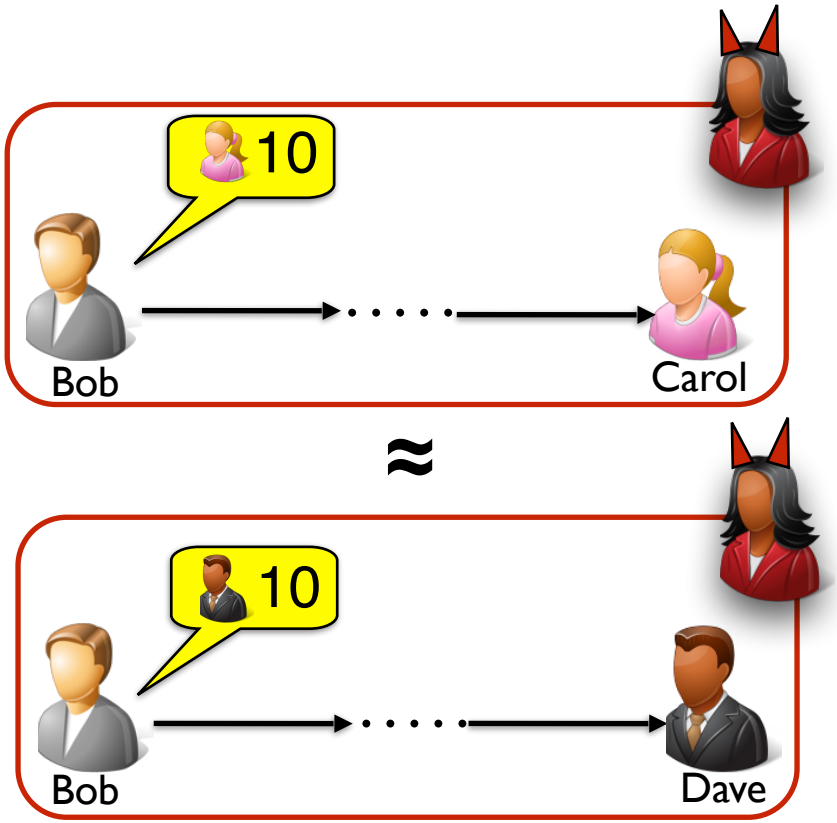


Transaction receiver privacy



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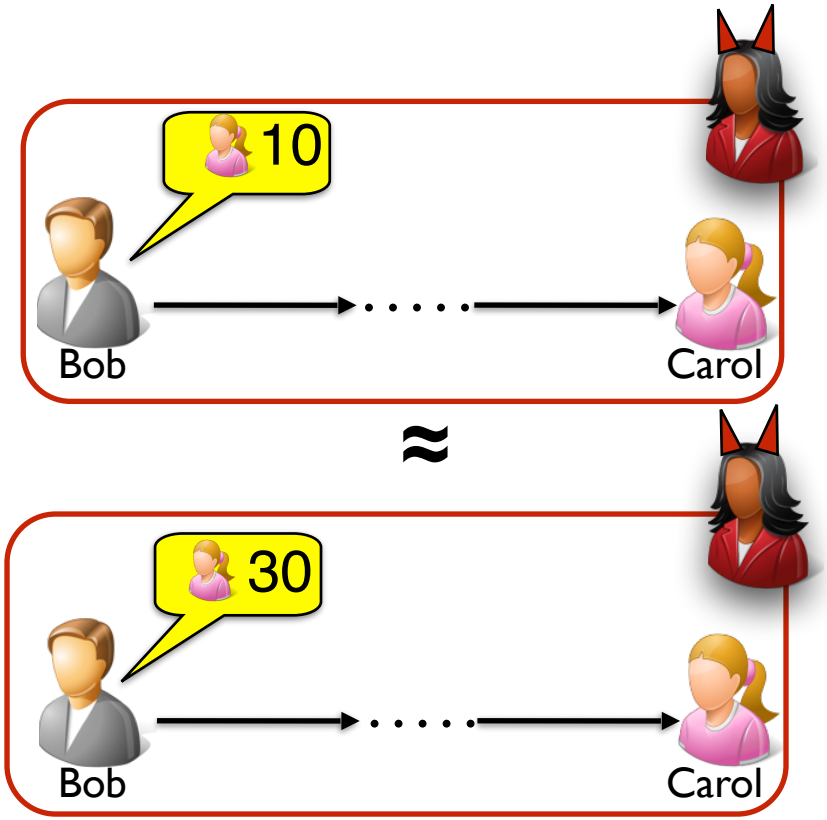

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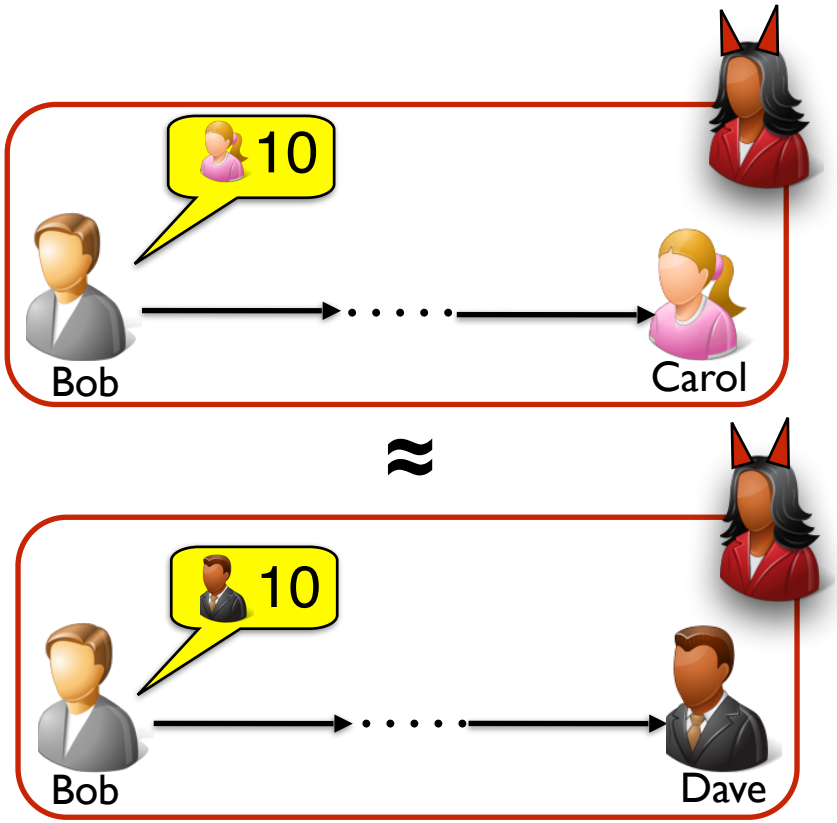

Transaction sender privacy can be defined similarly

Towards credit network privacy

Towards credit network privacy

- A decentralized or centralized architecture?

Towards credit network privacy

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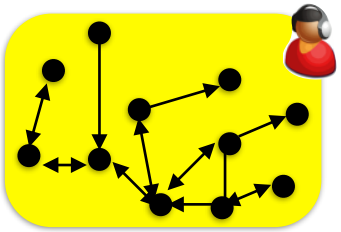
- Centralized setting: the network is maintained by a server
  - The service provider can trivially break the privacy
    - The routing computation can be performed privately, but any modifications to the edges not
    - Use of pseudonyms and anonymous channels (e.g, Tor) is not sufficient
  - In our NDSS'15 paper, we resolve this issue using minimally trusted hardware and oblivious algorithms



Towards credit network privacy

PURDUE UNIVERSITY

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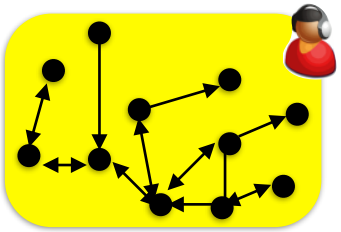
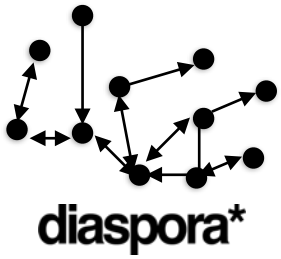
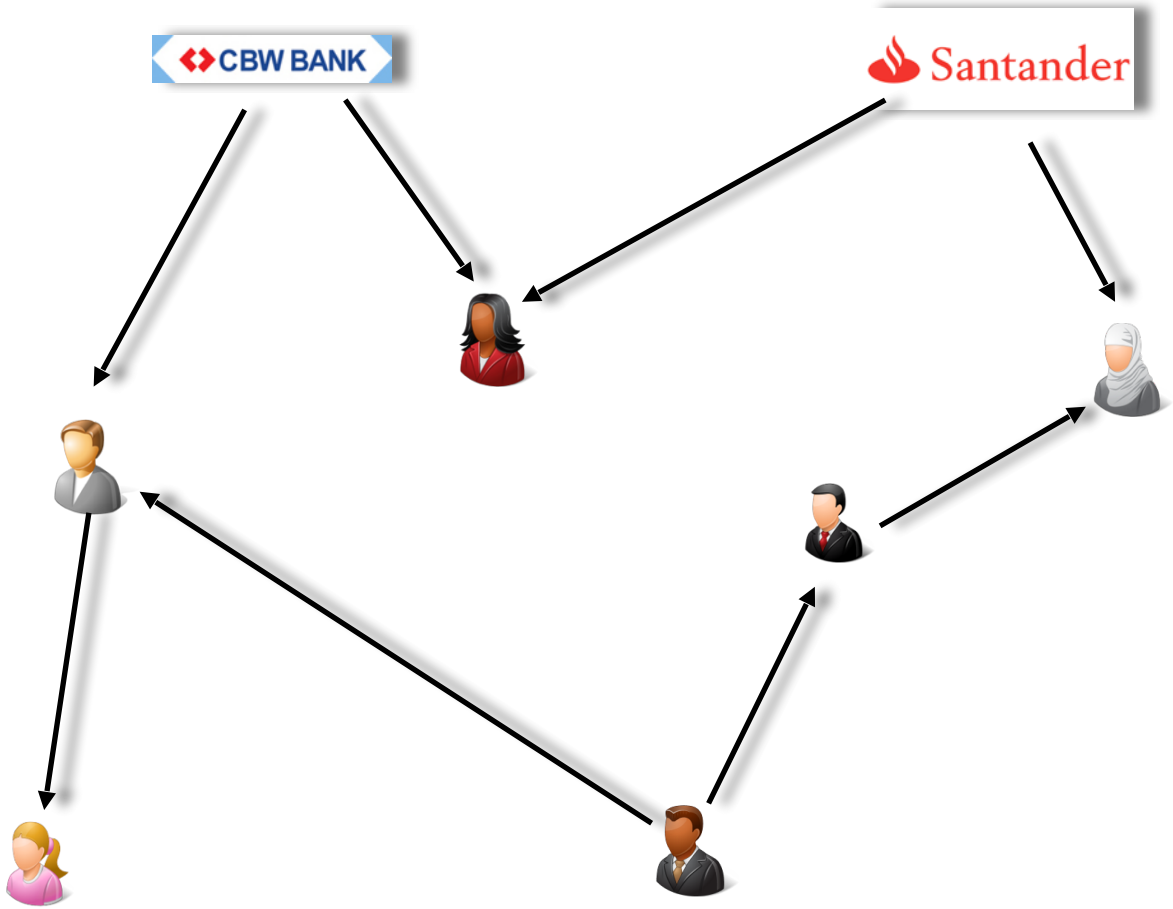


- Decentralized setting: edges are maintained locally
  - A transaction passing through a node requires its active involvement
  - We will focus on this solution in the rest of the talk



A Distributed Credit Network

- Each user maintains her own credit links



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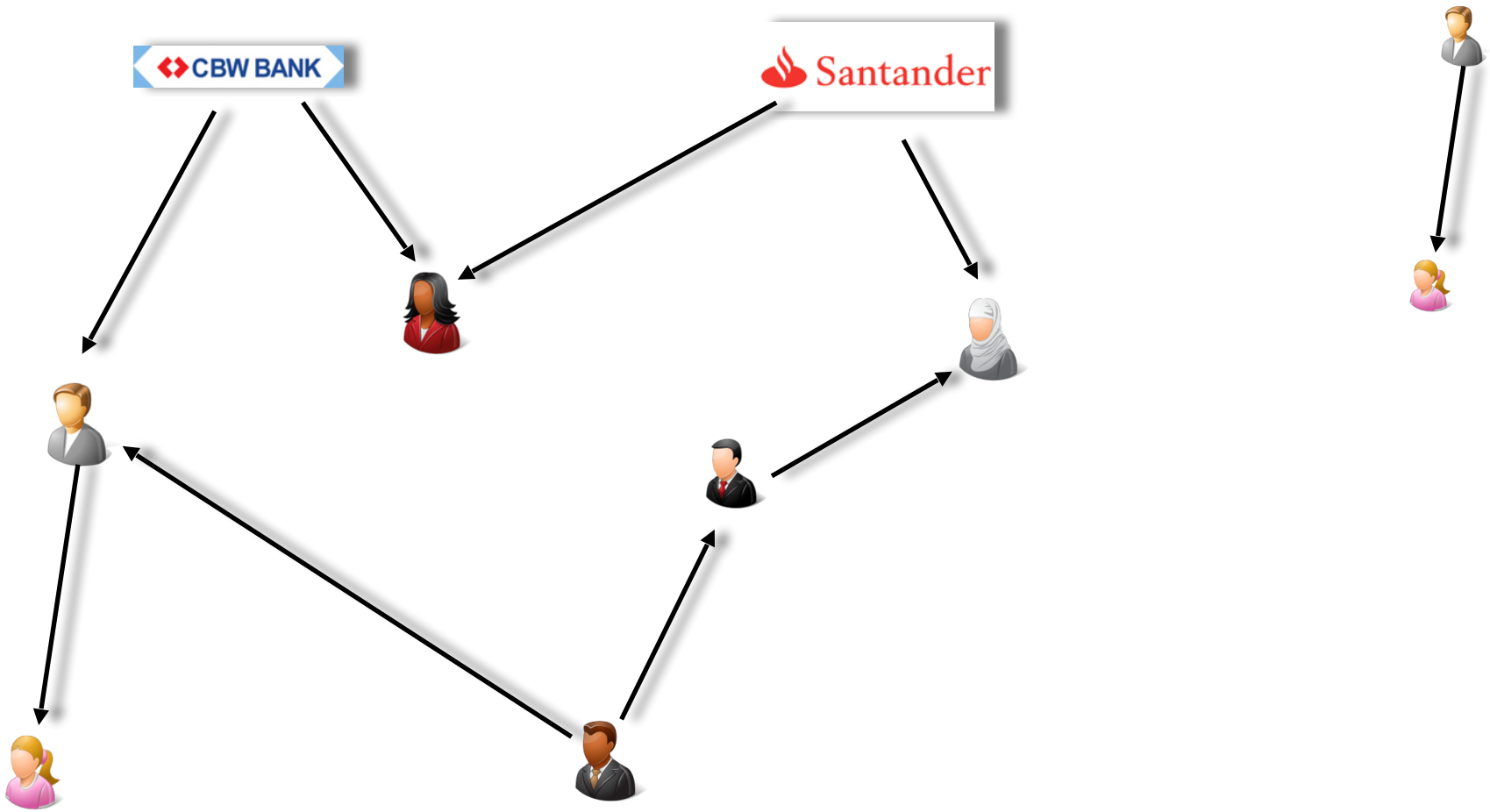

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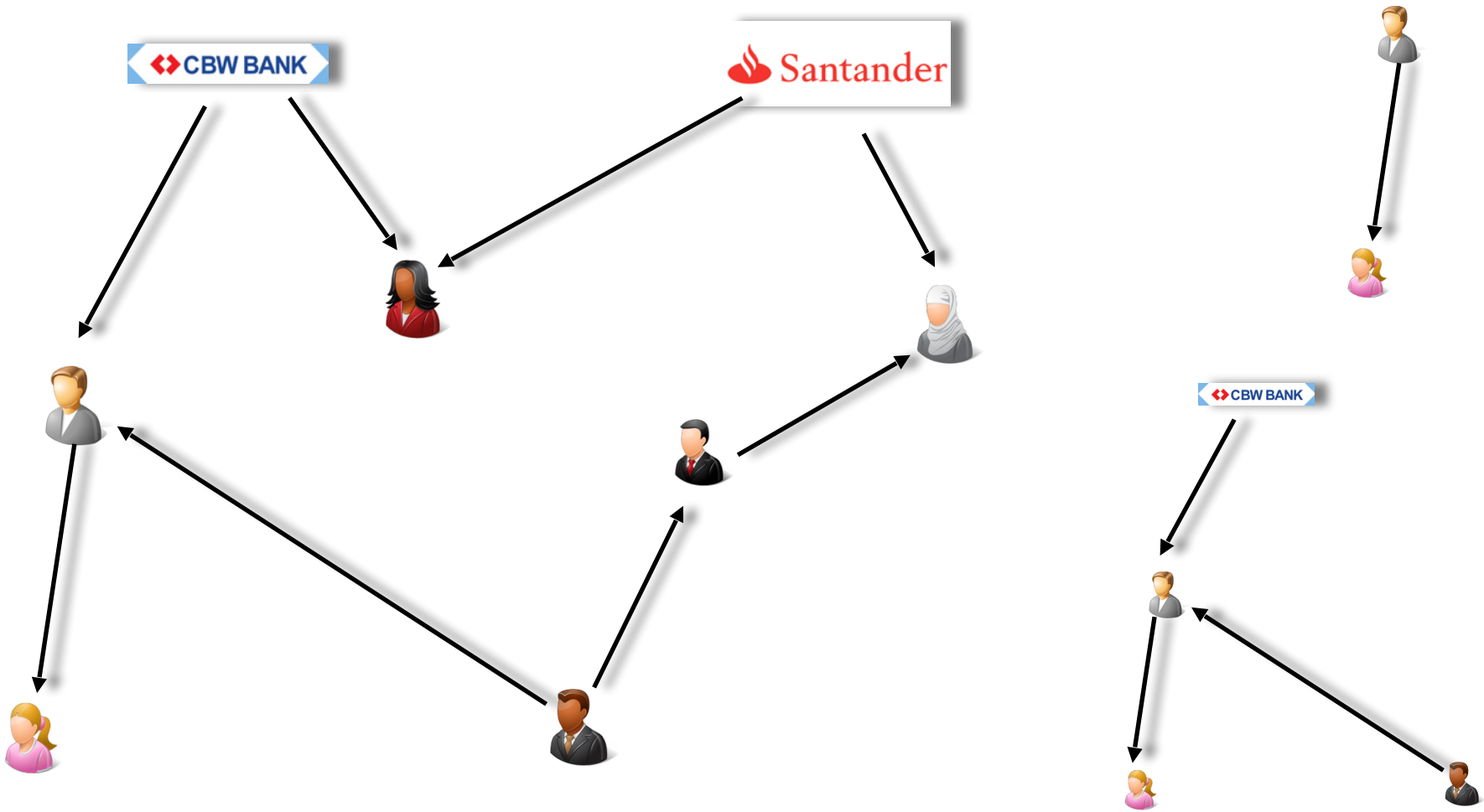

Local Knowledge is Sufficient!

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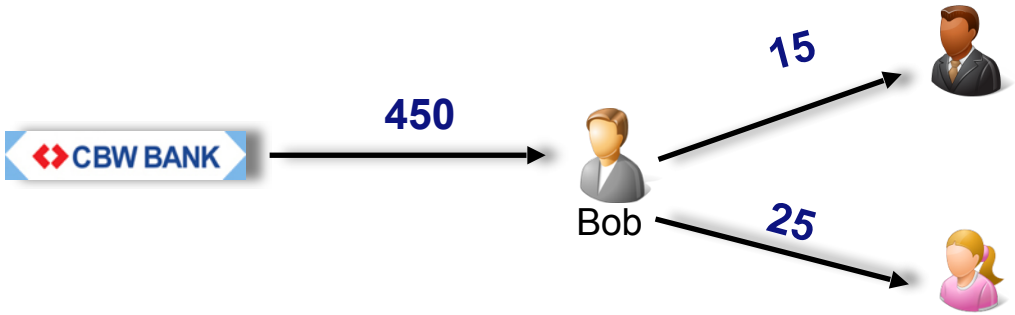

In-flow = 450
Out-flow = 40
Net-flow = 410

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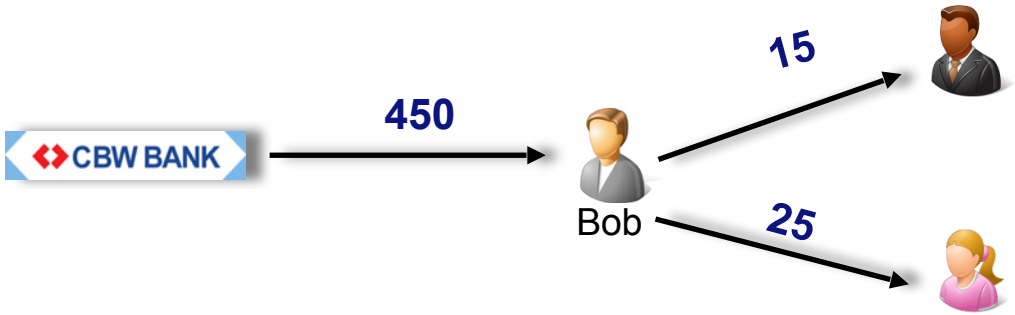

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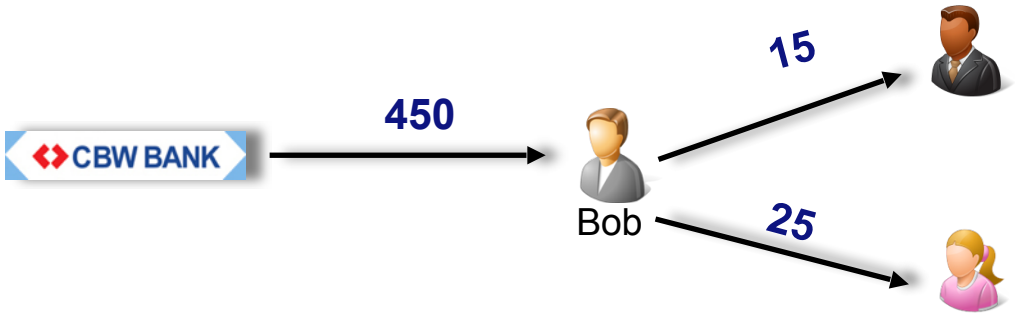

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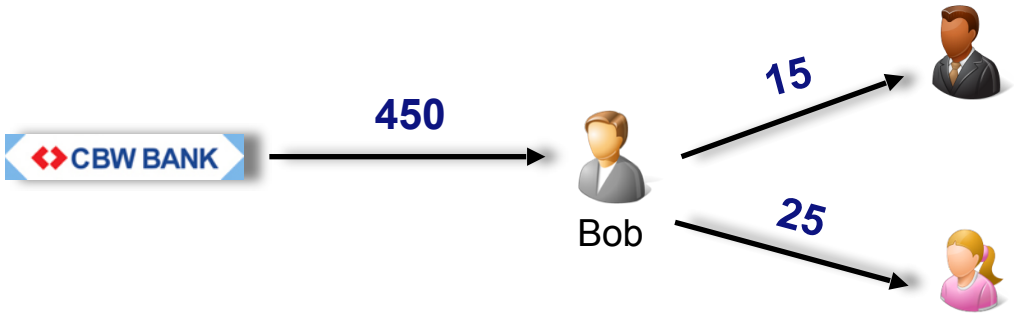

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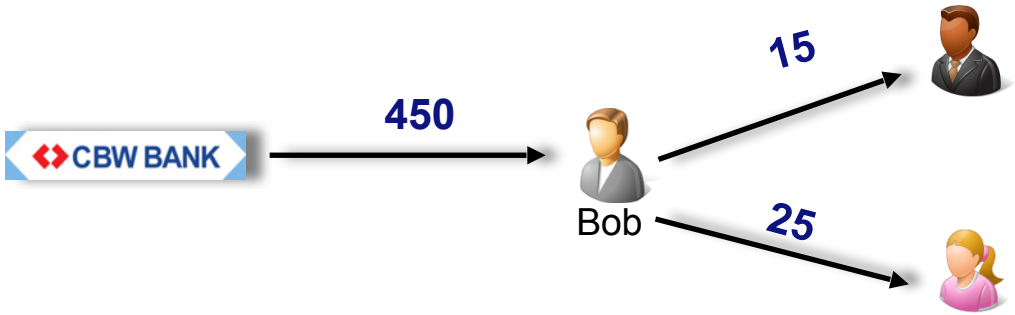

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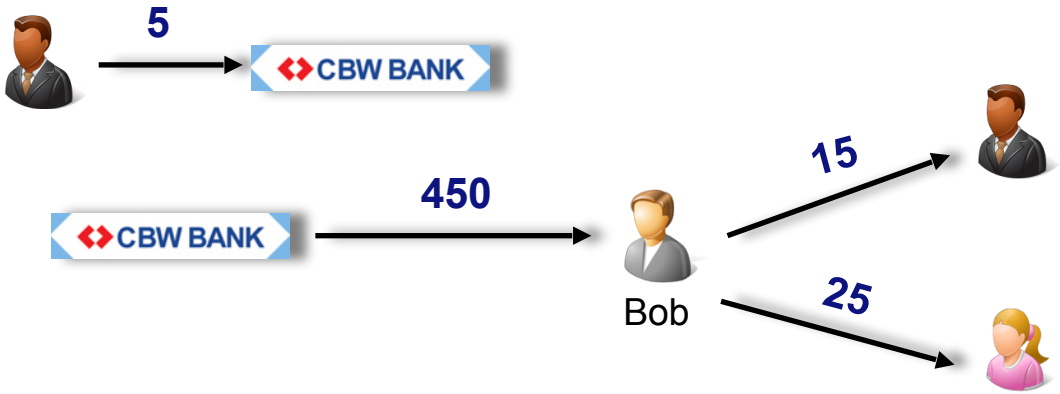

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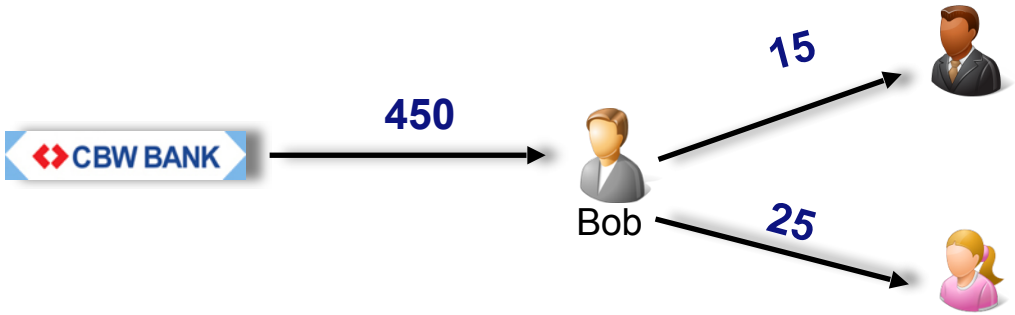

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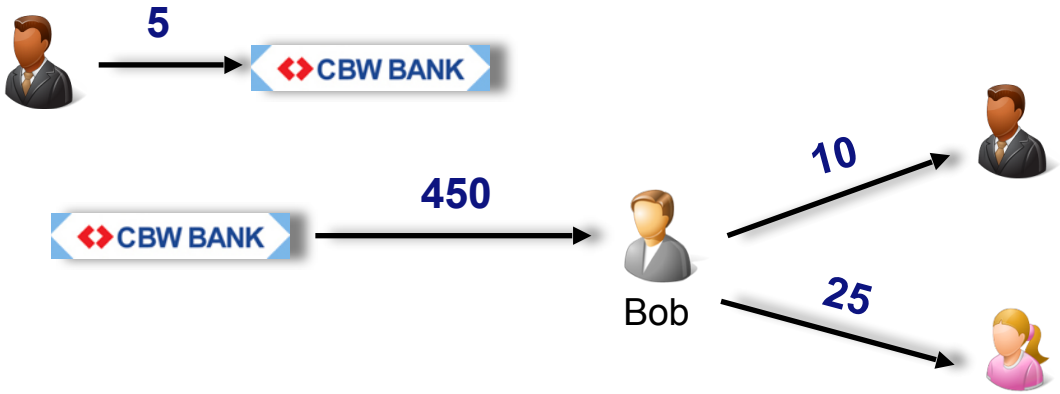

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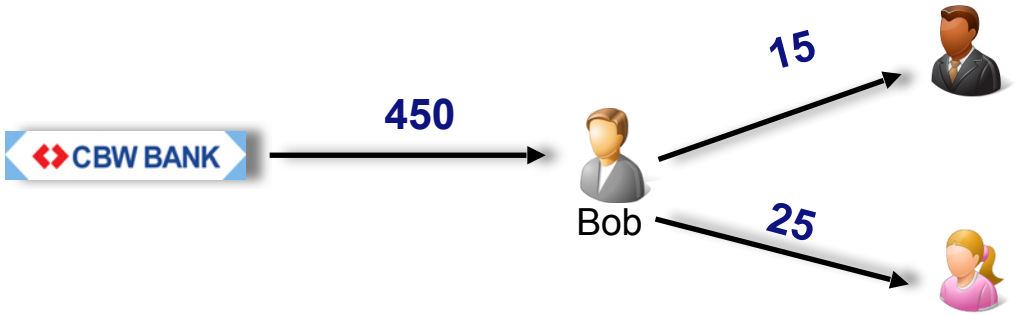

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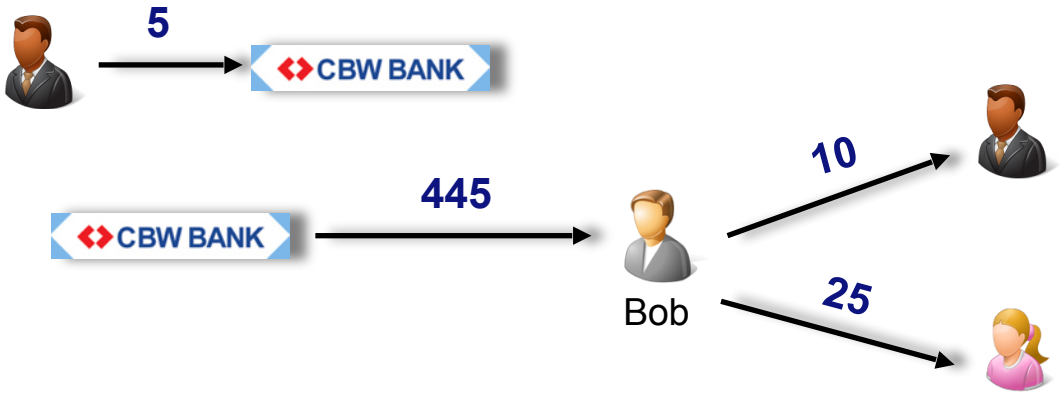

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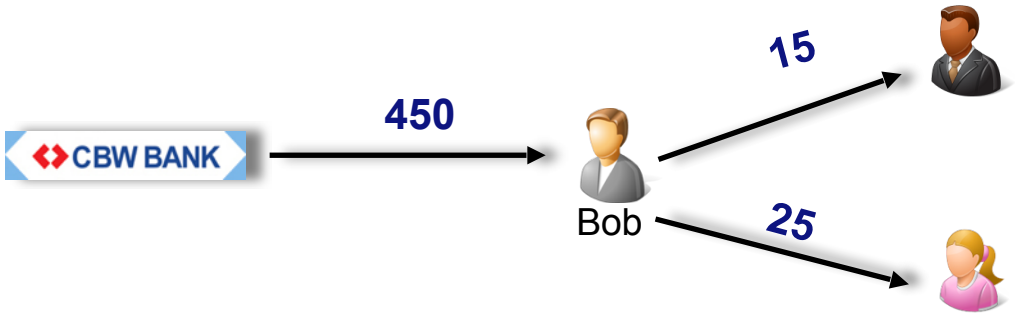

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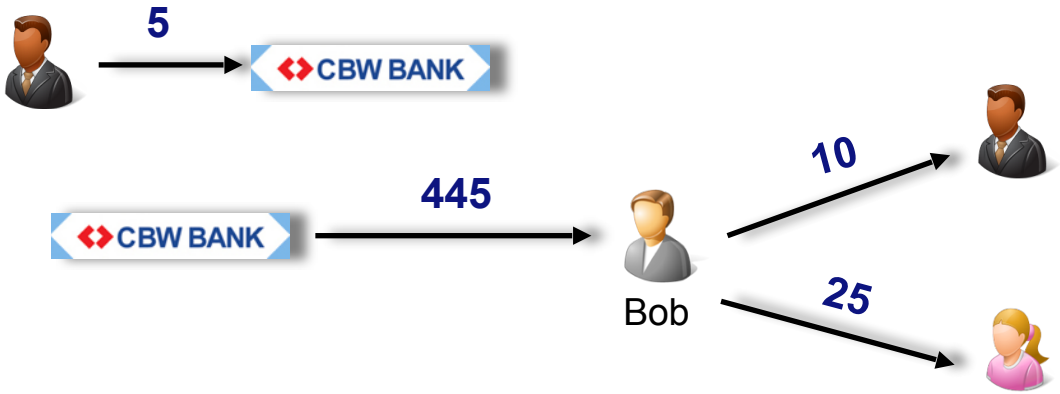

In-flow = ~~450~~ 445
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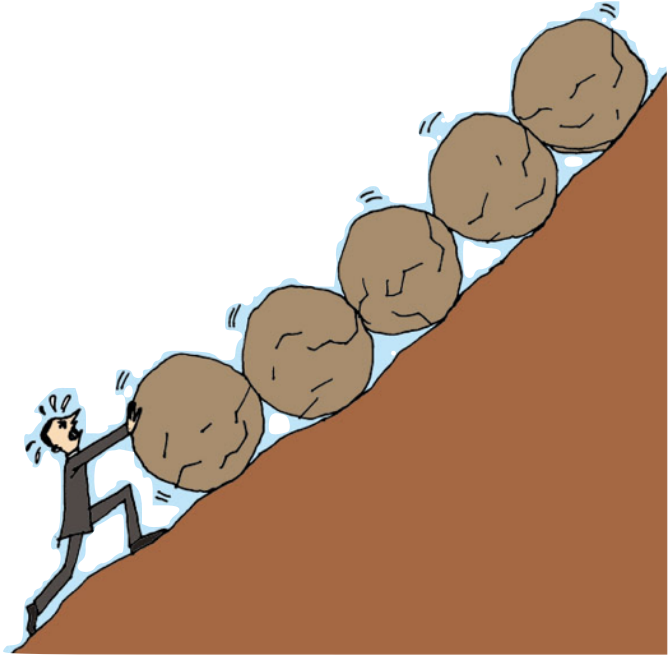
Challenges

- How to find paths between a sender and a receiver?
- How to find the IOU credit available in the path?
- How to ensure credit links form a path?
- And maintaining strong privacy and accountability guarantees…



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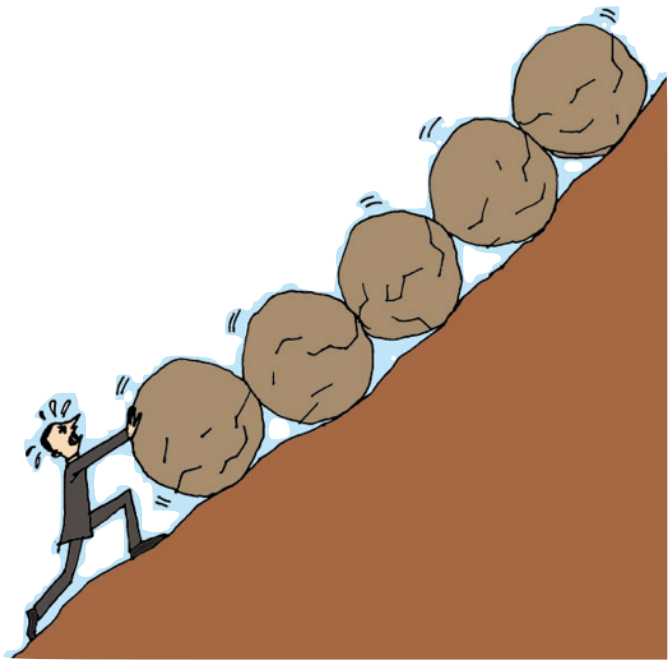

A. Kate, M. Maffei, G. Malavolta, and P. Moreno-Sanchez:
Whispers: A Distributed Architecture for Enforcing Privacy in Credit Networks.
TechReport: http://crypsys.mmci.uni-saarland.de/projects/DecentralizedPrivPay/

Routing: max-flow computation

- Routing challenge:
  Known max-flow algorithms are not scalable: $O(V^3)$ or $O(V^2 \log(E))$
- We employ landmark routing:
  Calculate only a subset of all possible routes through intermediary nodes called landmarks [Tsuchiya SigComm'88] [Vishanath et al. Eurosys'12]

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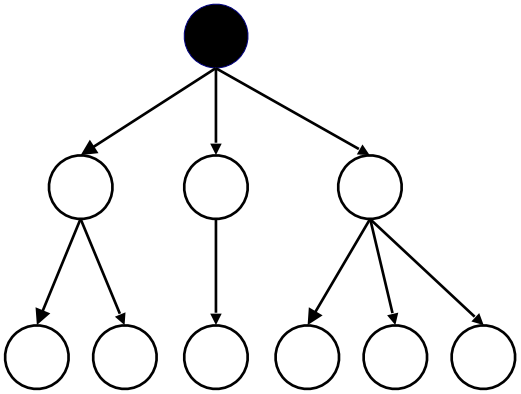

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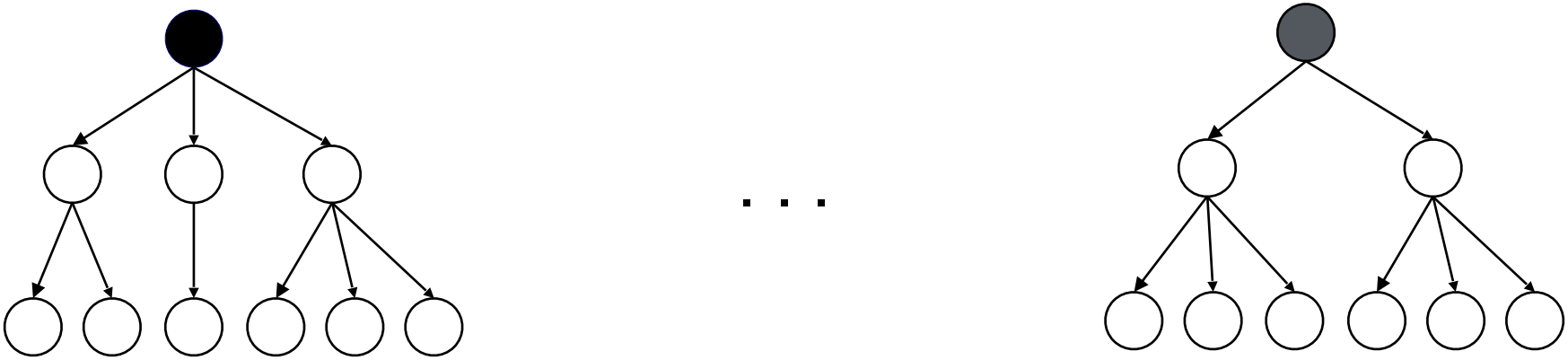

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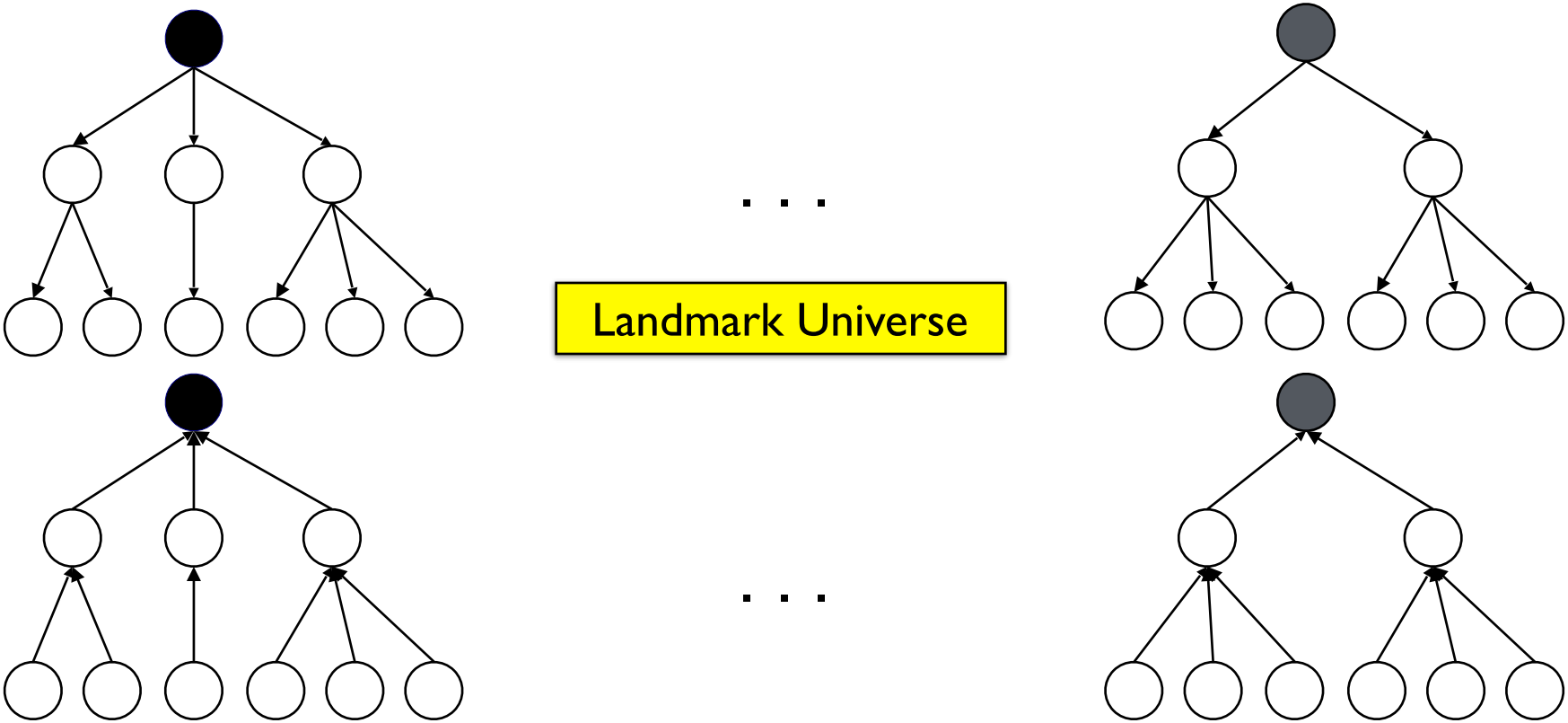

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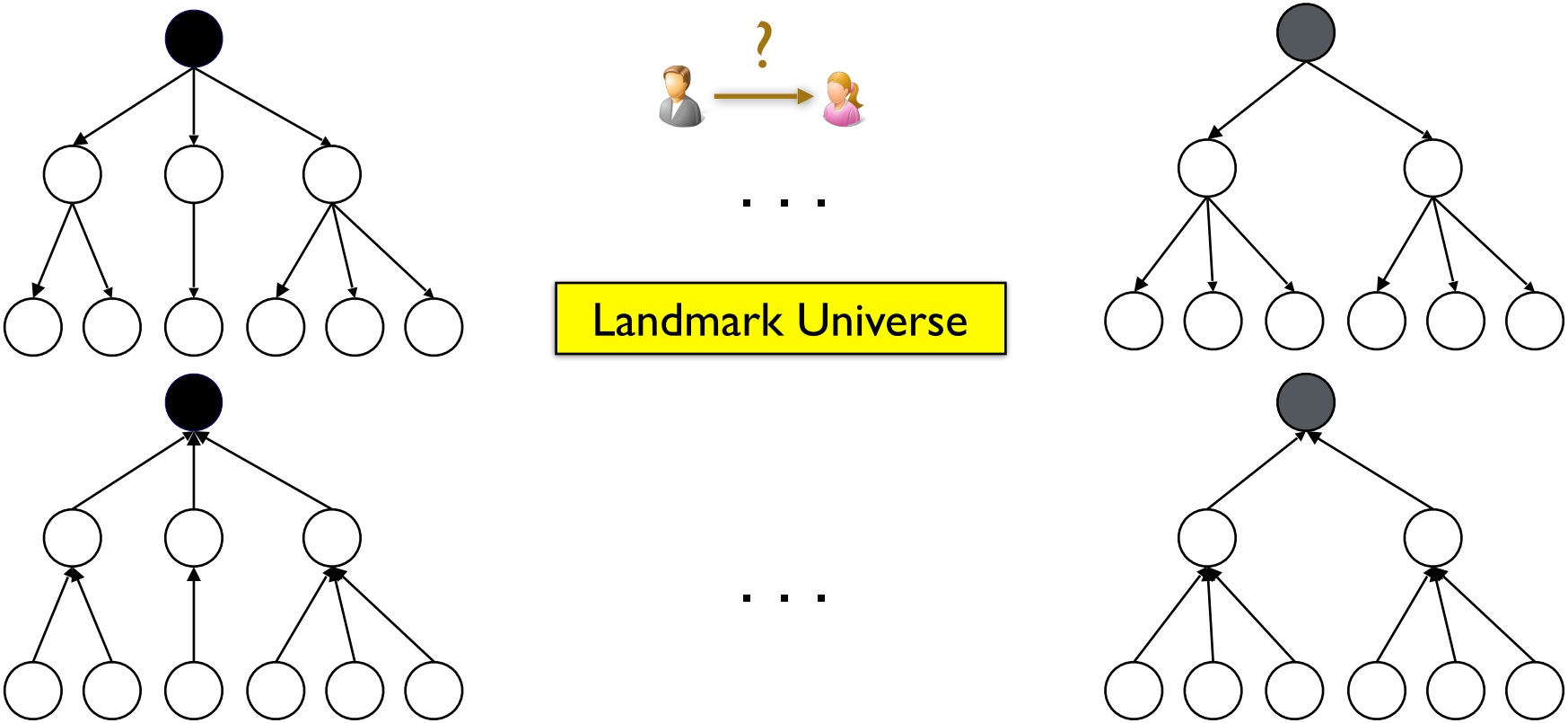

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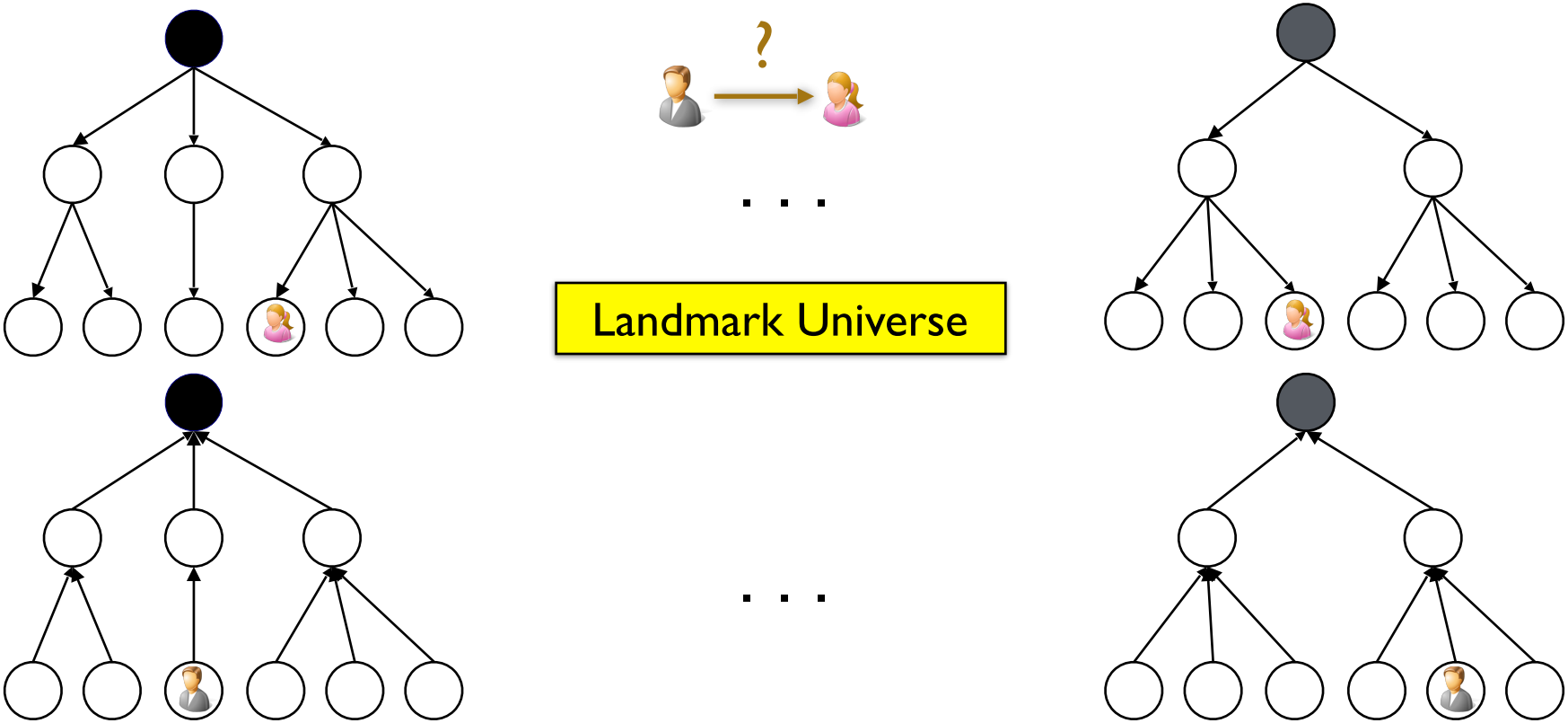

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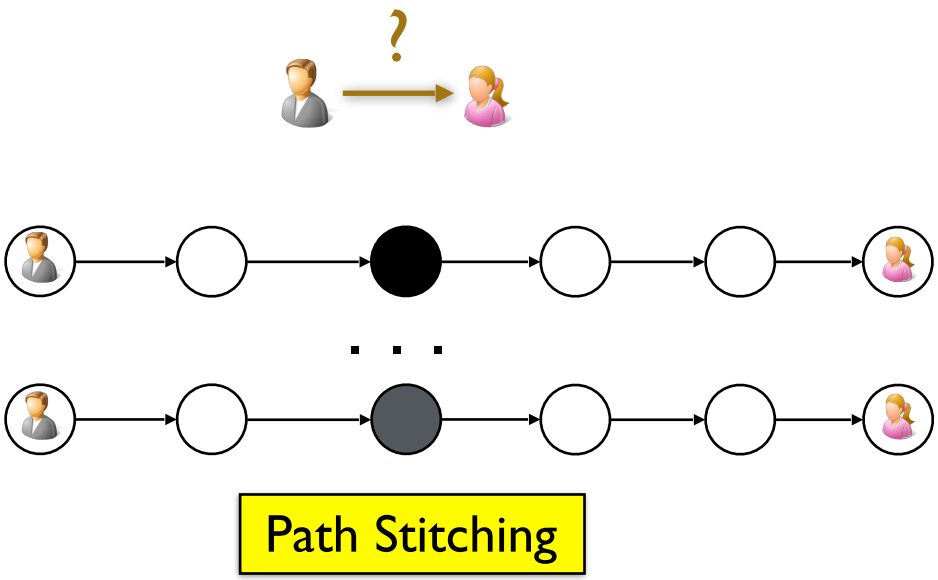
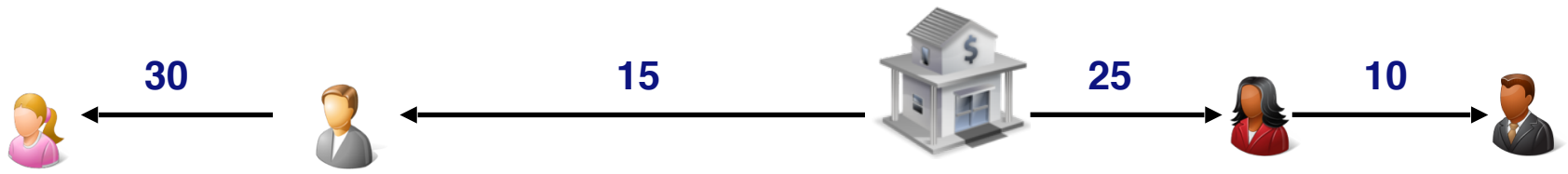


Credit in a Path

[x]: Secret sharing of x



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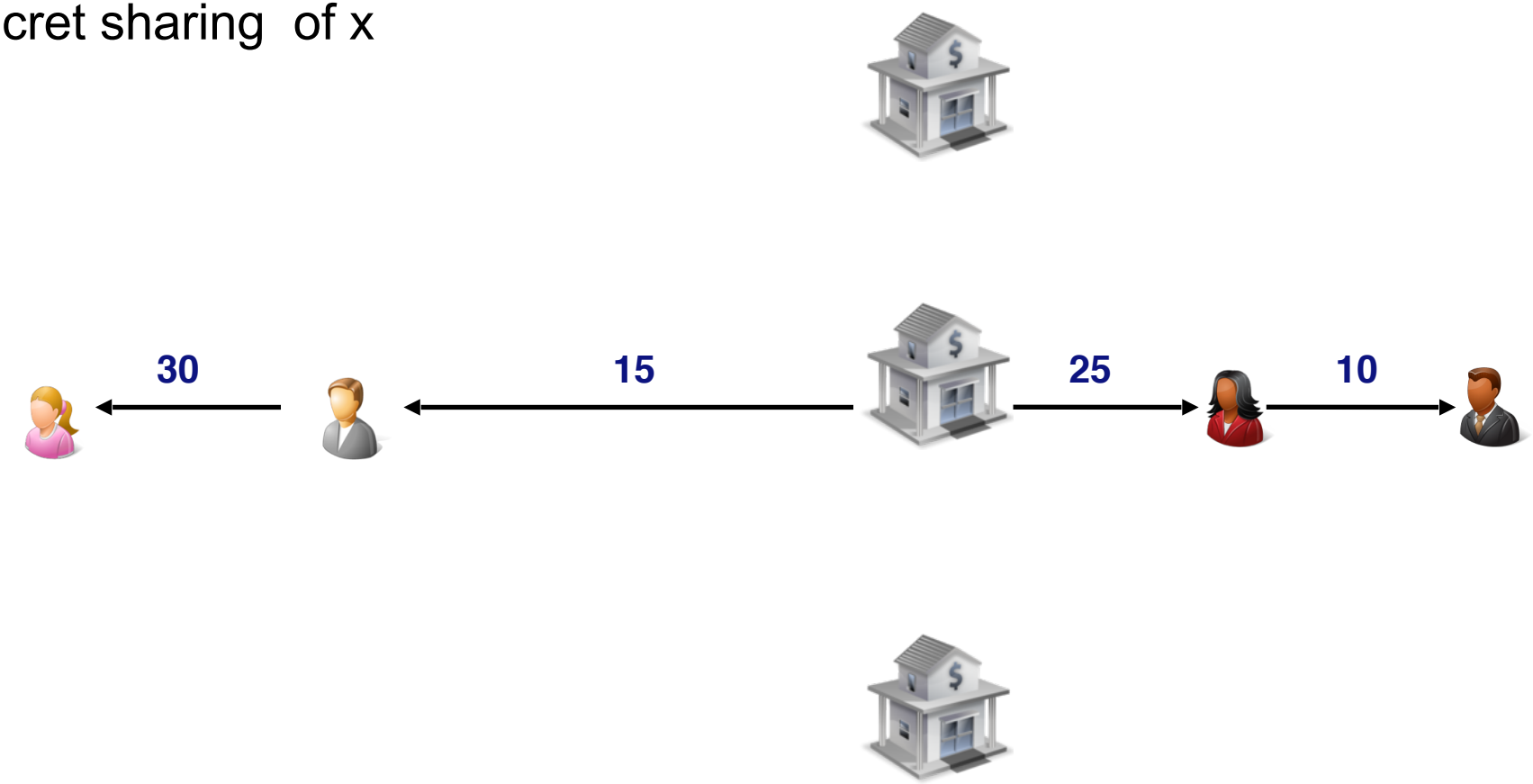

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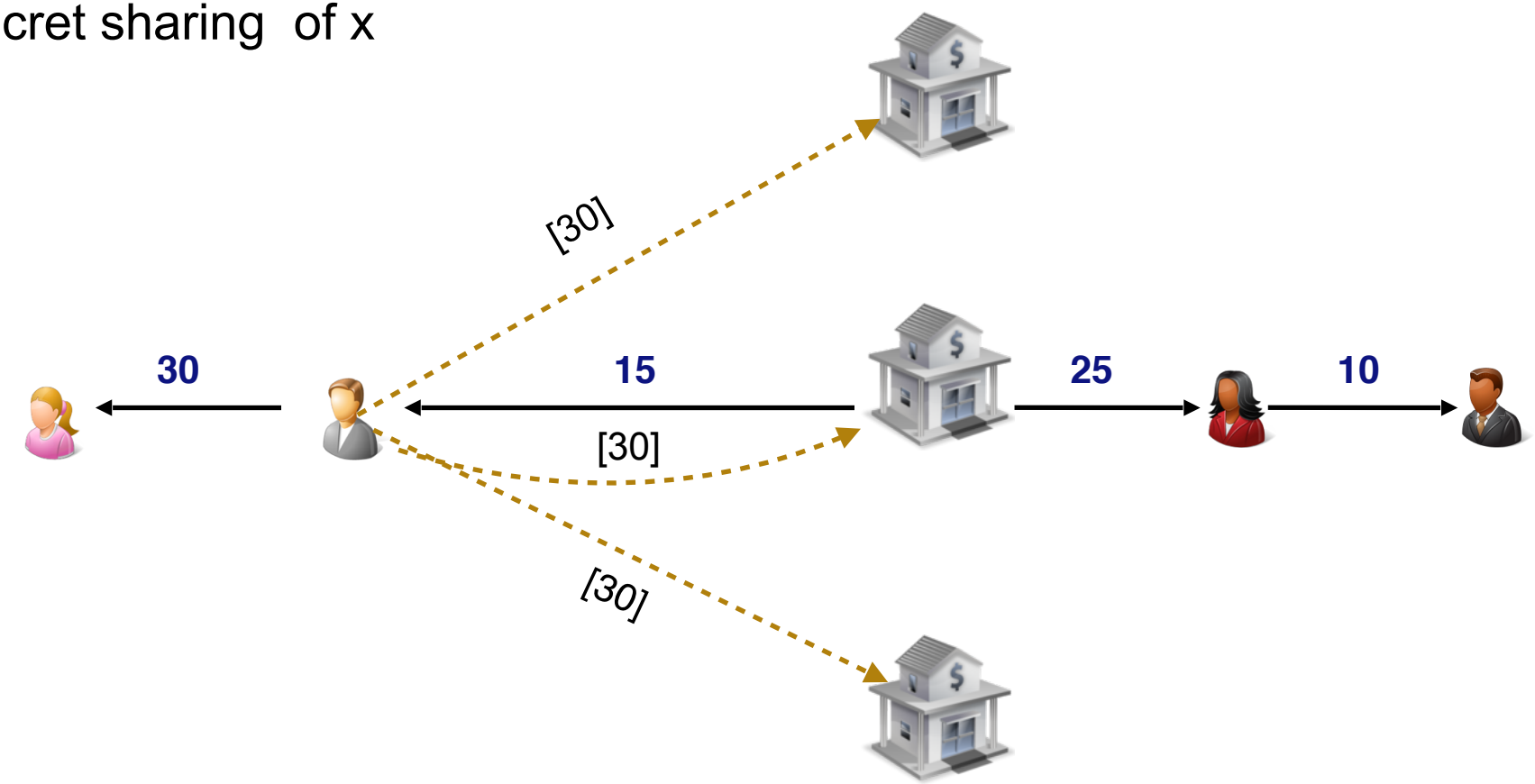

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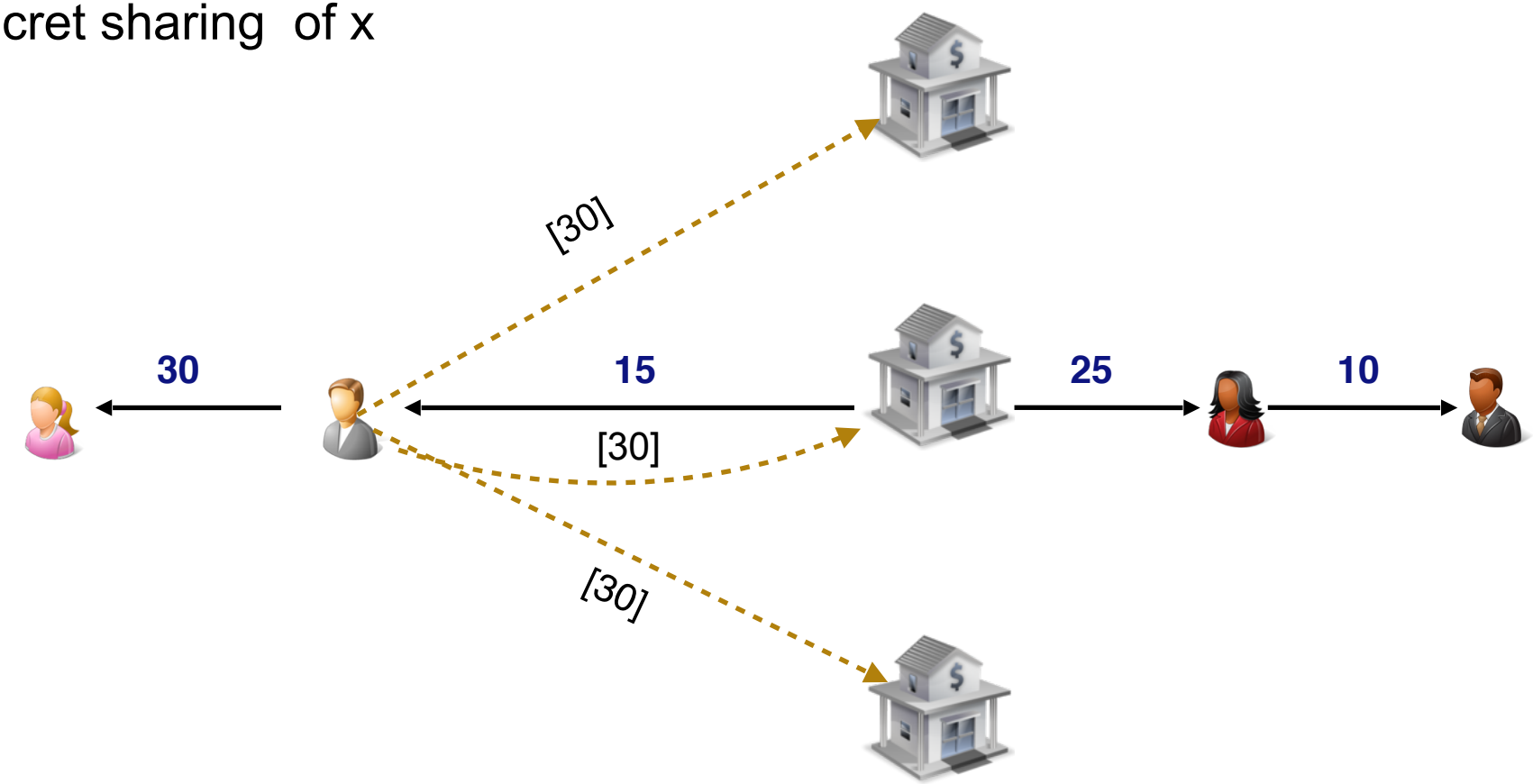

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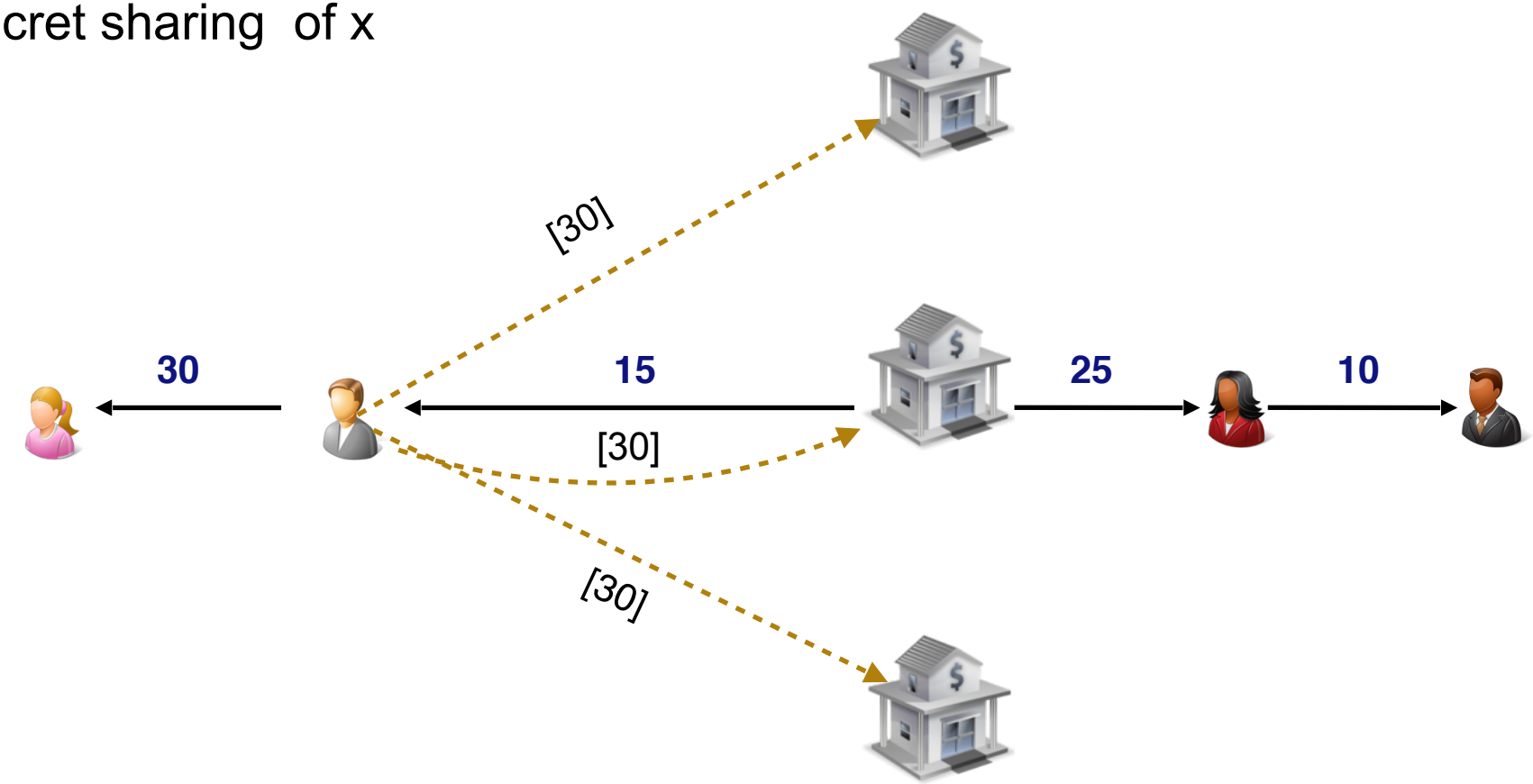

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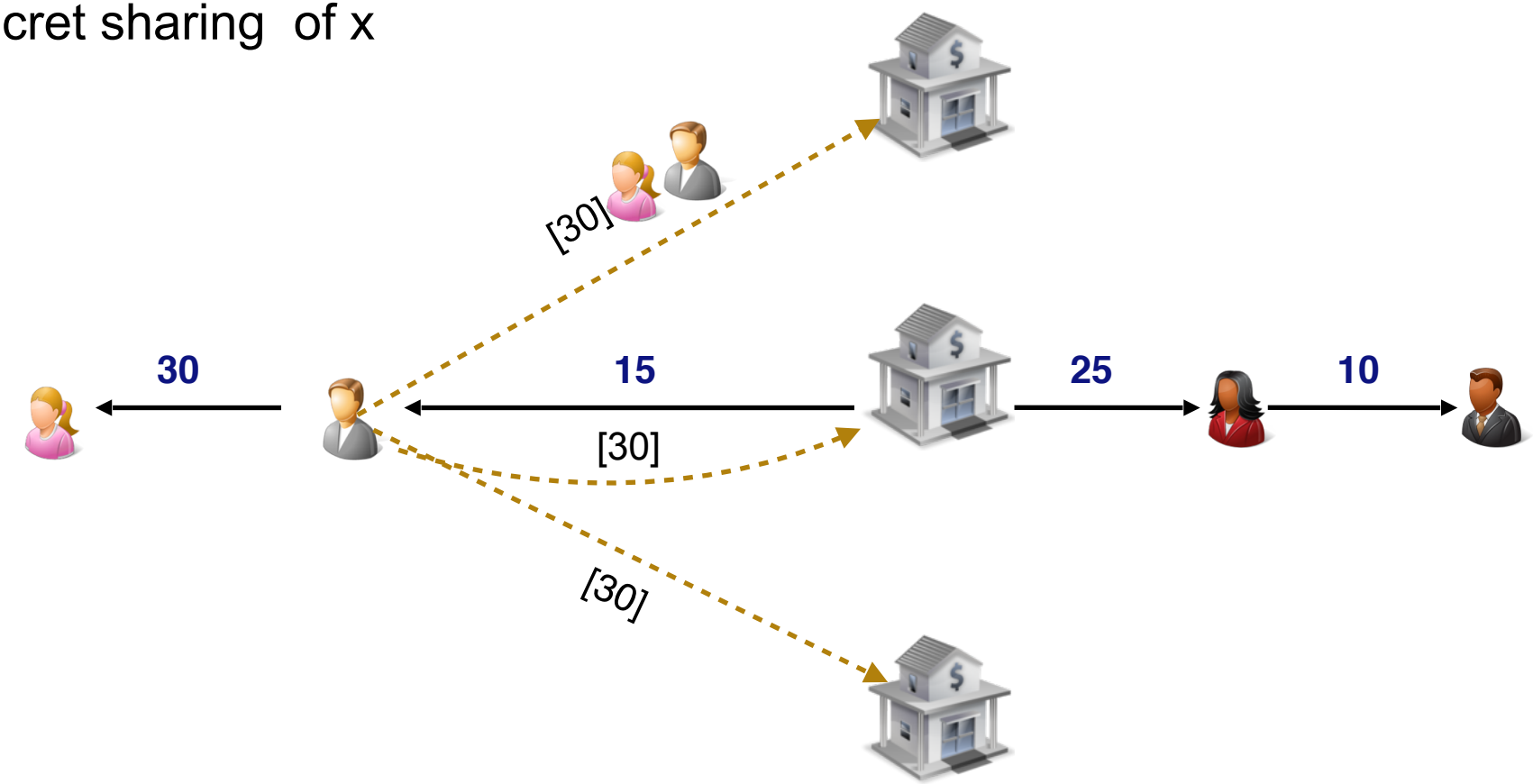

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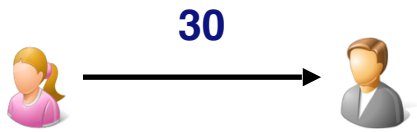
Proof of Credit Links in a Path



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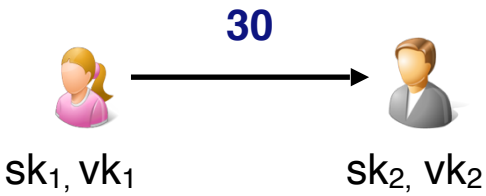

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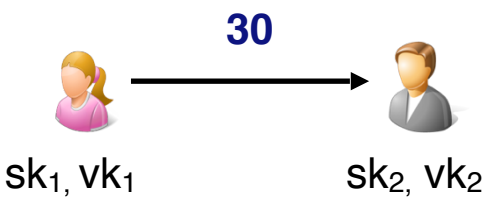

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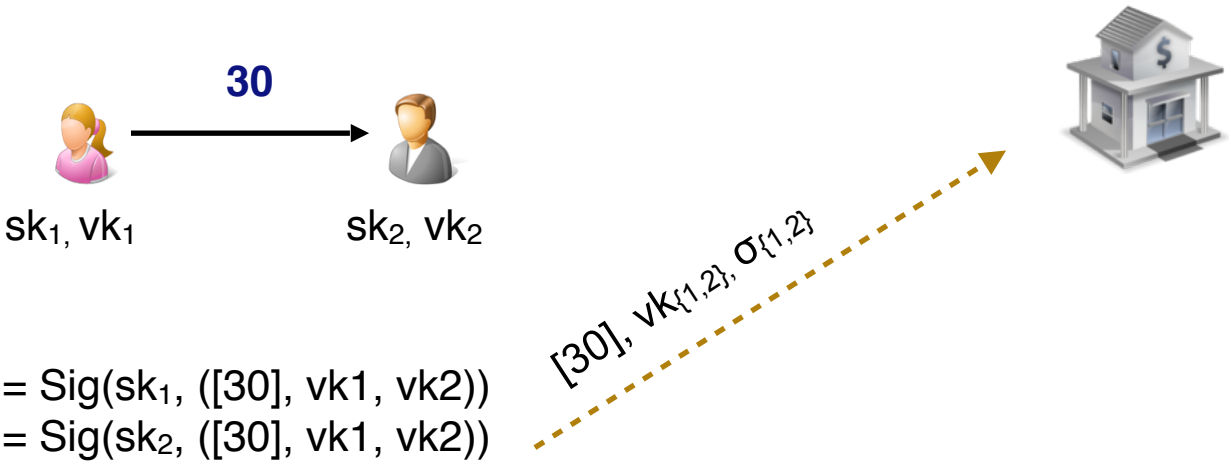

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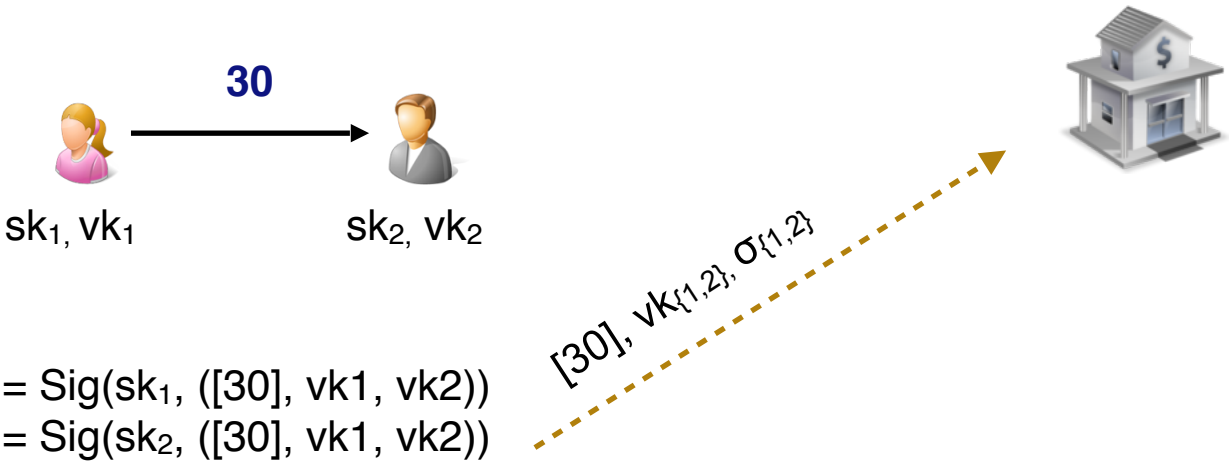

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Correct proof for a path

$(vk_1, vk_2), (vk_2, vk_3), (vk_3, vk_4), \ldots$

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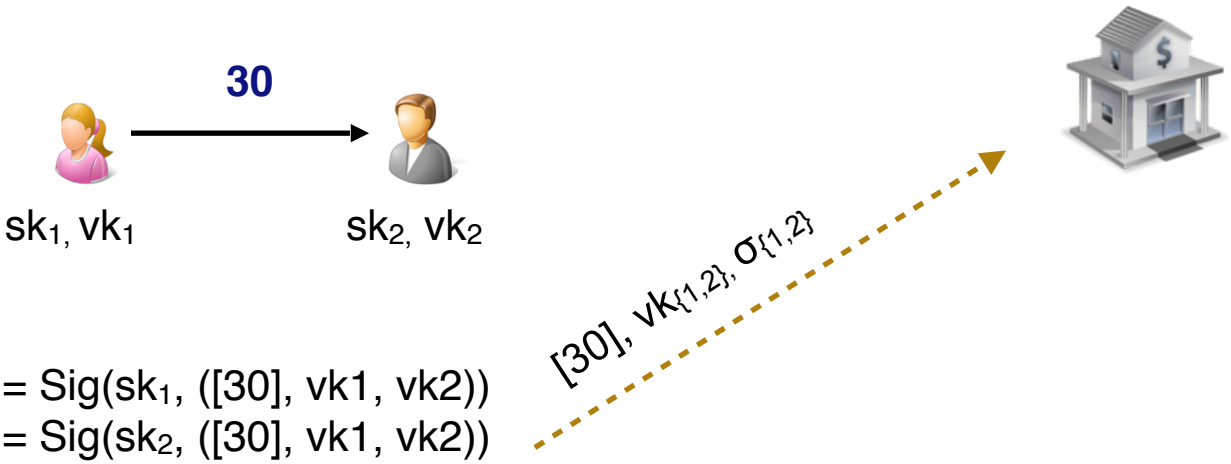

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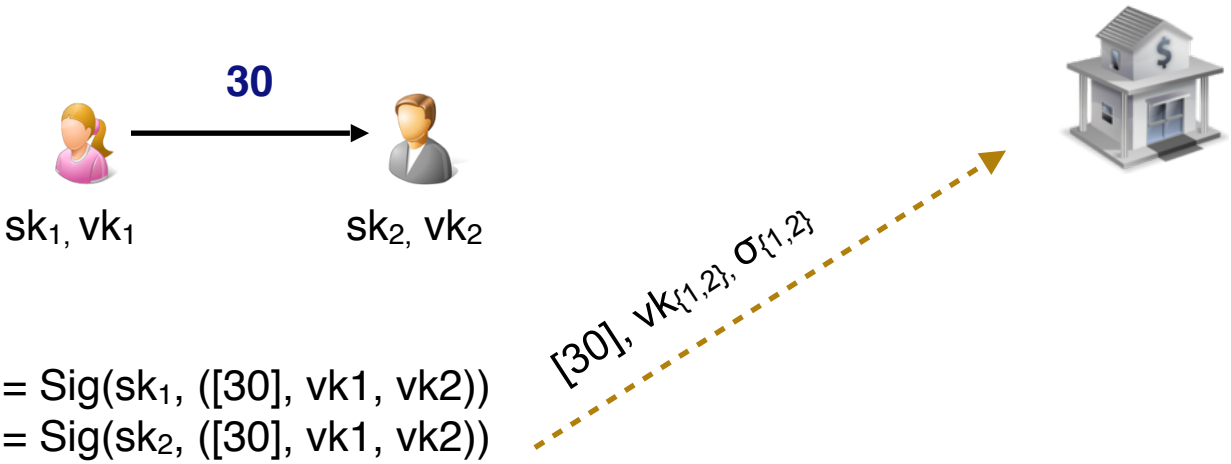

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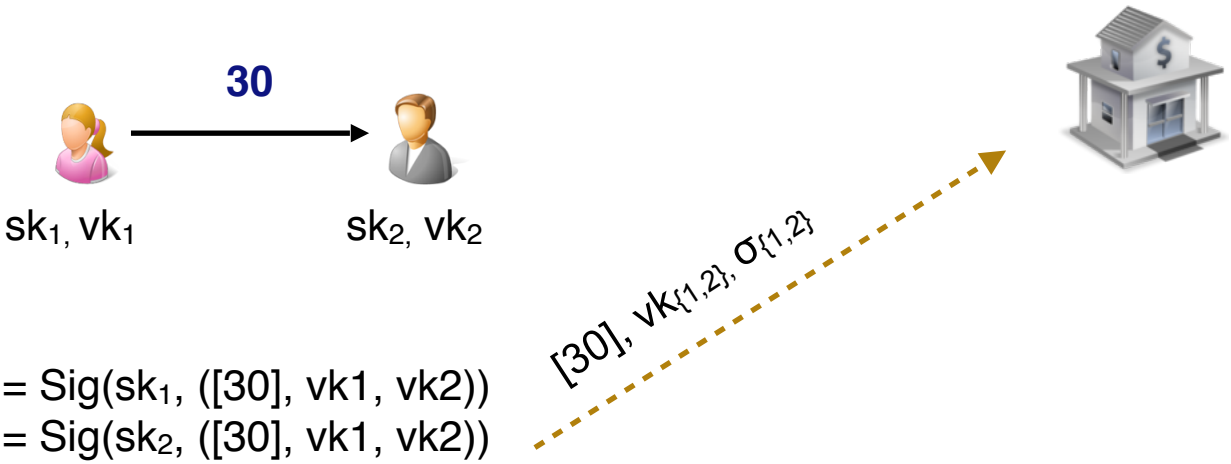
Proof of Credit Links in a Path



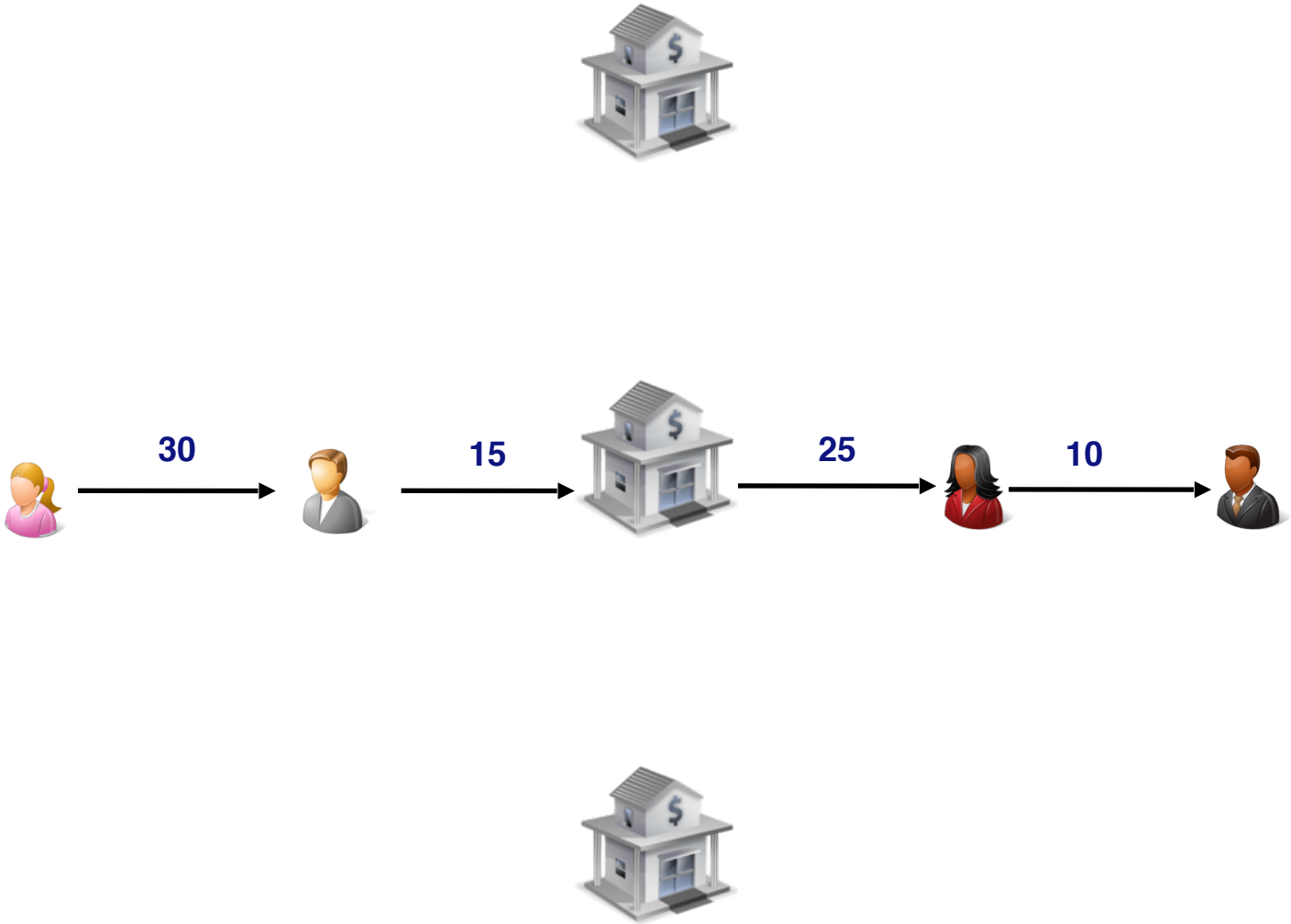
$\sigma_1 := Sig(sk_1, ([30], vk1, vk2))$
$\sigma_2 := Sig(sk_2, ([30], vk1, vk2))$

Correct proof for a path

$(vk_1, \boxed{vk_2}), \boxed{(vk_2,} vk_3), (vk_3, vk_4), \ldots$

Fresh keys per transaction

Privacy-preserving Credit in a Path



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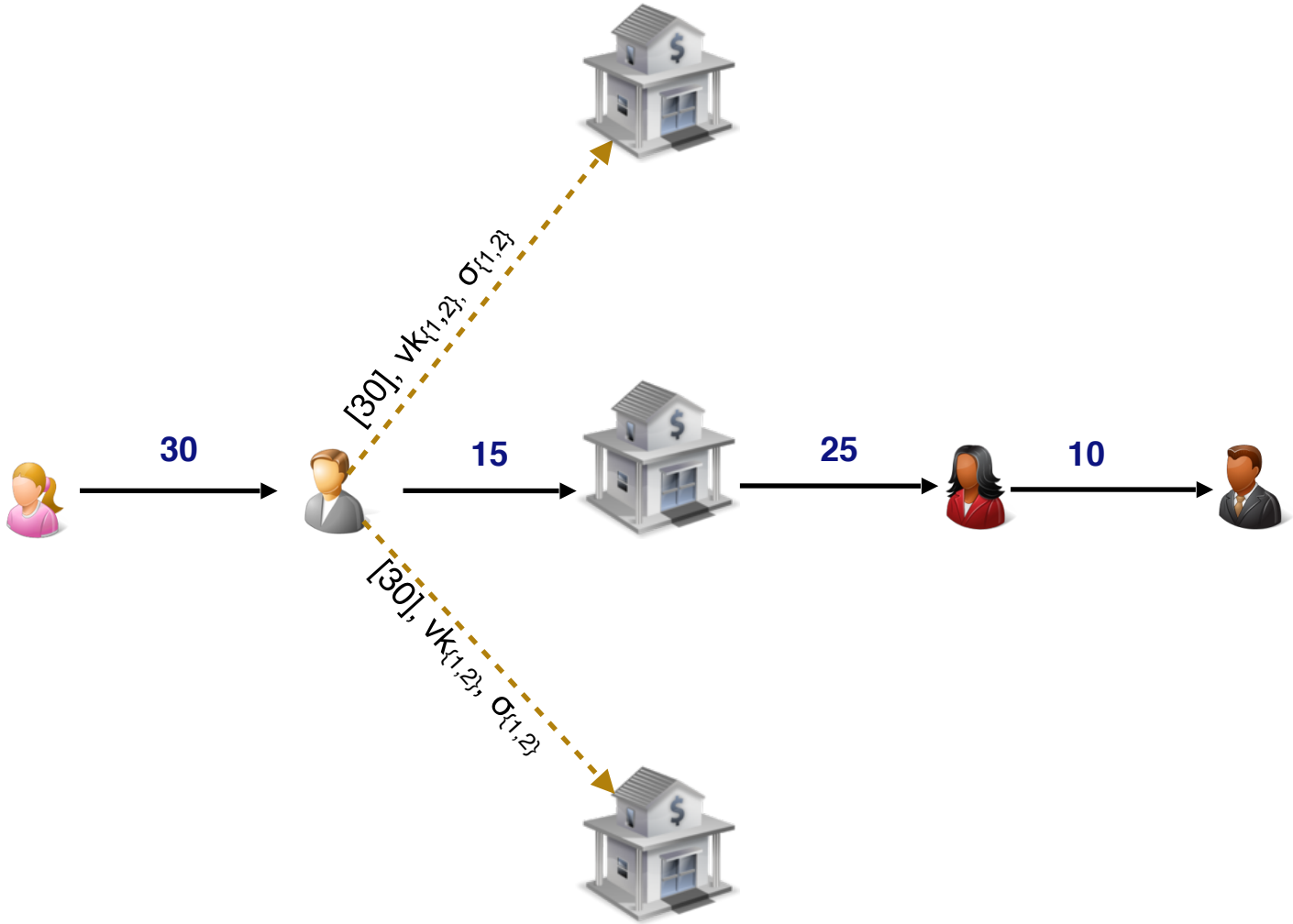

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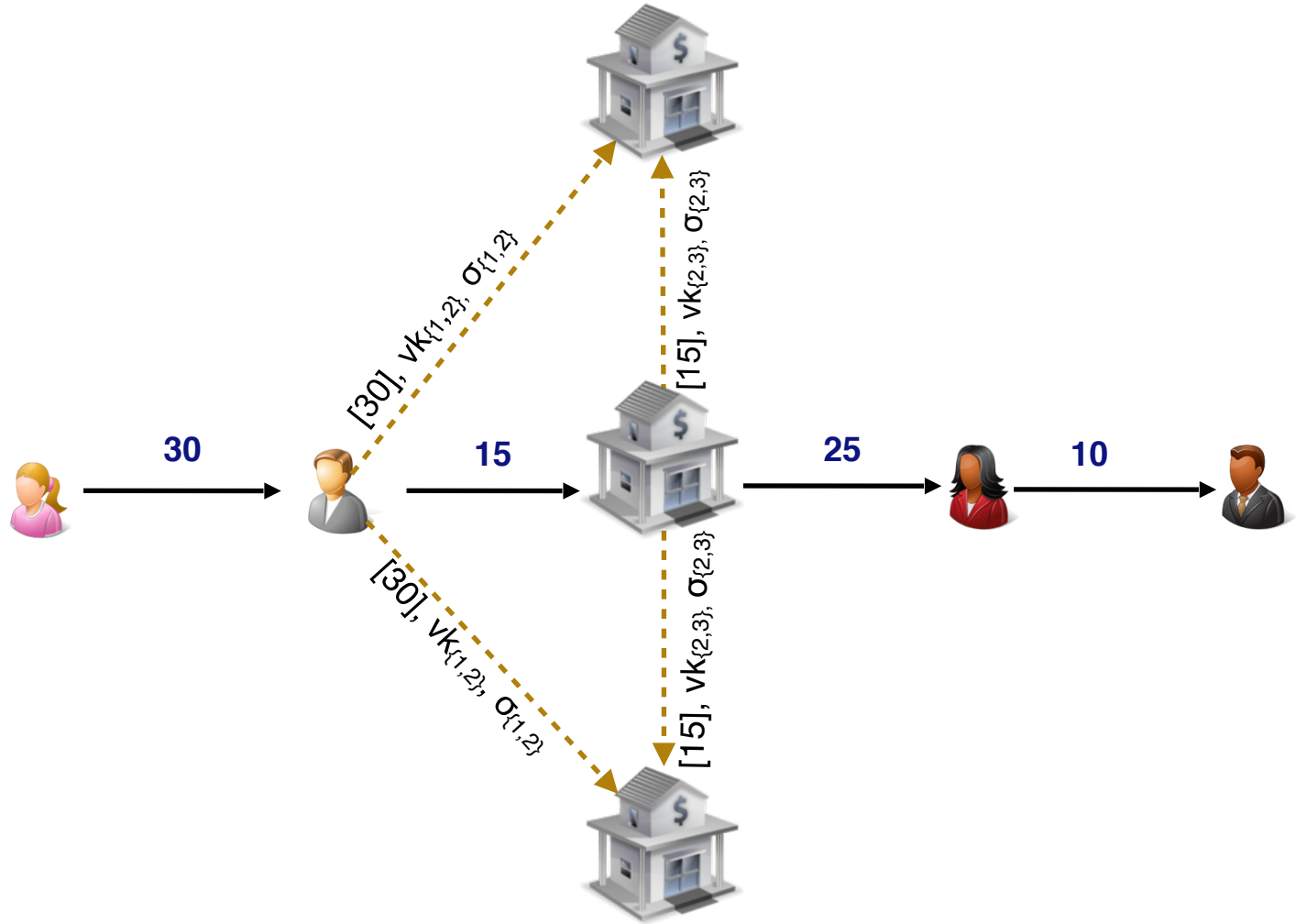

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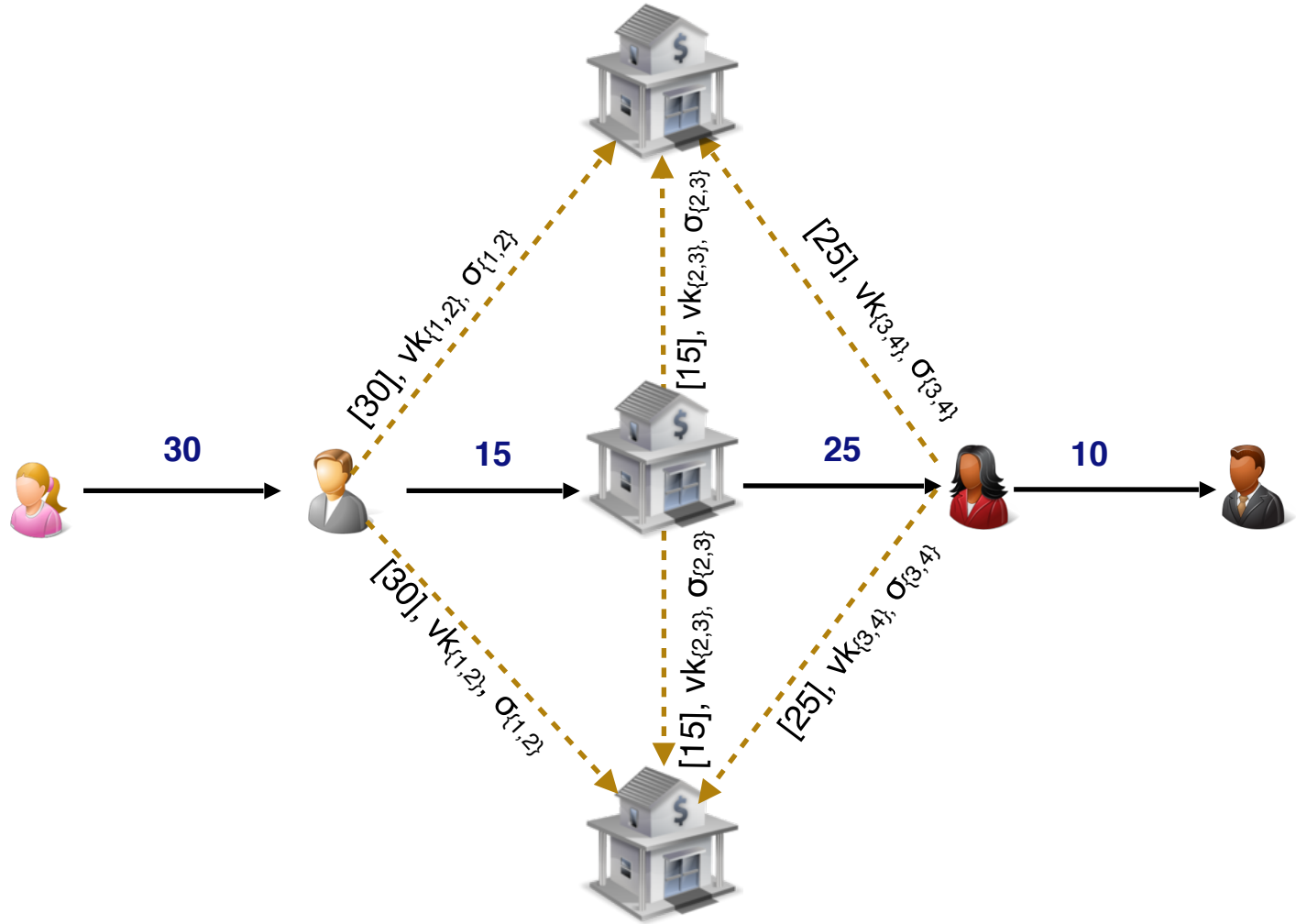

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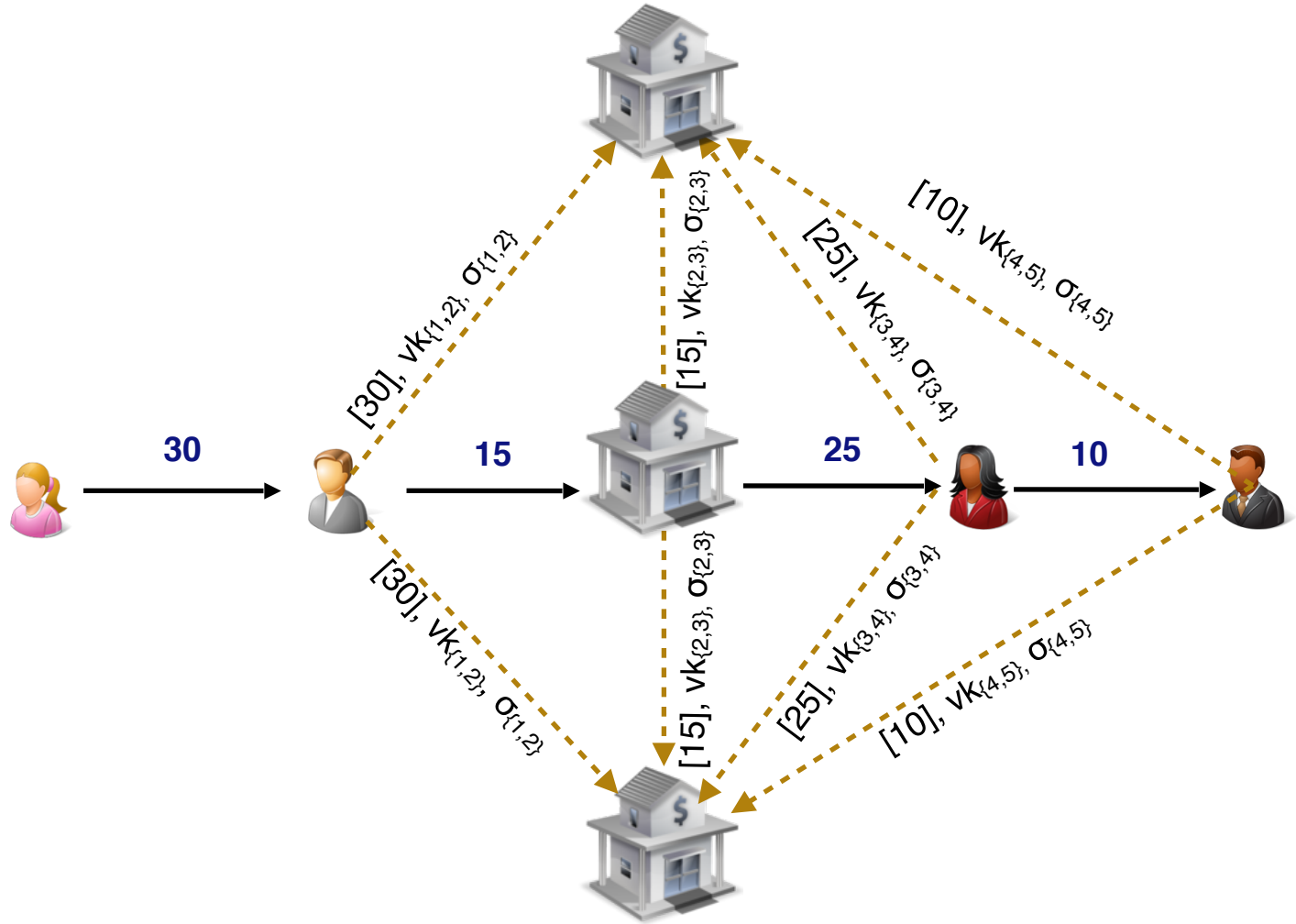

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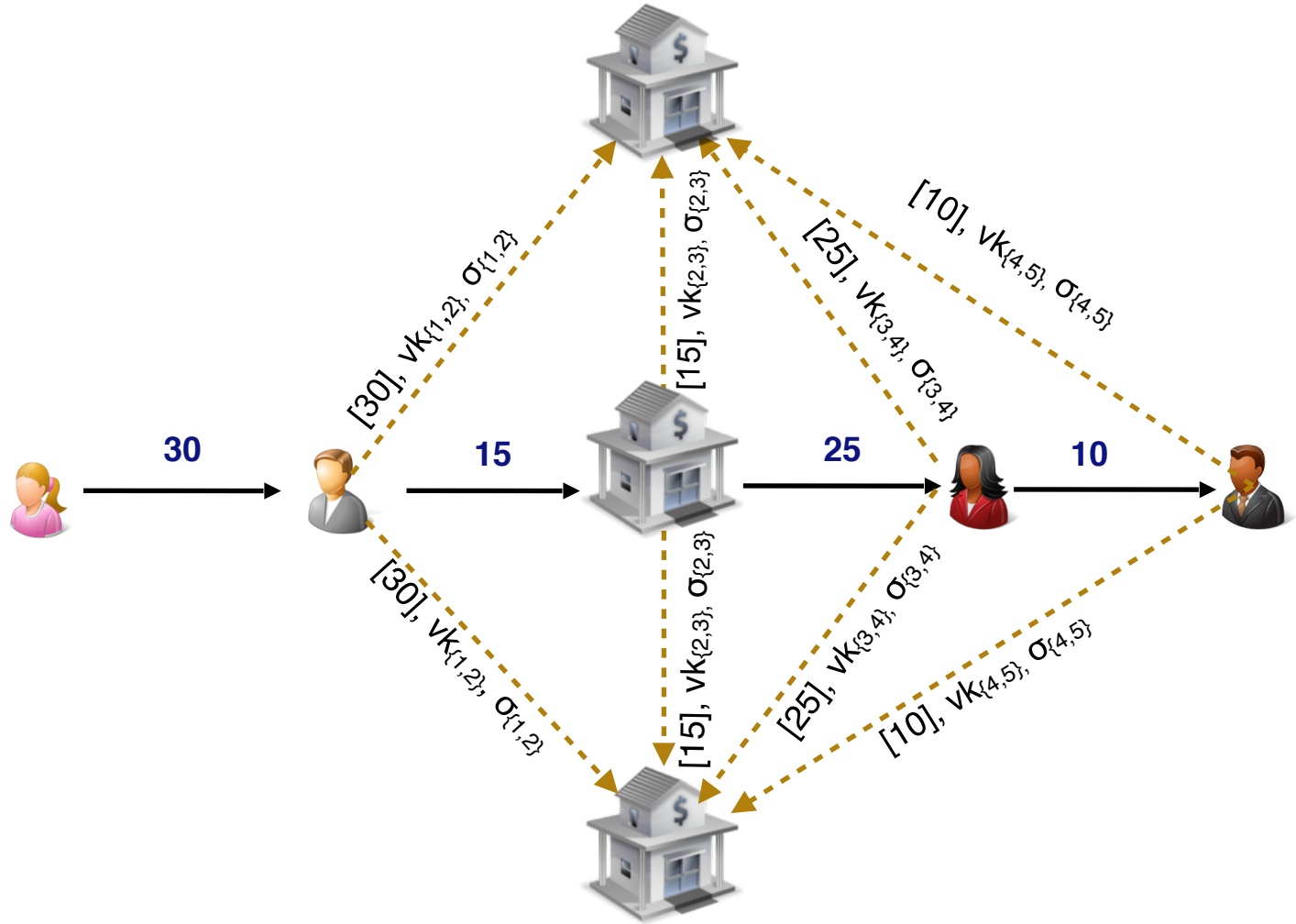

- Landmarks perform SMPC min computation over the shared link values

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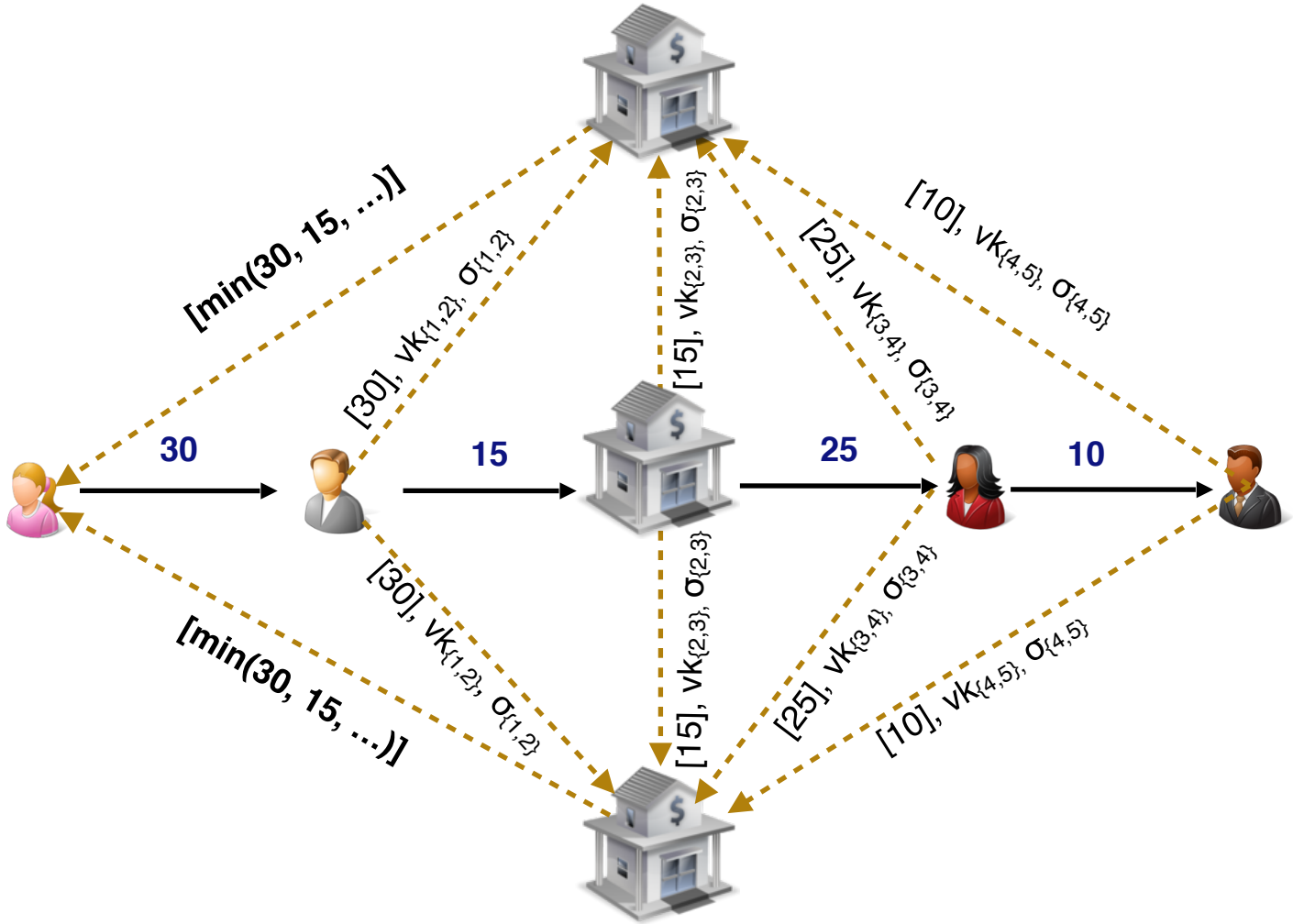

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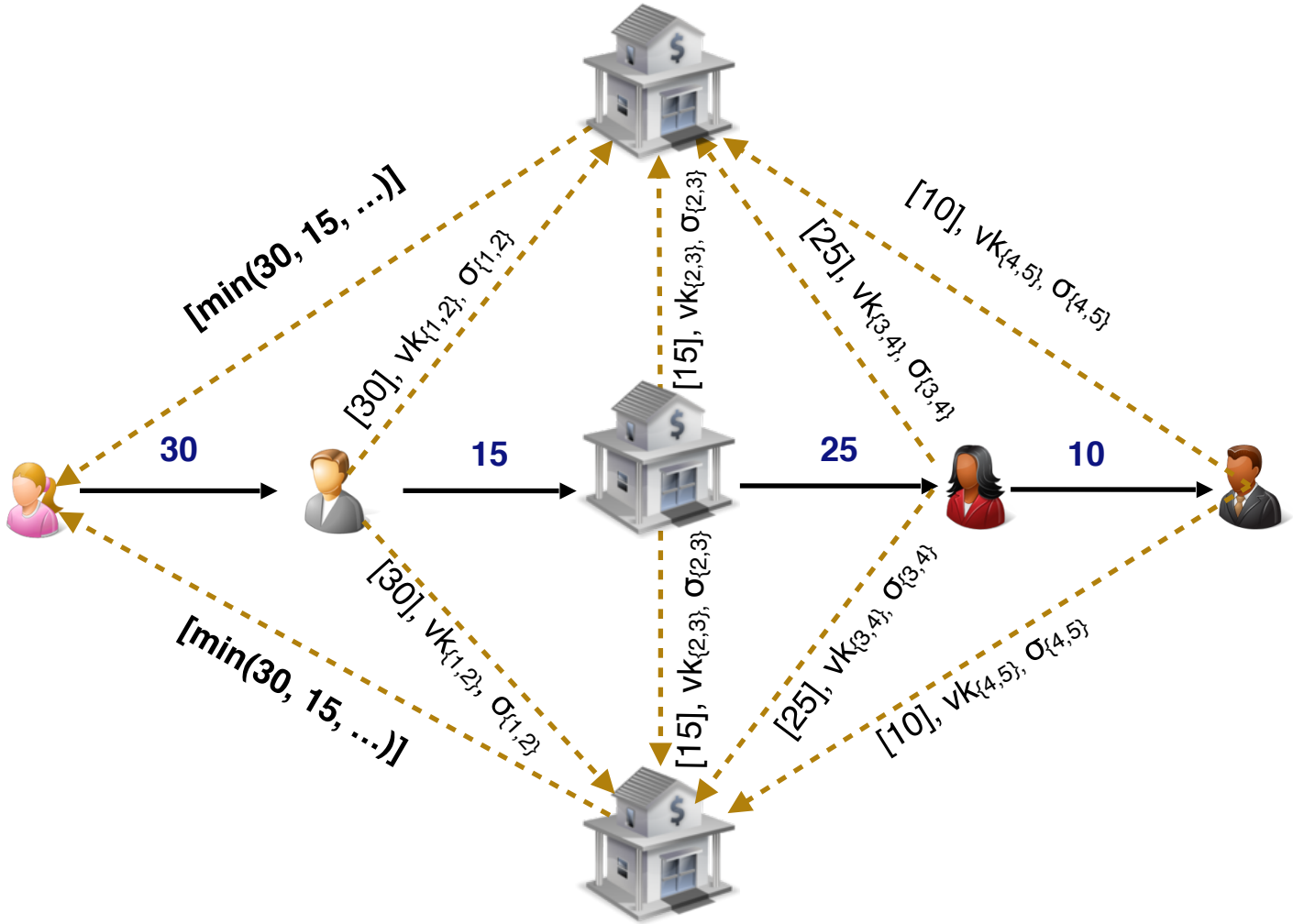

- Landmarks perform SMPC min computation over the shared link values
- Given enough “copies” of [x] it is possible to recover x for Alice

Transaction Execution

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- Sequential friend-to-friend communication

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- Two-step transaction: on hold (or block) and settle

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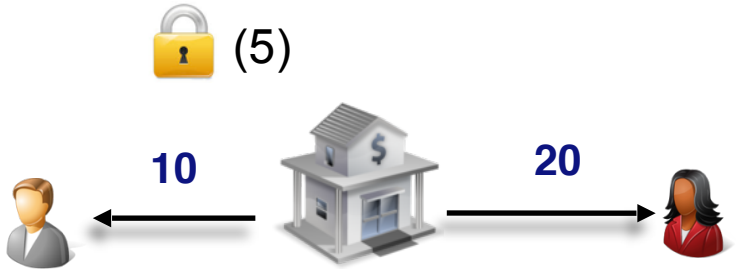

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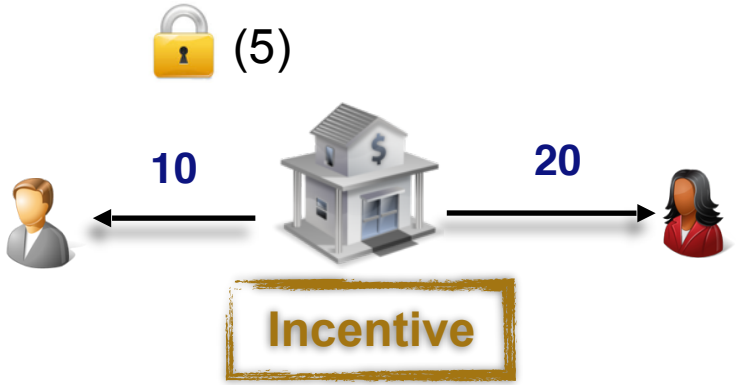

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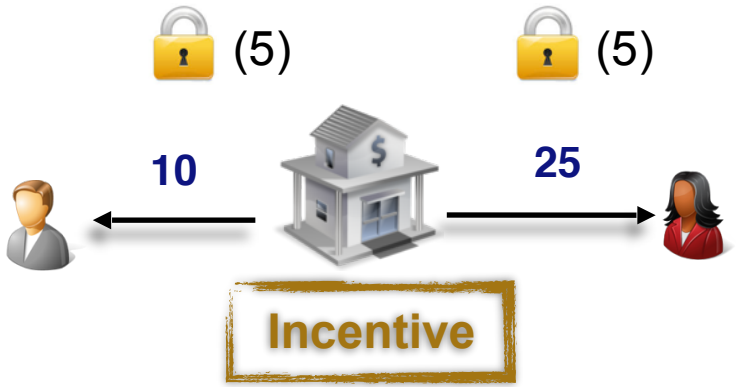

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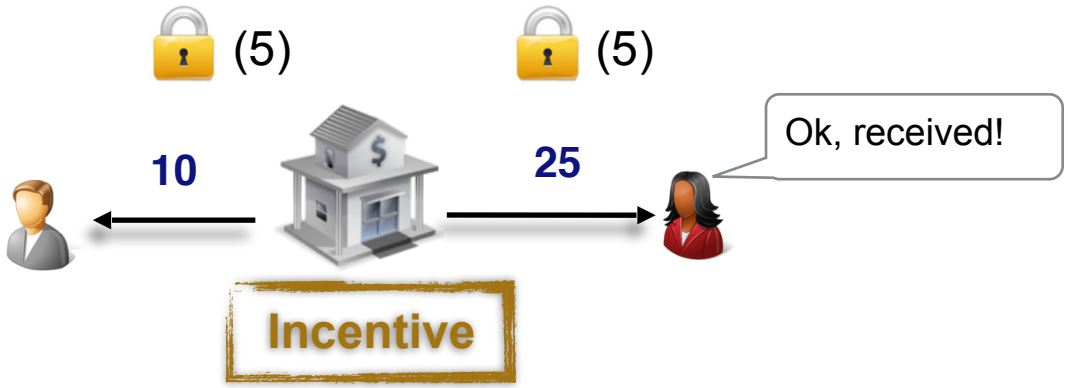

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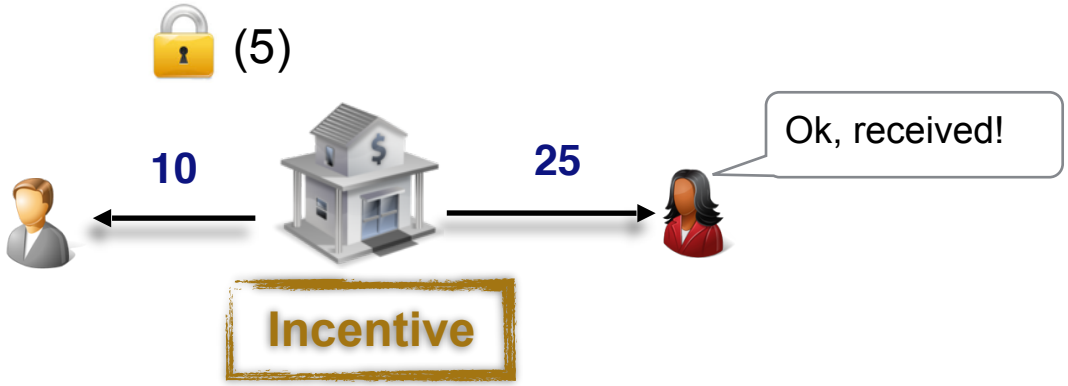

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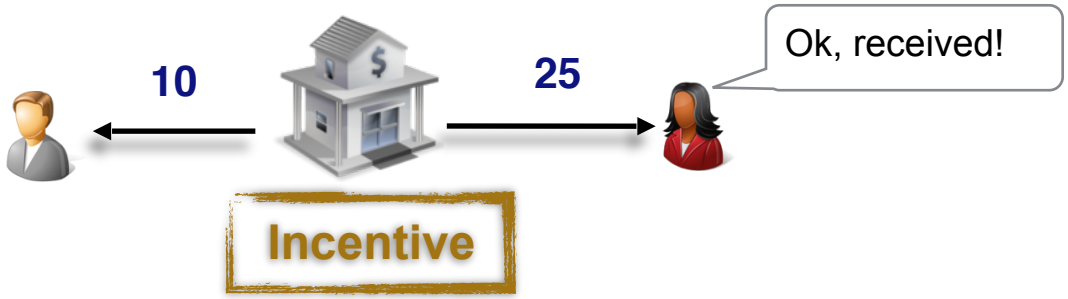

Whispers: Characteristics/Limitations

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- Distributed credit network transactions are possible without requiring
  - a blockchain ledger
  - a proof-of-work
- Whispers can be modified by using landmarks as distributed stores

  [more details in the techreport]
- In case of disputes, this leaves task of proving links to the users
- It is blocking solution, and deadlocks are possibles
- In the near future
  - design non-blocking solutions in the asynchronous communication setting
    - distributed max-flow computation and atomic broadcast

In the Future

In the Future

- Payment Channels and lighting network

https://lightning.network

  - Designing distributed solutions for lighting network

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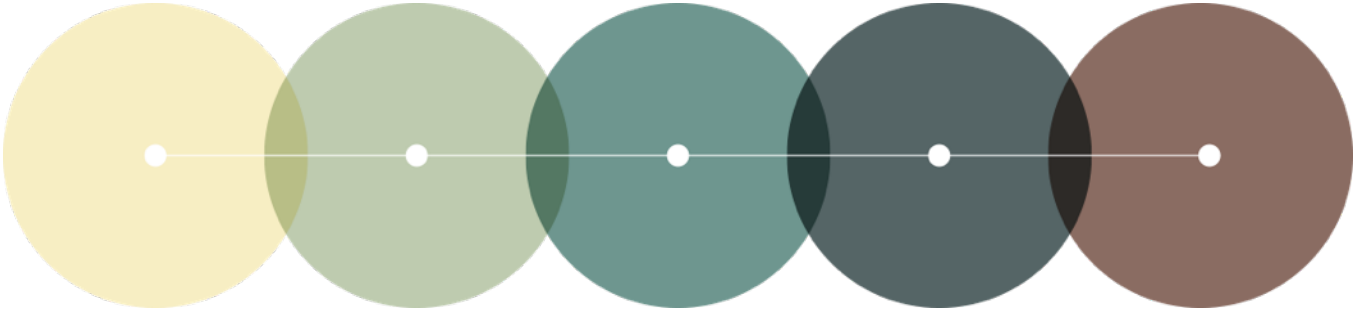
- The Interledger Protocol

  https://www.w3.org/community/interledger

  - Several distributed/decentralized/centralized ledger solutions are coming up
  - Performing transactions across different ledgers



Take home message

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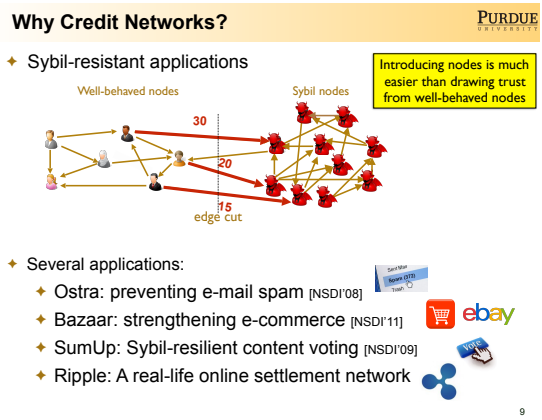
- Credit networks have interesting properties and can be used in multiple scenarios



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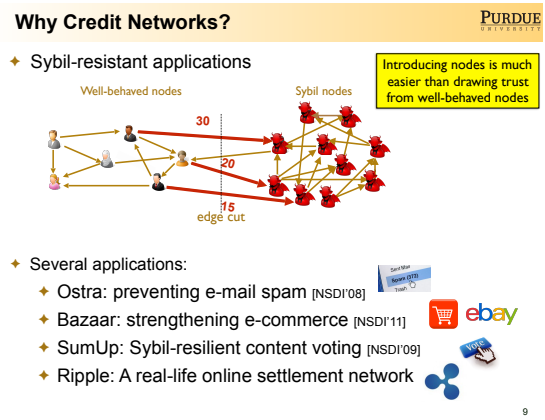
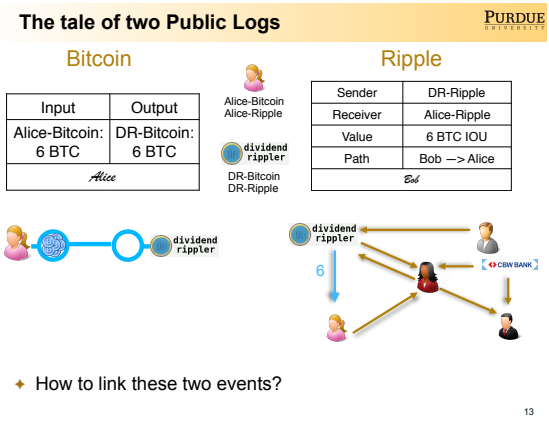


- Ledgers although provide accountability, it makes privacy a real problem in credit networks



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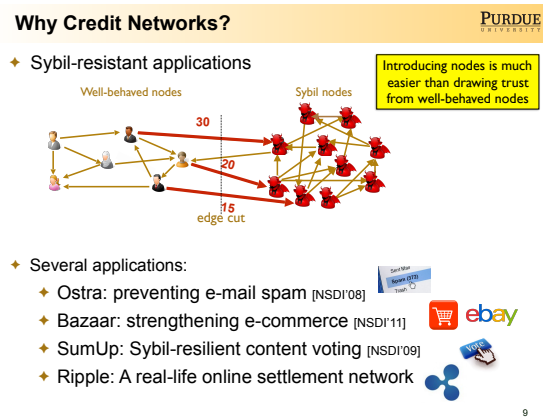
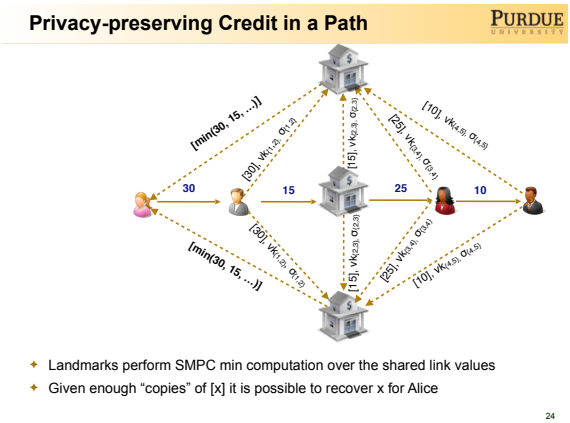


- Whispers: a decentralized architecture for providing accountability and privacy for credit networks



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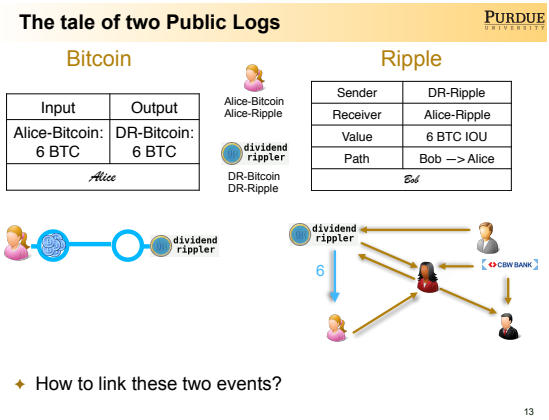

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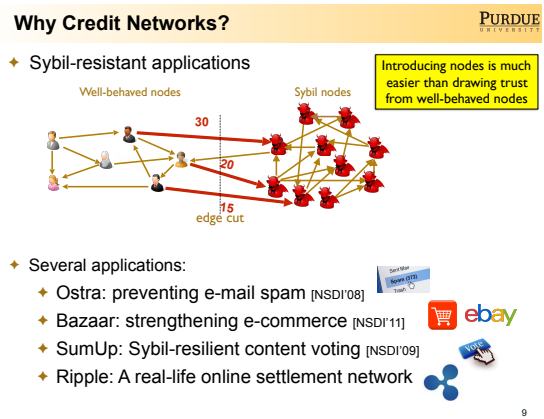

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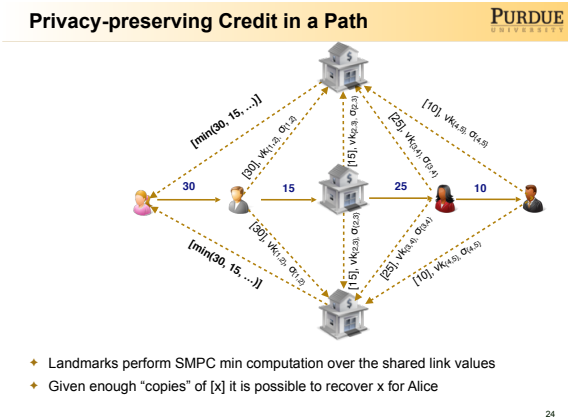

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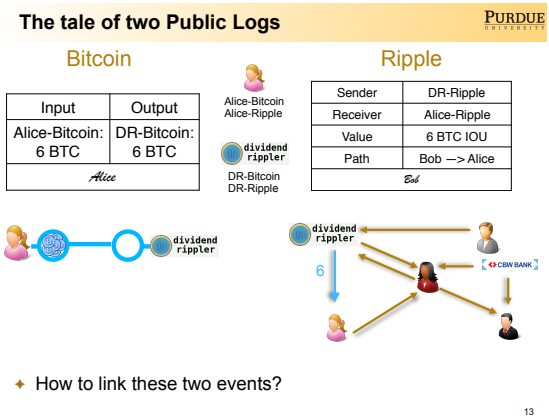

- Several questions remain unanswered leaving lots of open problems