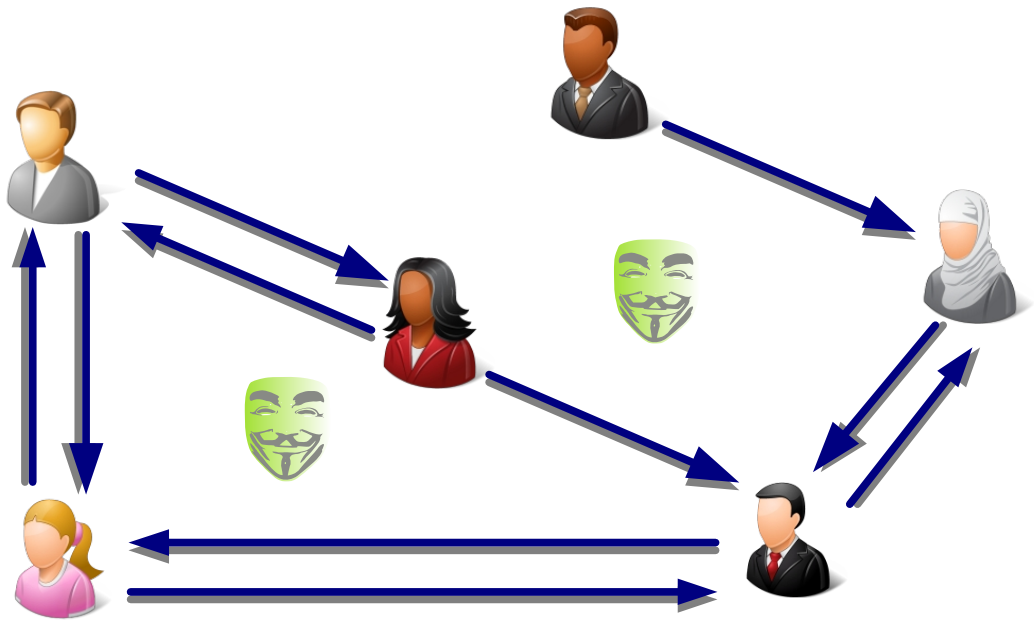
Privacy Preserving Payments in Credit Networks



Pedro Moreno-Sanchez, Aniket Kate, Matteo Maffei and Kim Pecina

CISPA, Saarland University

NDSS 2015

Credit Networks Introduction

Real World

Credit Network

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Real World

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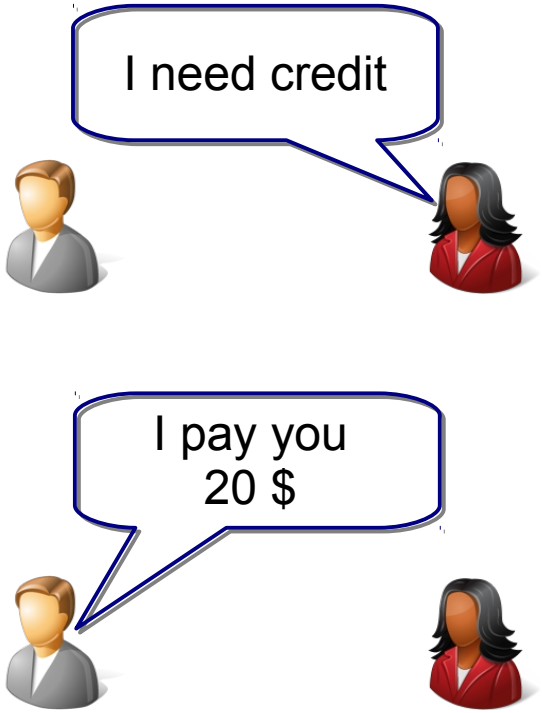
Real World



Credit Network

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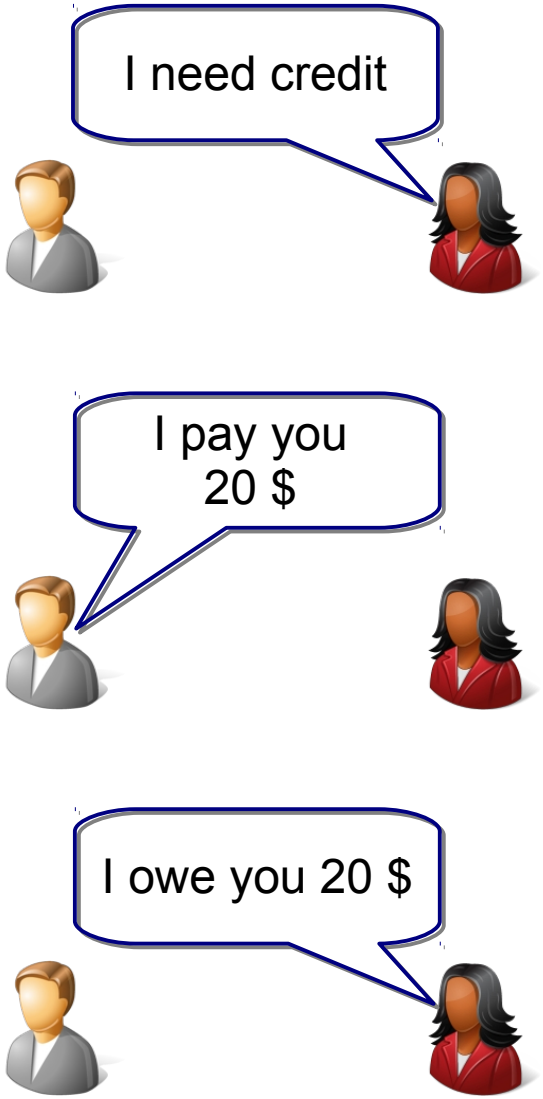

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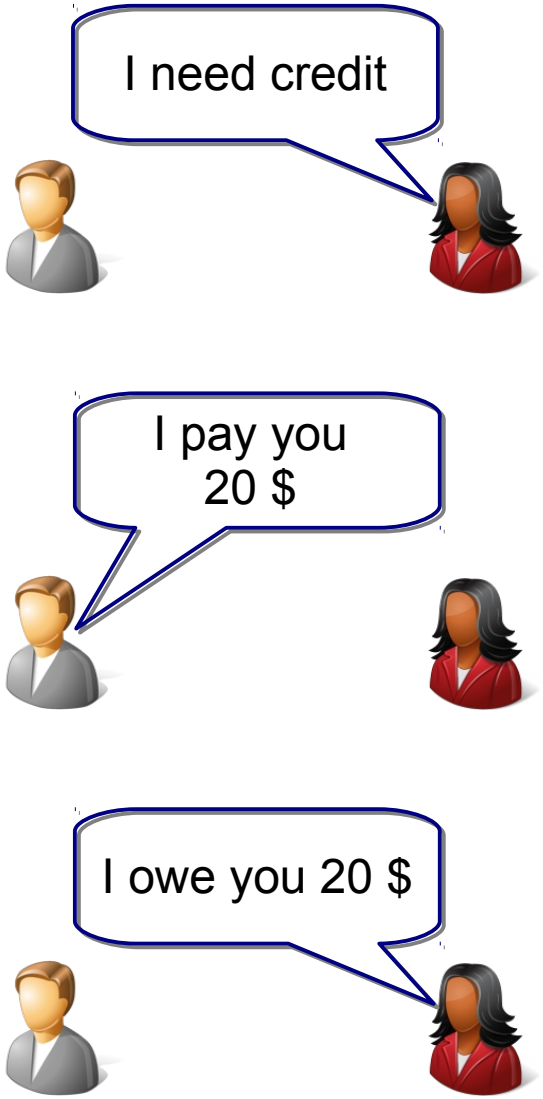

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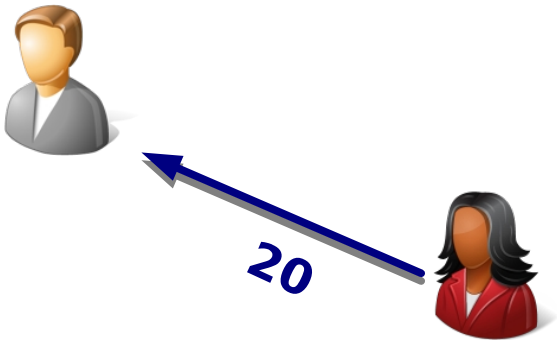

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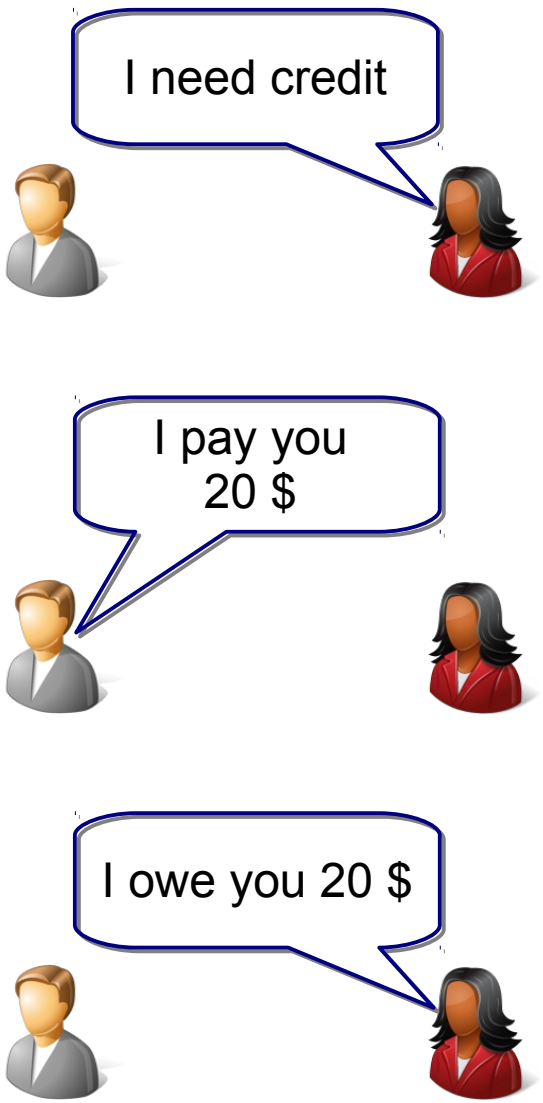

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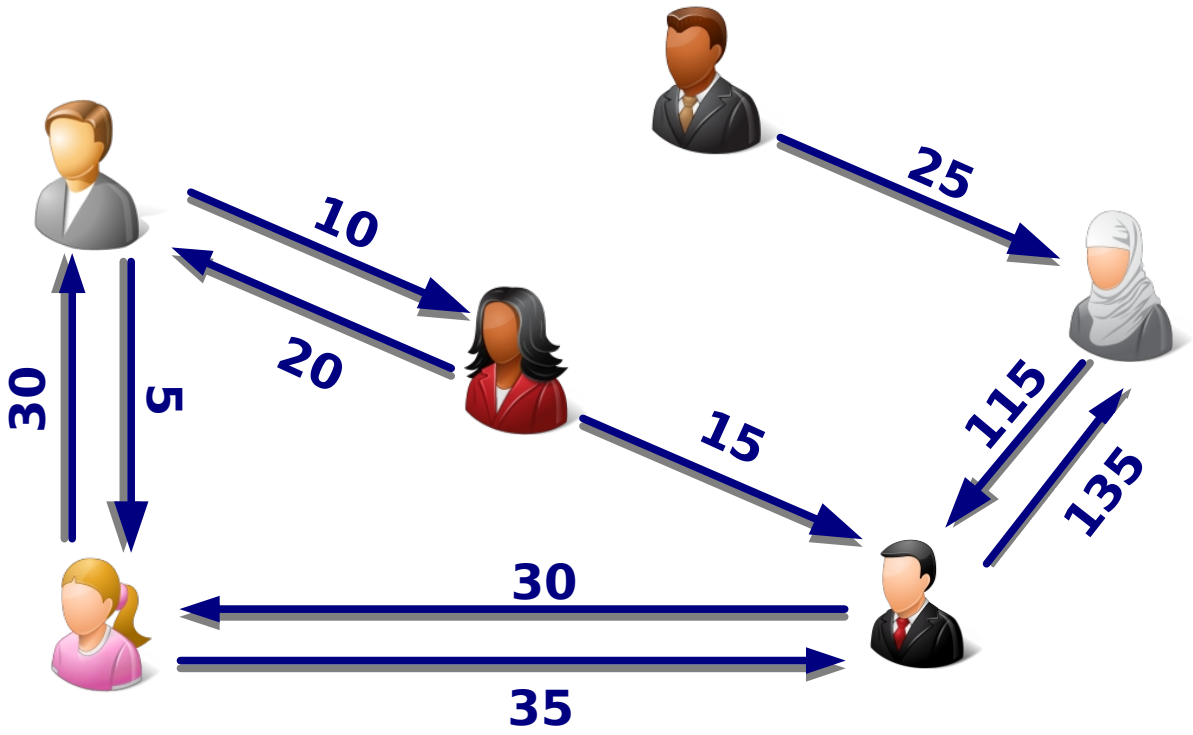

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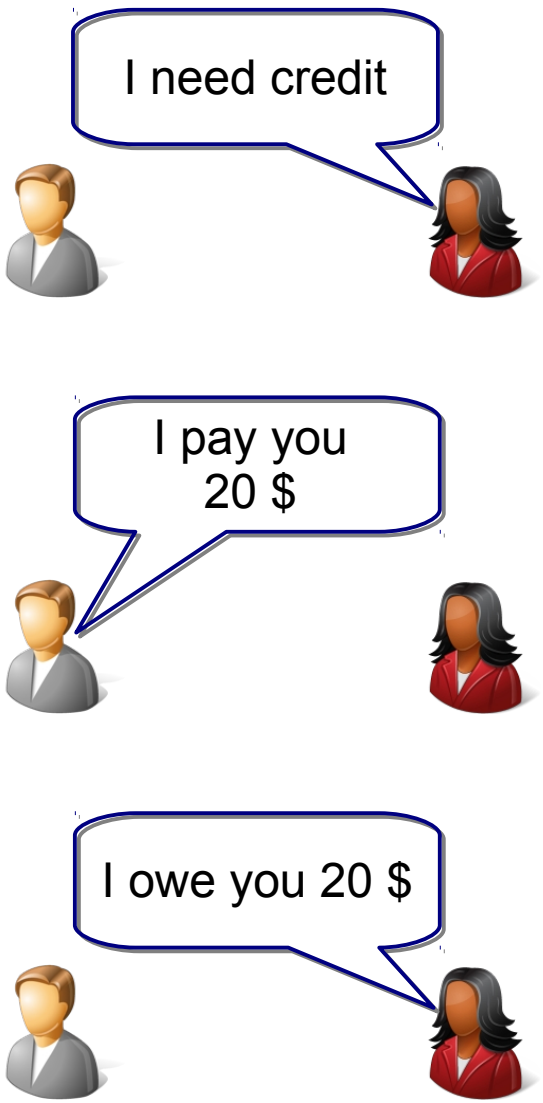

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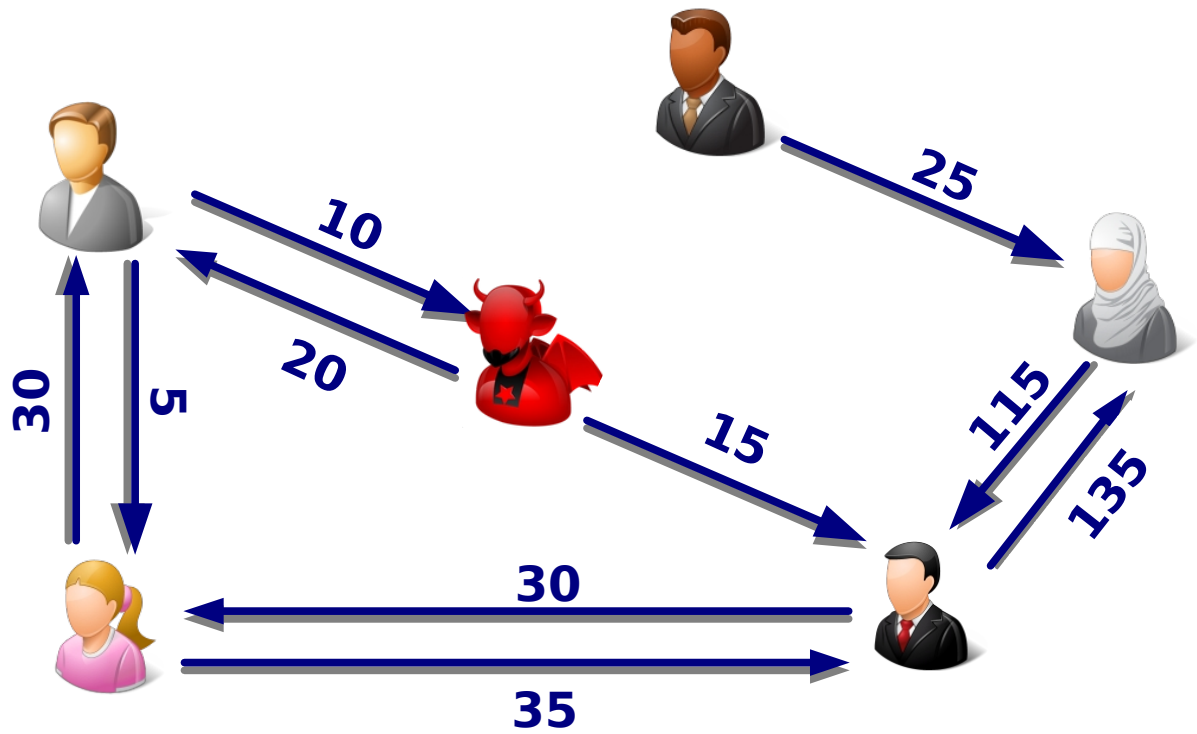

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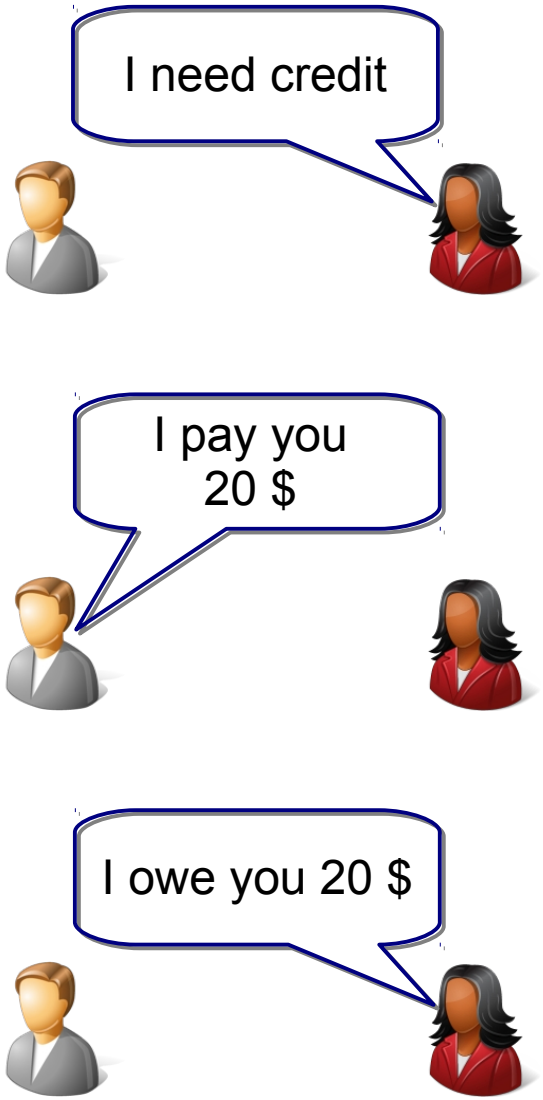

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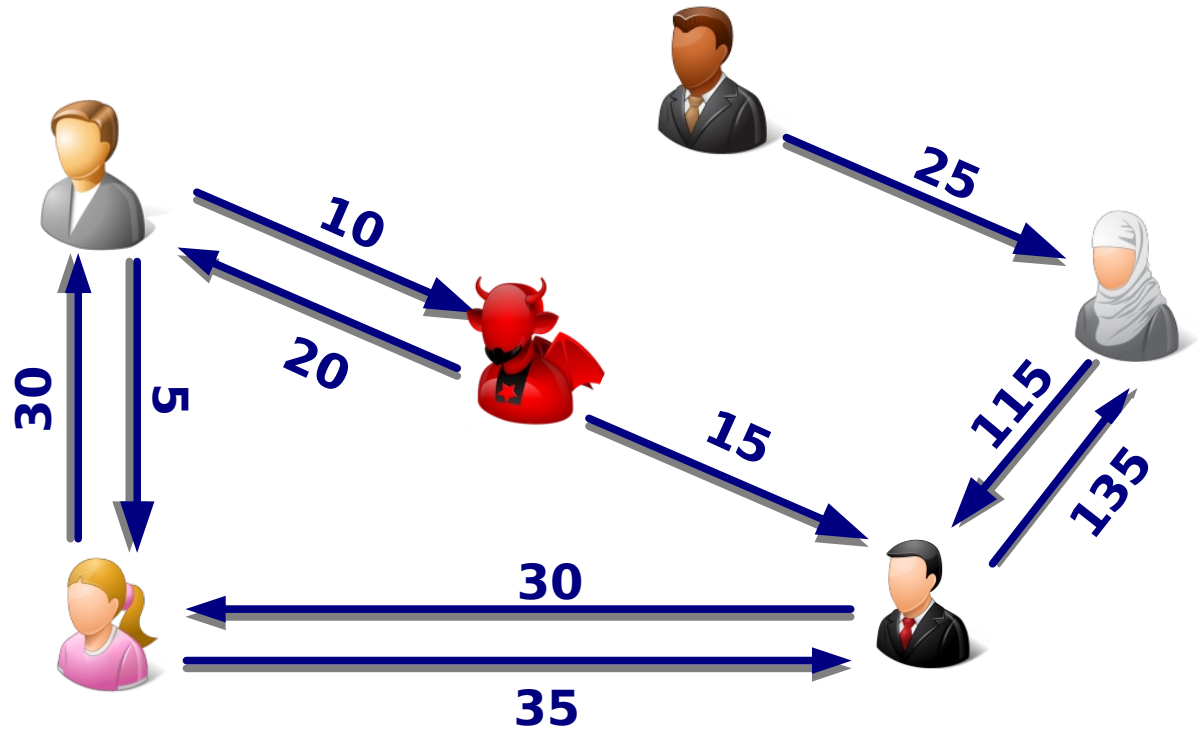

Misbehaving user's effect is:

Localized

Bounded

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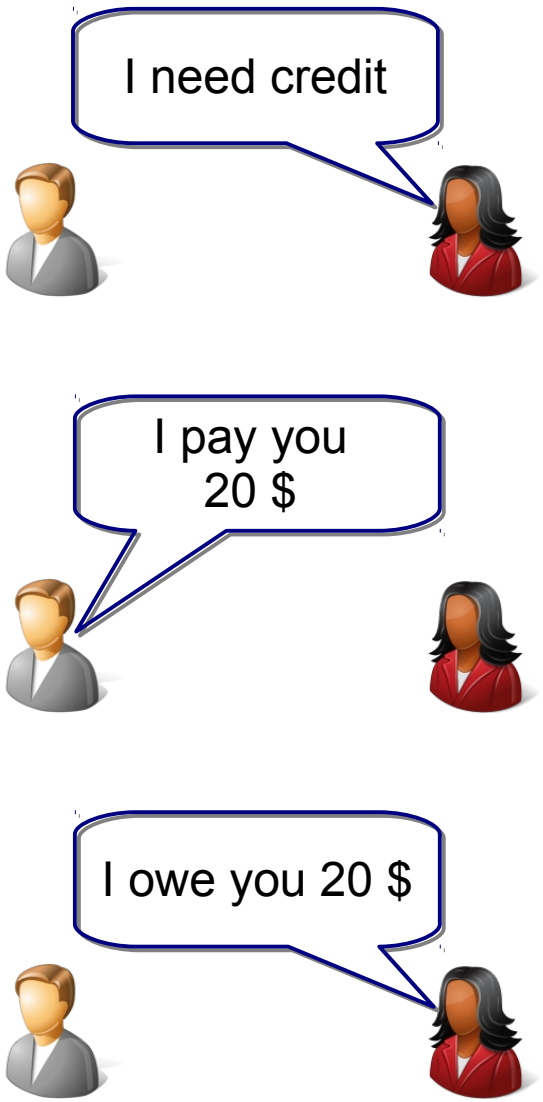

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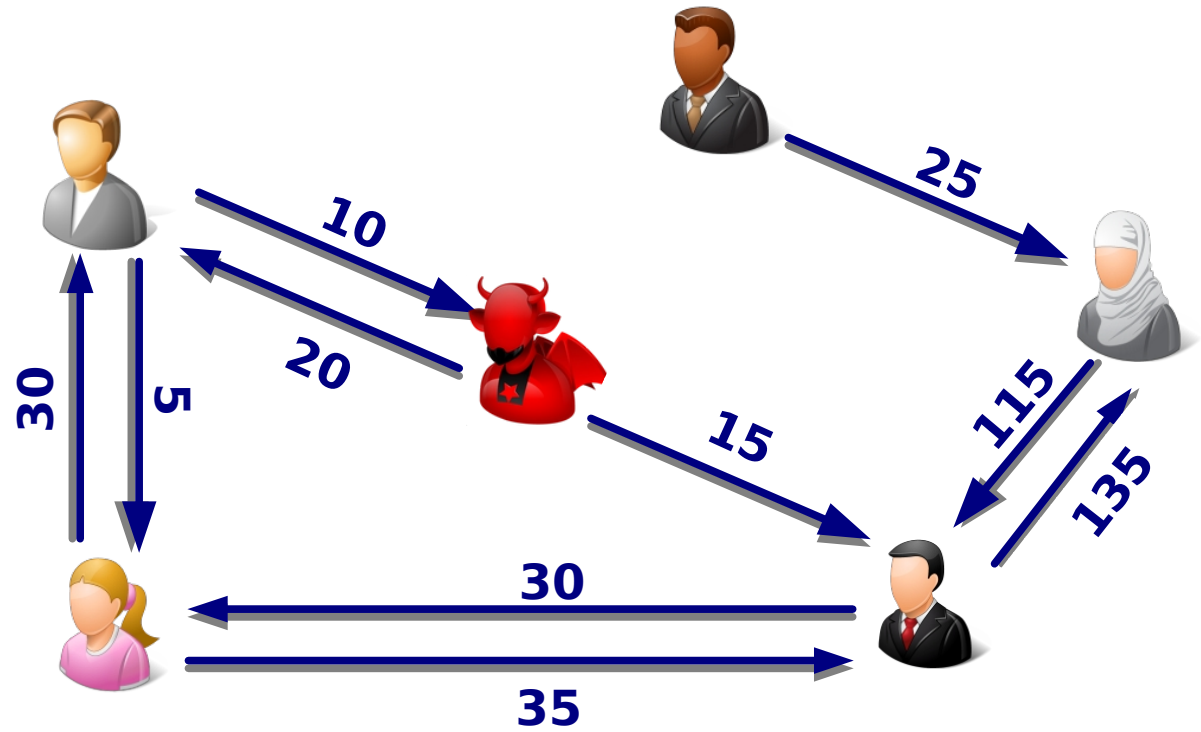

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Multiple applications:

Ostra: mitigate spam in email system

Bazaar: strengthen online marketplaces, e.g., eBay

Etc.

Credit Networks Application: Payment Systems

- Payment systems: **Ripple [> 140,000 users, > $15M transaction volume]**

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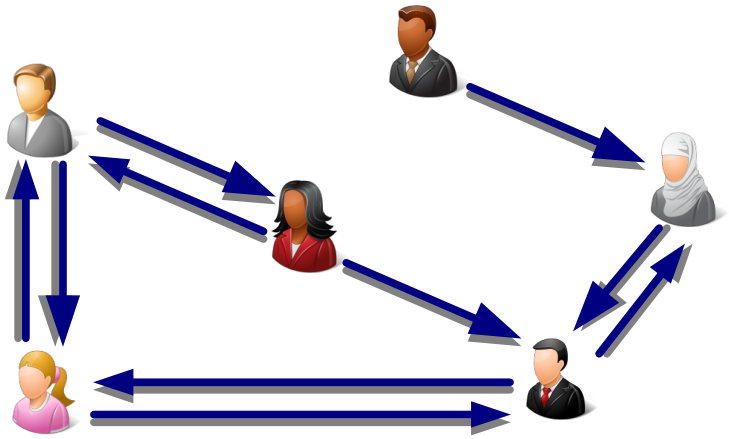

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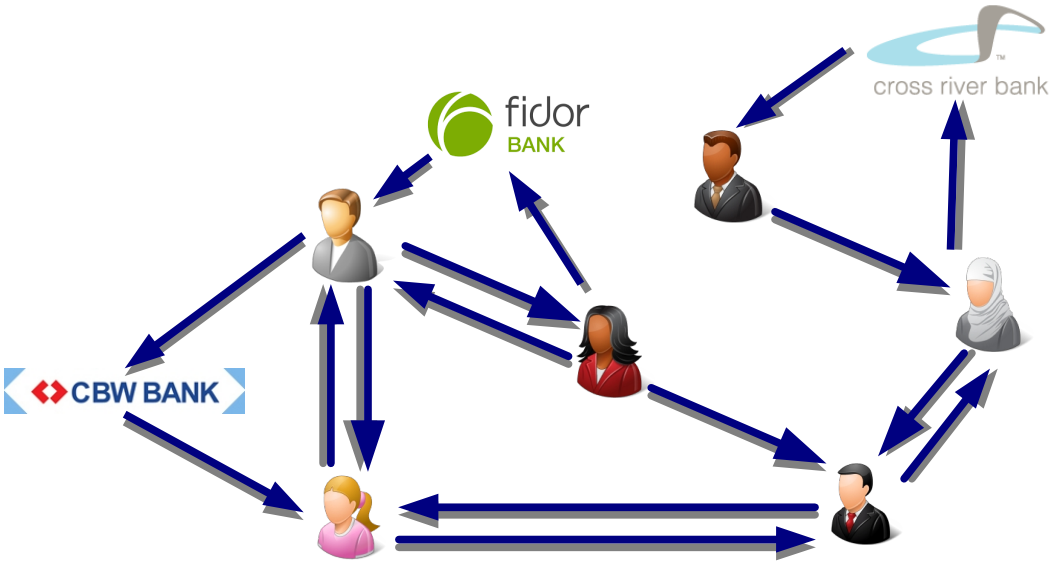

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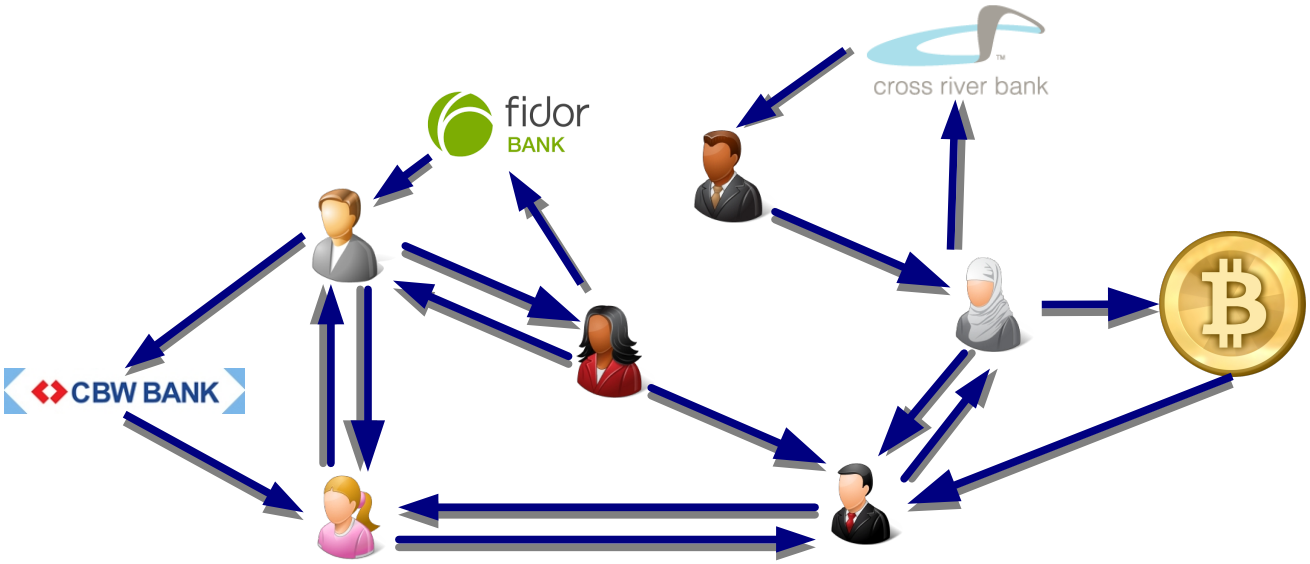

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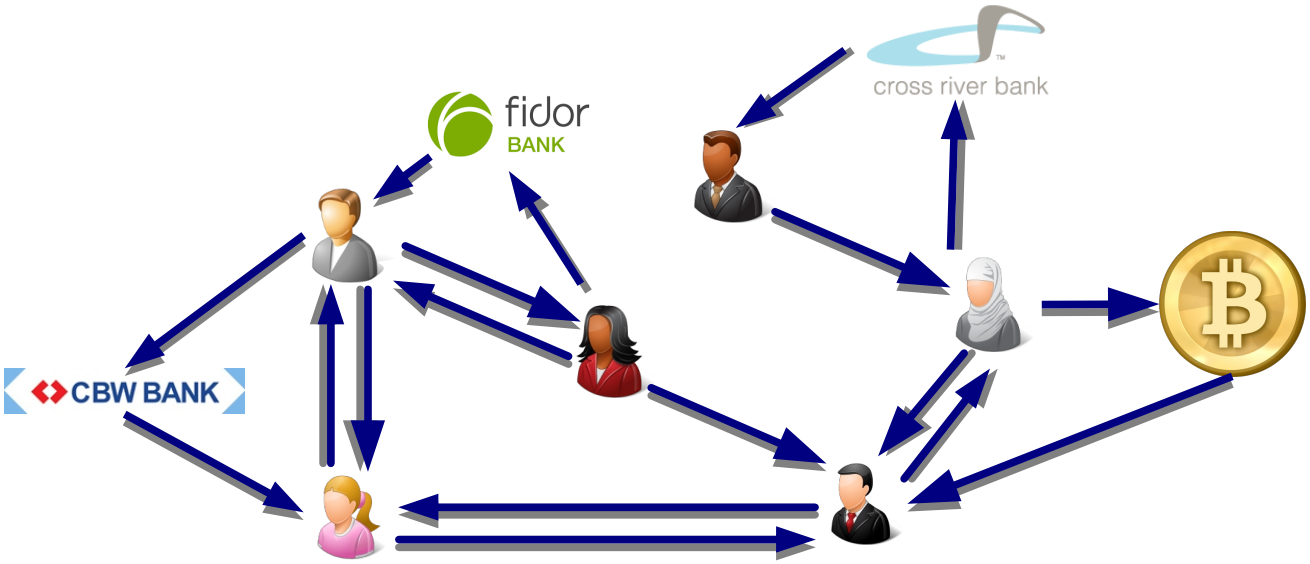


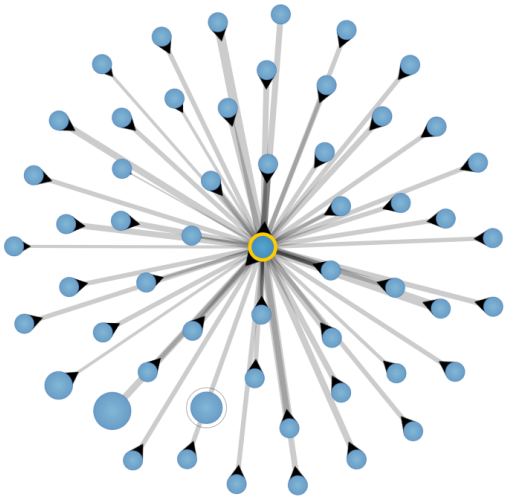
	Banking System	Ripple
Transaction	~ 1 day	~ 5 seconds
Multi-currency & worldwide transactions	High fees	Small fees
Integrity	Bank-only verifiable	Publicly verifiable

Public Verifiability & Privacy Problem

Ledger

	50
	30
fidor BANK	200
...	...

Credit links



Transaction details

Account	Destination	Amount
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rLSBpSquSHKbbfvcKt1c54…	rKoDt7VL83AKJZewLxVZEs…	75/XRP
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r42WJGvV9MJa4t5QcF8Cnx…	rBeToNo4AwHaNbRX2n4BNC…	0.0821058028231/CCK/rB…
rUnr1p7xkuSBxyAqHEopZ5…	r3H4rynDShFMRKWuJcadLY…	1129.916679154465/EUR/…
rw7UfGvzCeZwJxxUEeZHLG…	rBwgTdzzMHnouLk5DJD3xd…	100/XRP
rpVVzfSTUJX9CrKBSS2Z5W…	rDCgaaSBAWYfsxUYhCk1n2…	999.99/XRP

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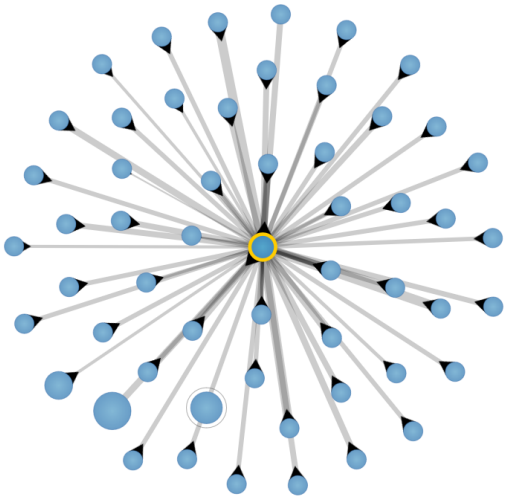

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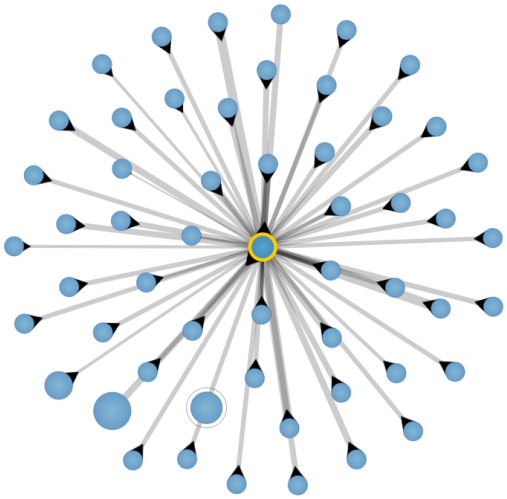

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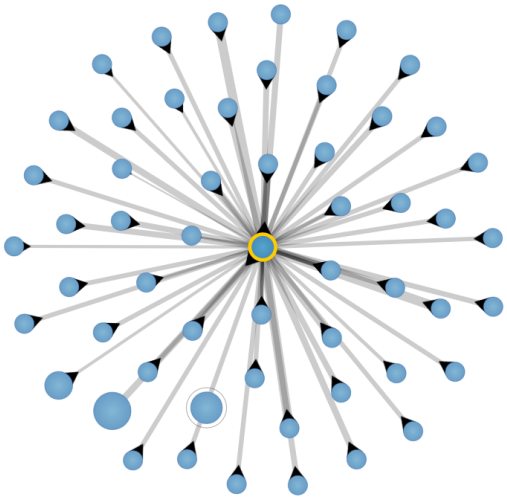

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rpVVzfSTUJX9CrKBSS2Z5W…	rDCgaaSBAWYfsxUYhCk1n2…	999.99/XRP

LINKABLE ANONYMITY

Contributions

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rwvctTPLKZqK59f1fXpDkQ…	rMnVZ9maUWp5cAvmqBECZM…	300/XRP
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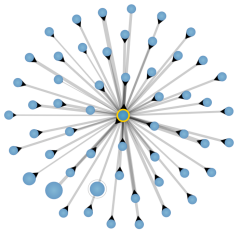

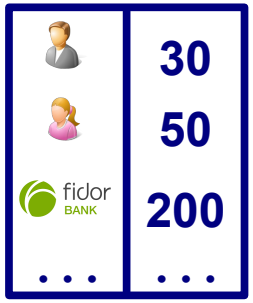

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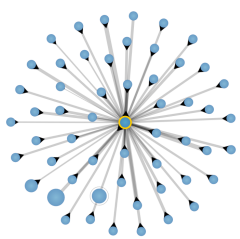

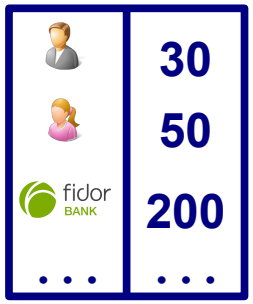

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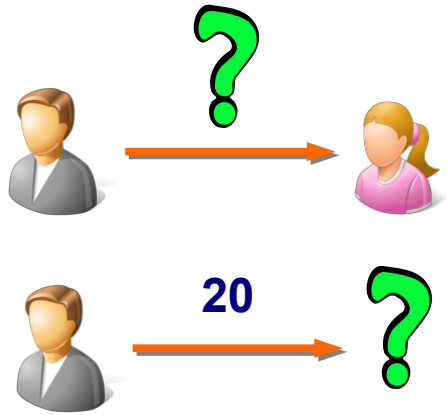

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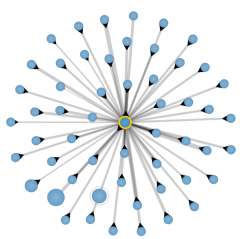

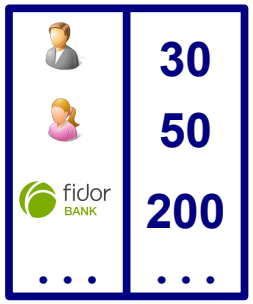

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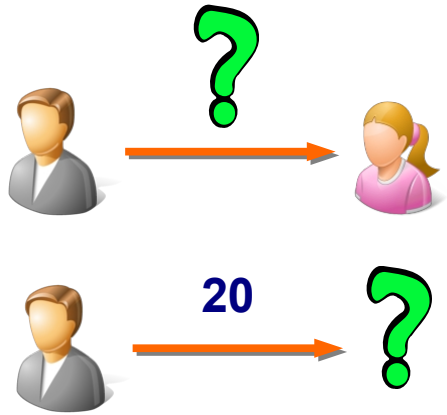

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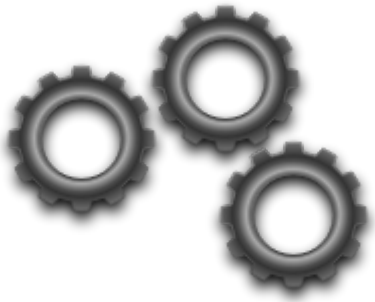

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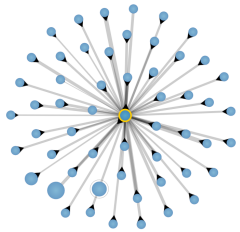

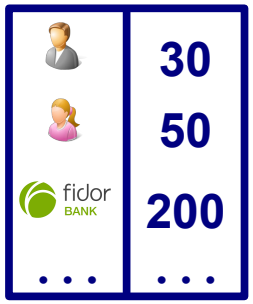

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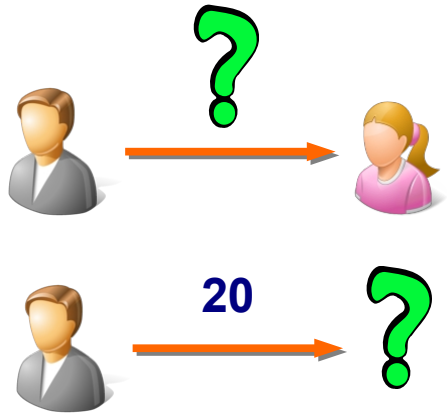

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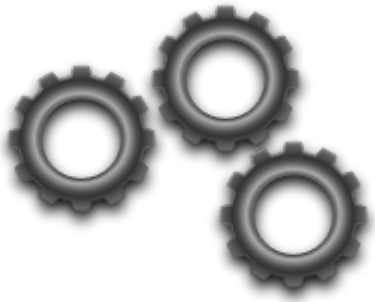
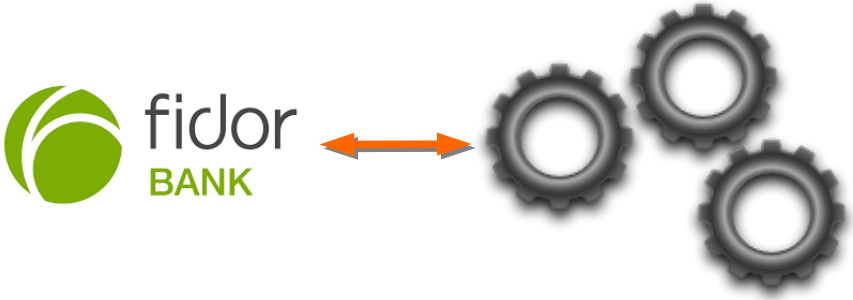
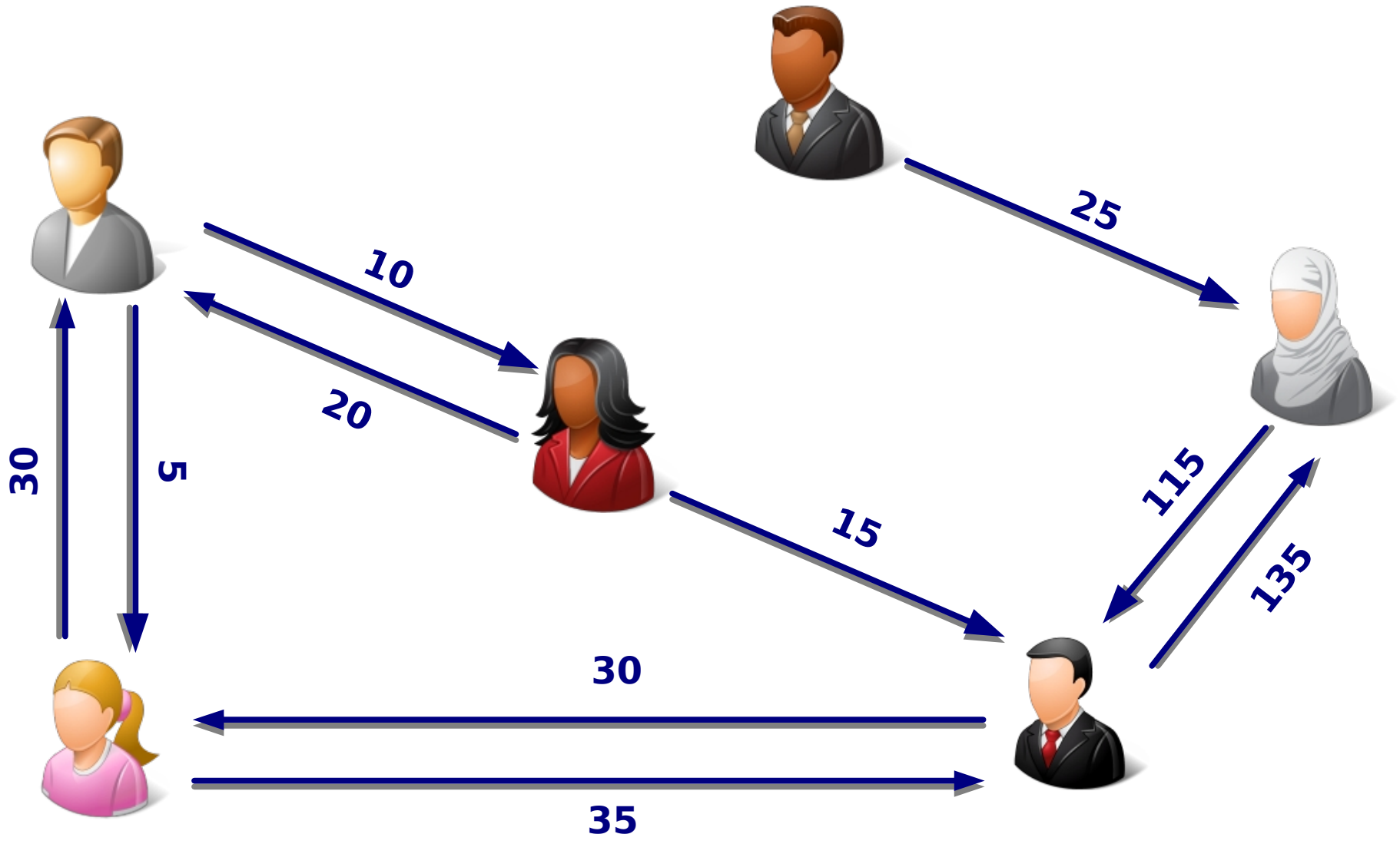


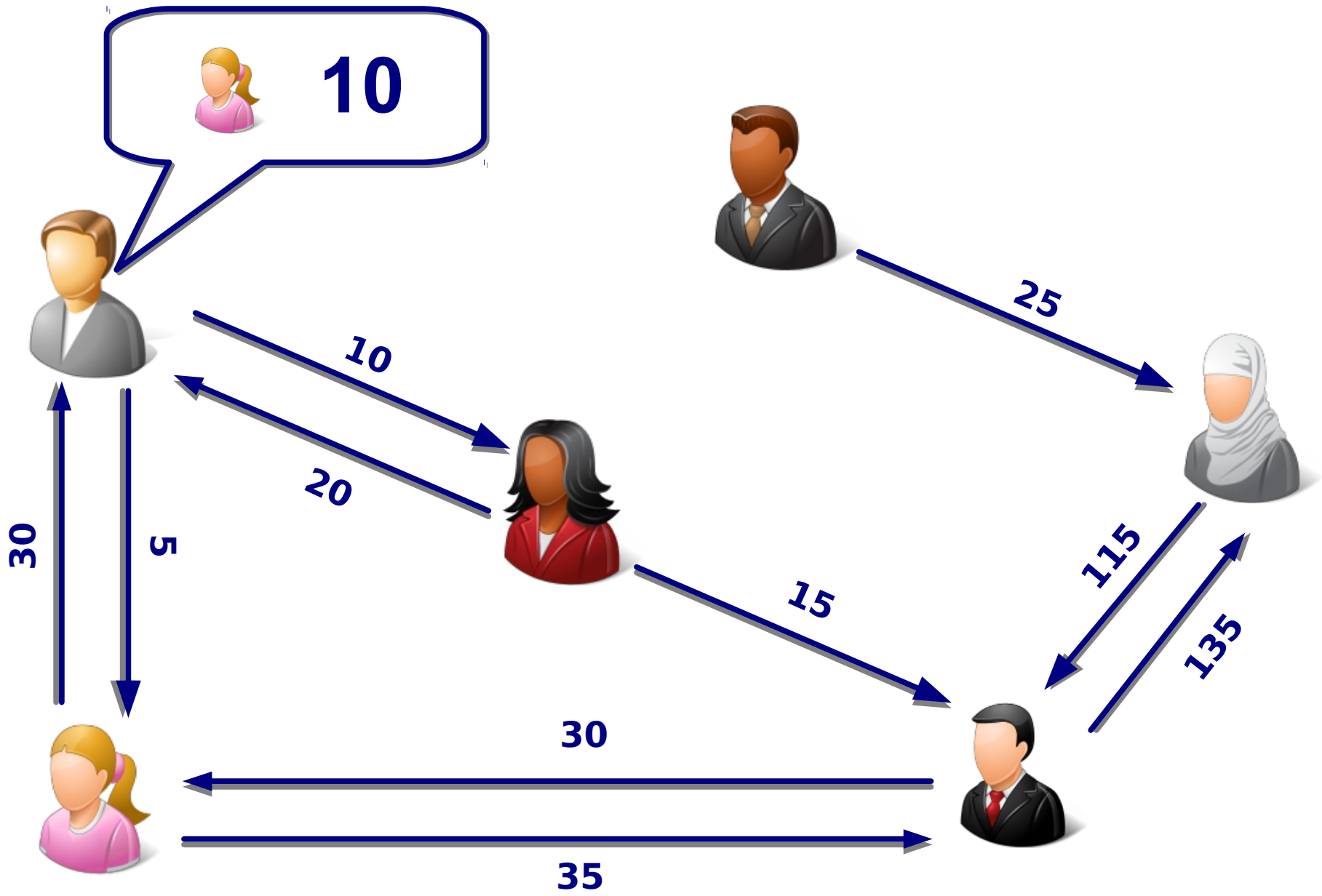
- Evaluation: **feasible to deploy** in practice



Credit Network Transaction



Credit Network Transaction



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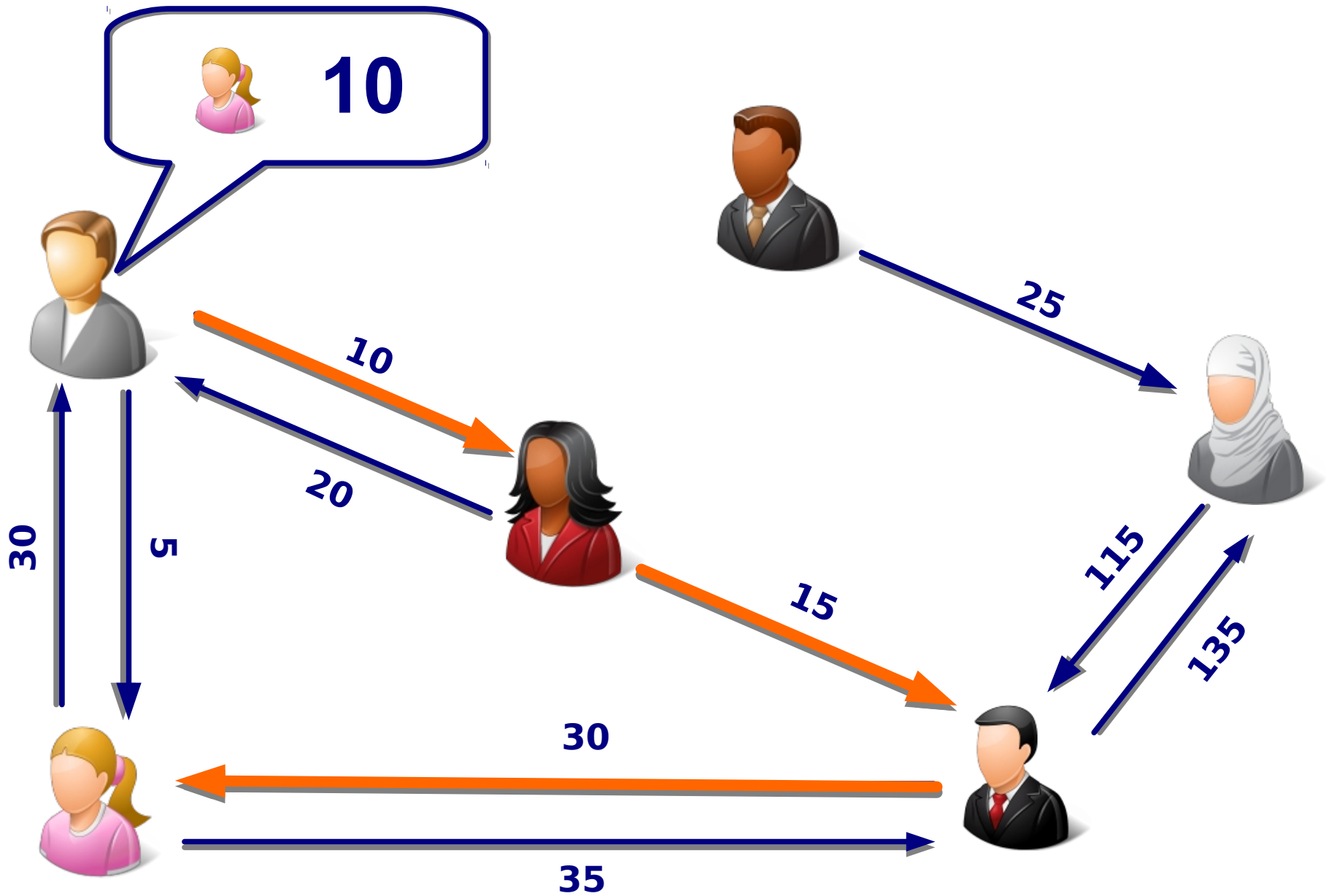

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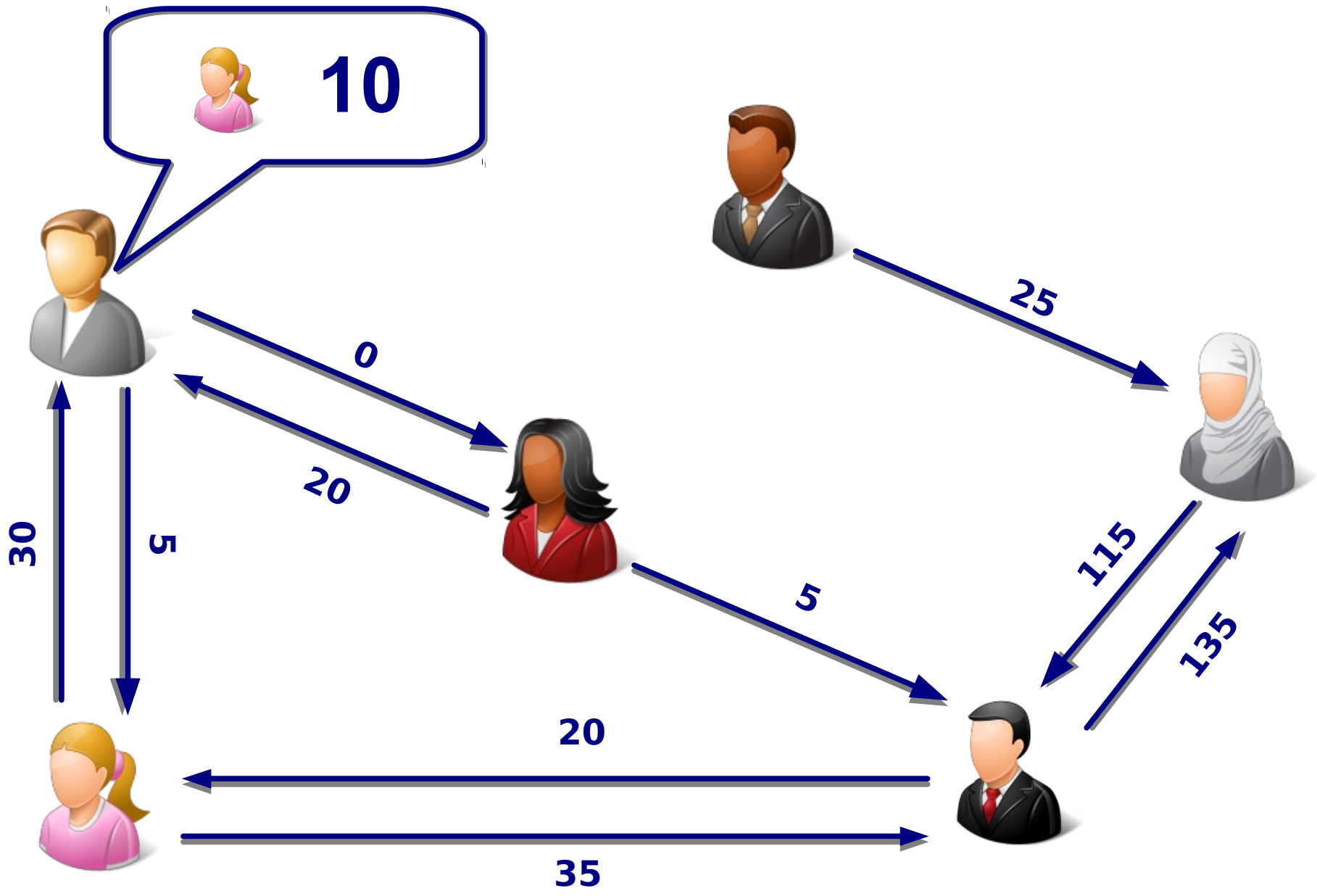

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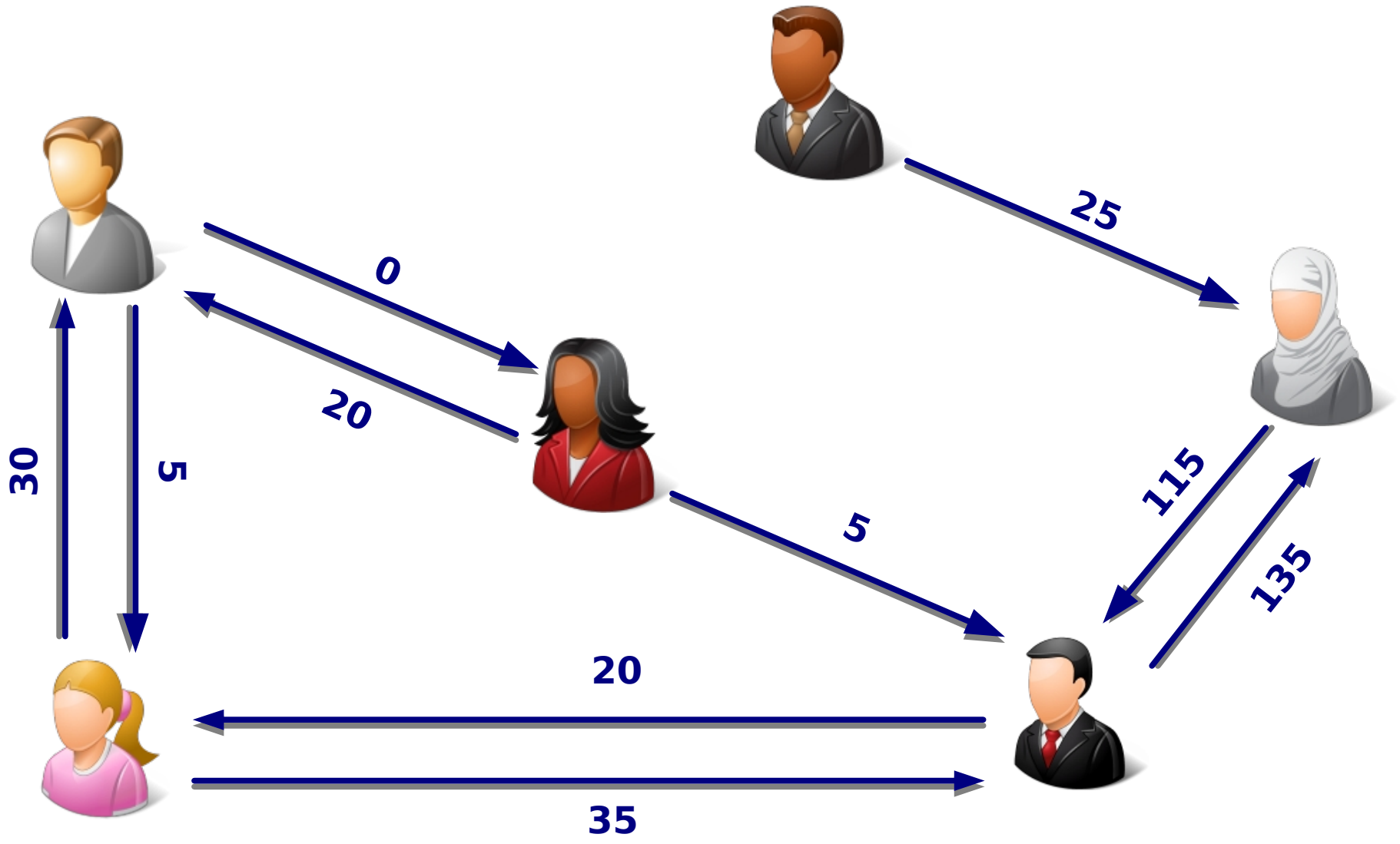

Credit Network: Routing challenge

Routing: determine credit route from a sender to a receiver

- Existing systems use the max-flow approach:
  - **Inefficient** algorithms: $O(V^3)$ or $O(V^2 log(E))$
- Landmark routing [Tsuchiya, SIGCOMM'98]: calculate only a subset of all possible routes

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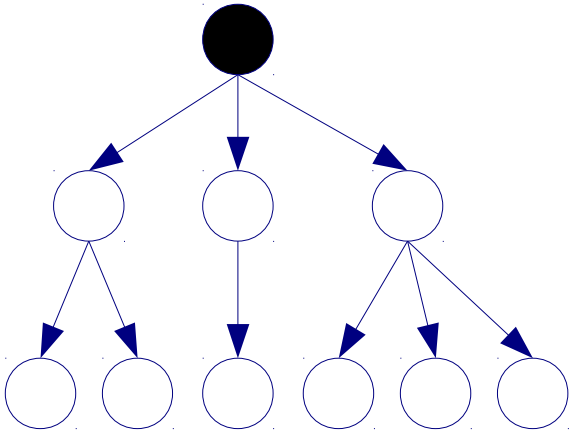

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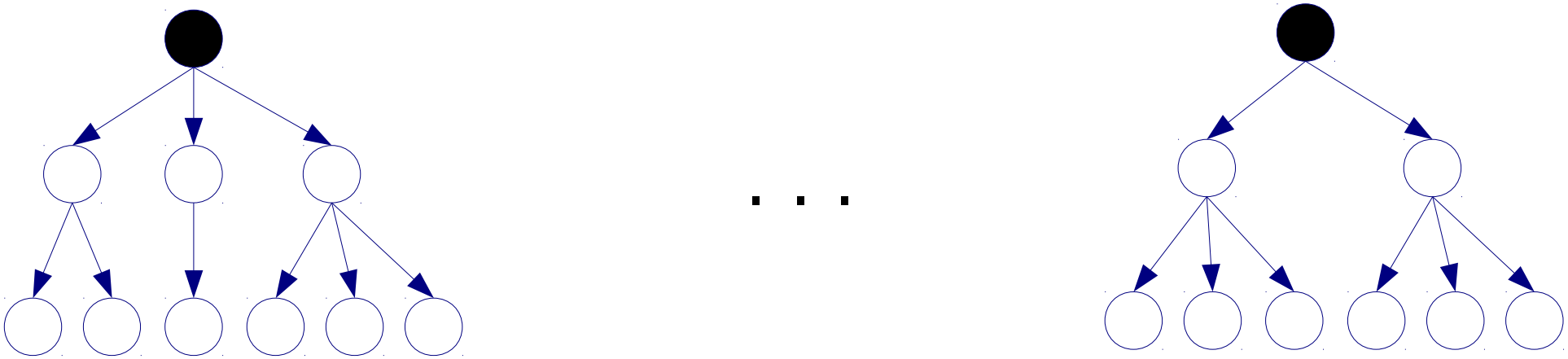

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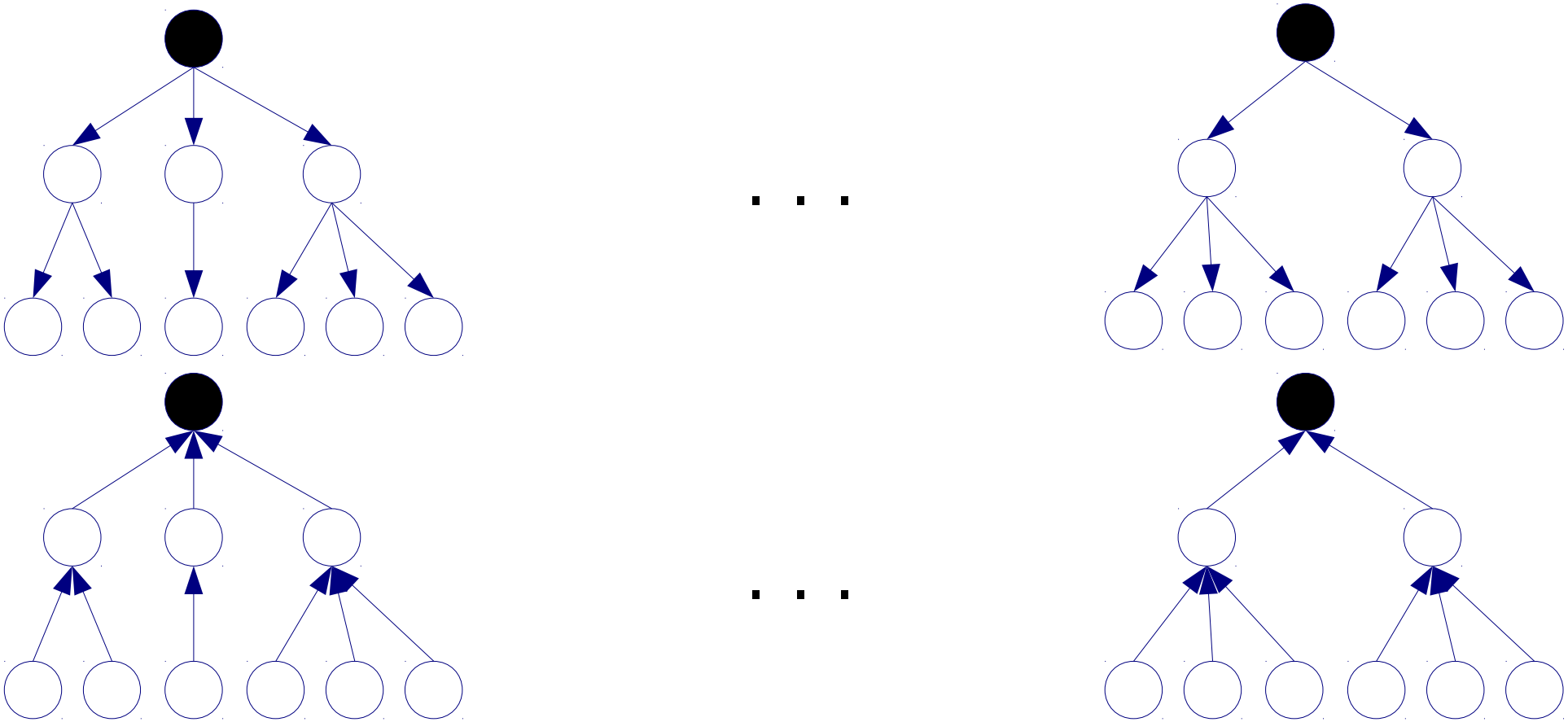

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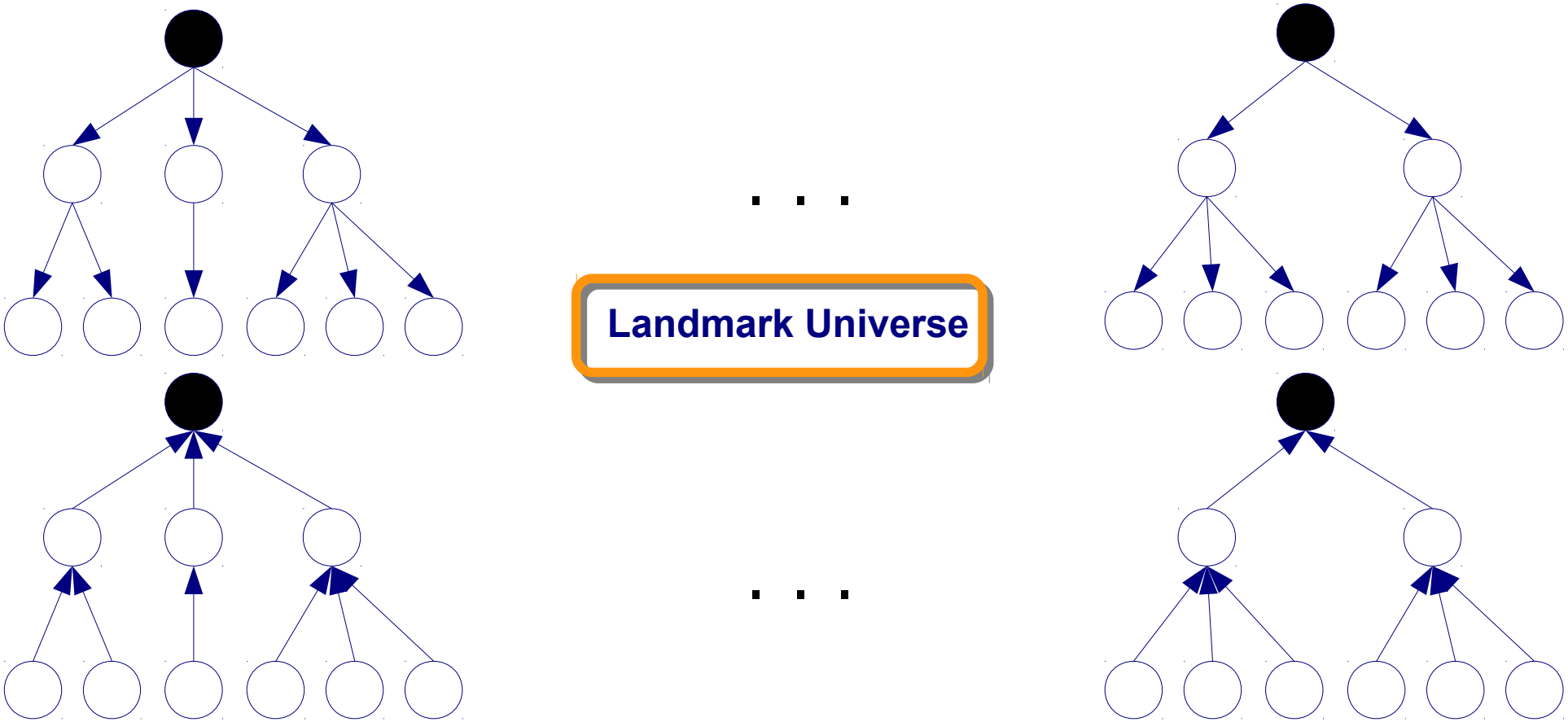

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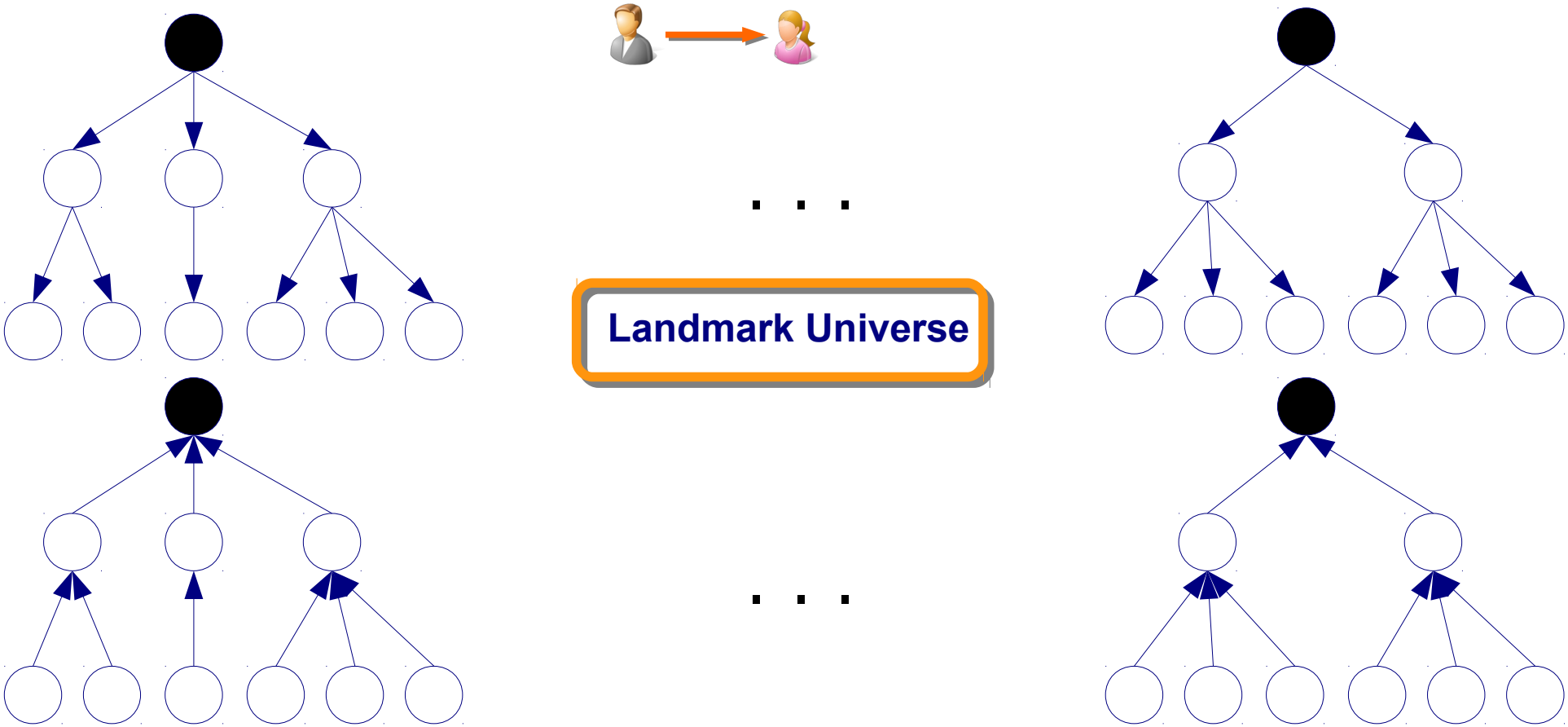

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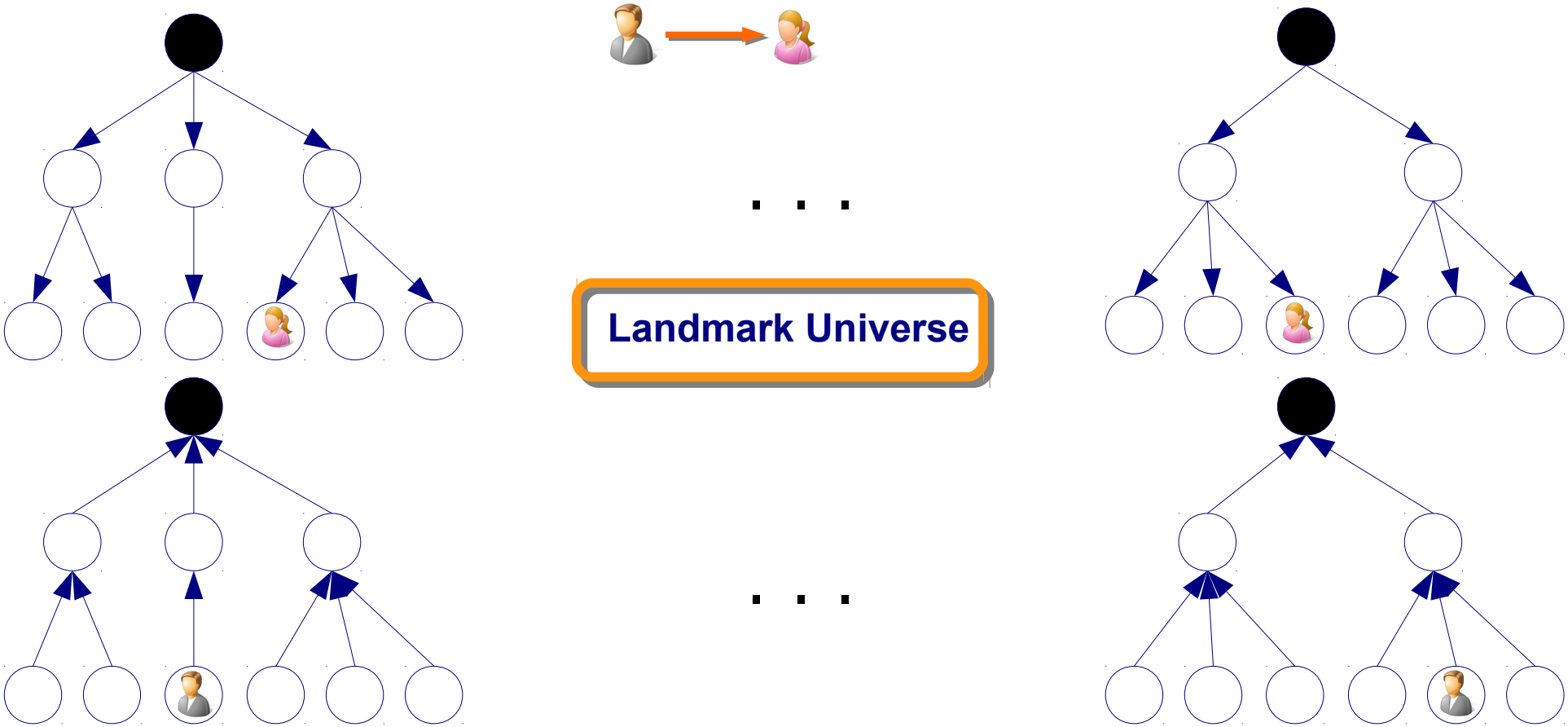

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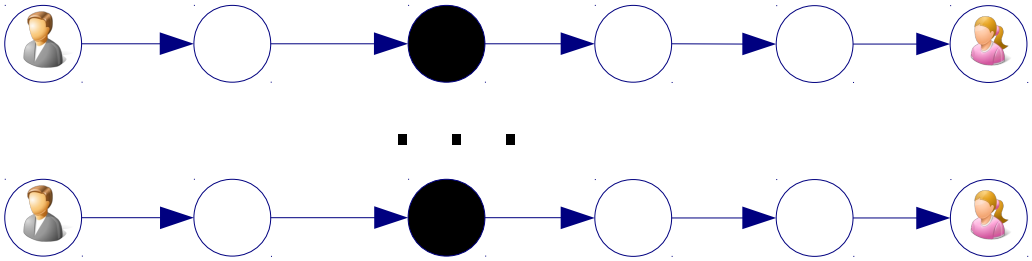
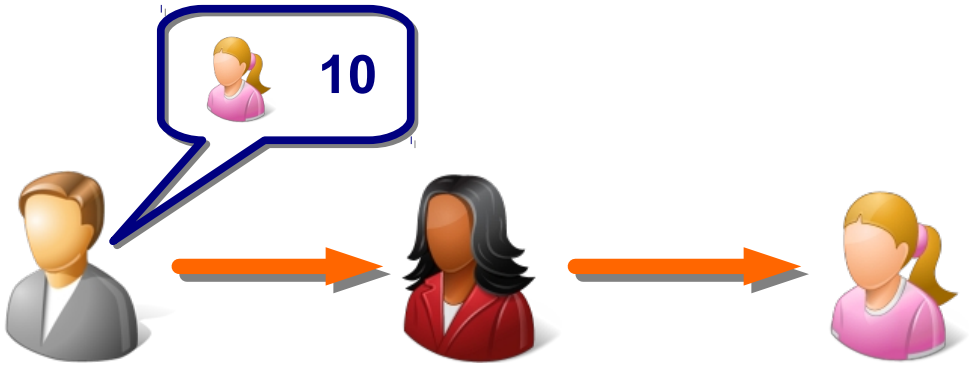


Credit Network: Privacy Definitions

Transaction Value Privacy



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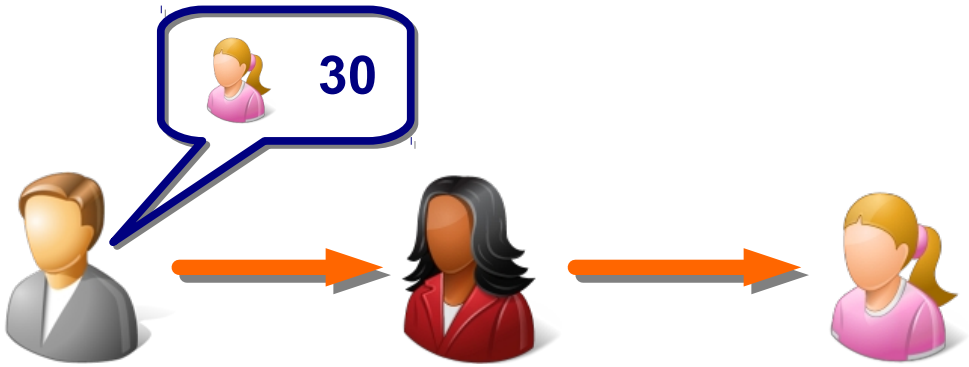

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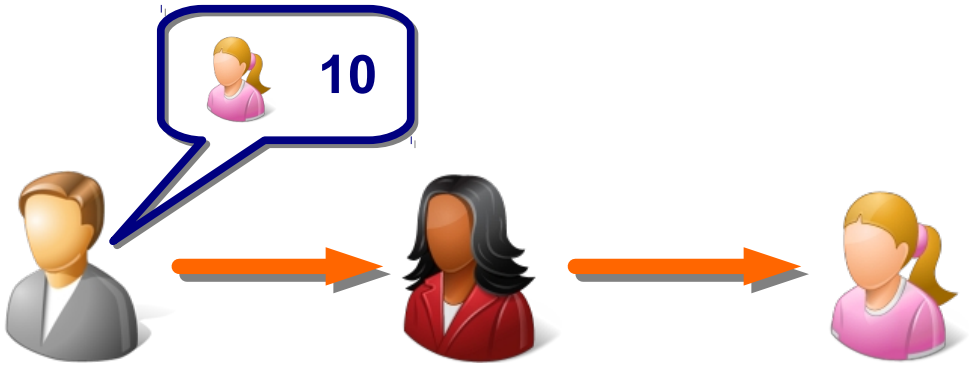

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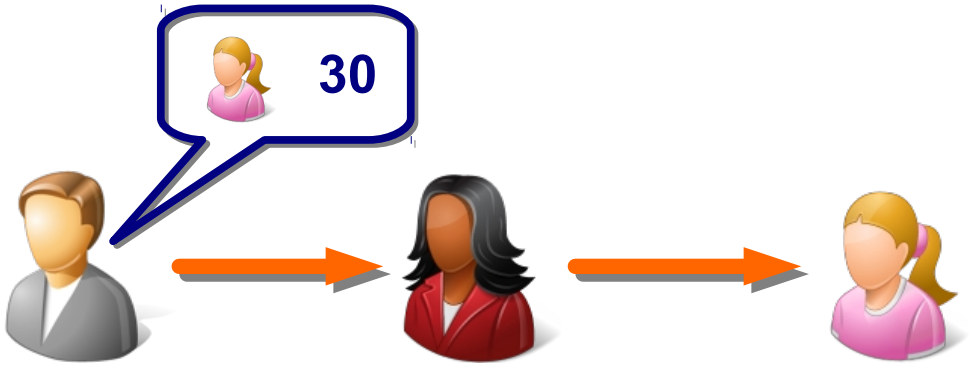
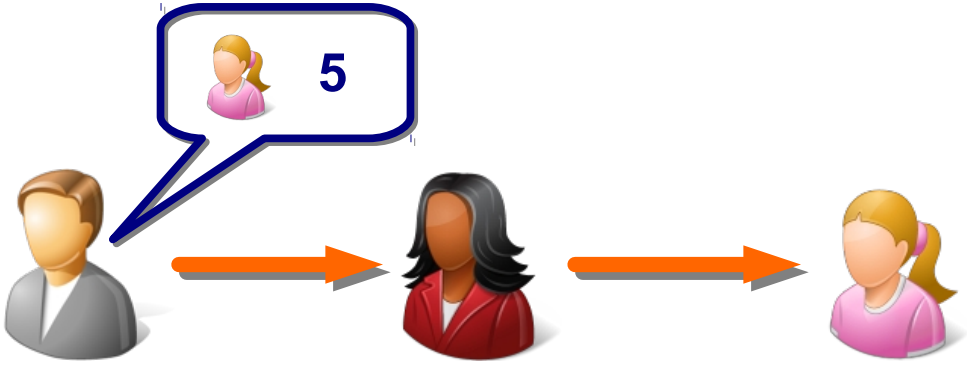


Transaction Receiver Privacy



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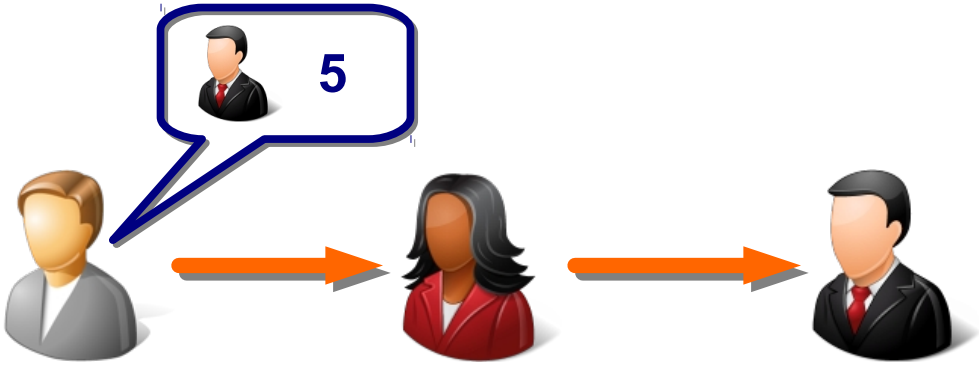

Transaction Value Privacy: Definition (I)

Query phase

payment

change link

Challenger

Attacker

Transaction Value Privacy: Definition (I)

Query phase

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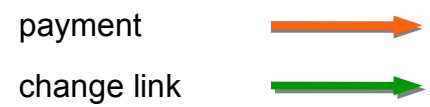

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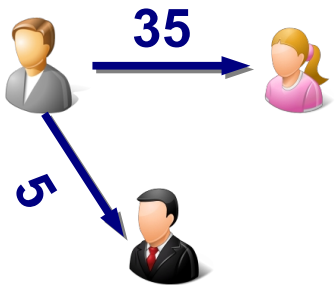

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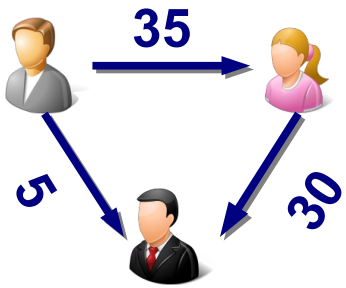

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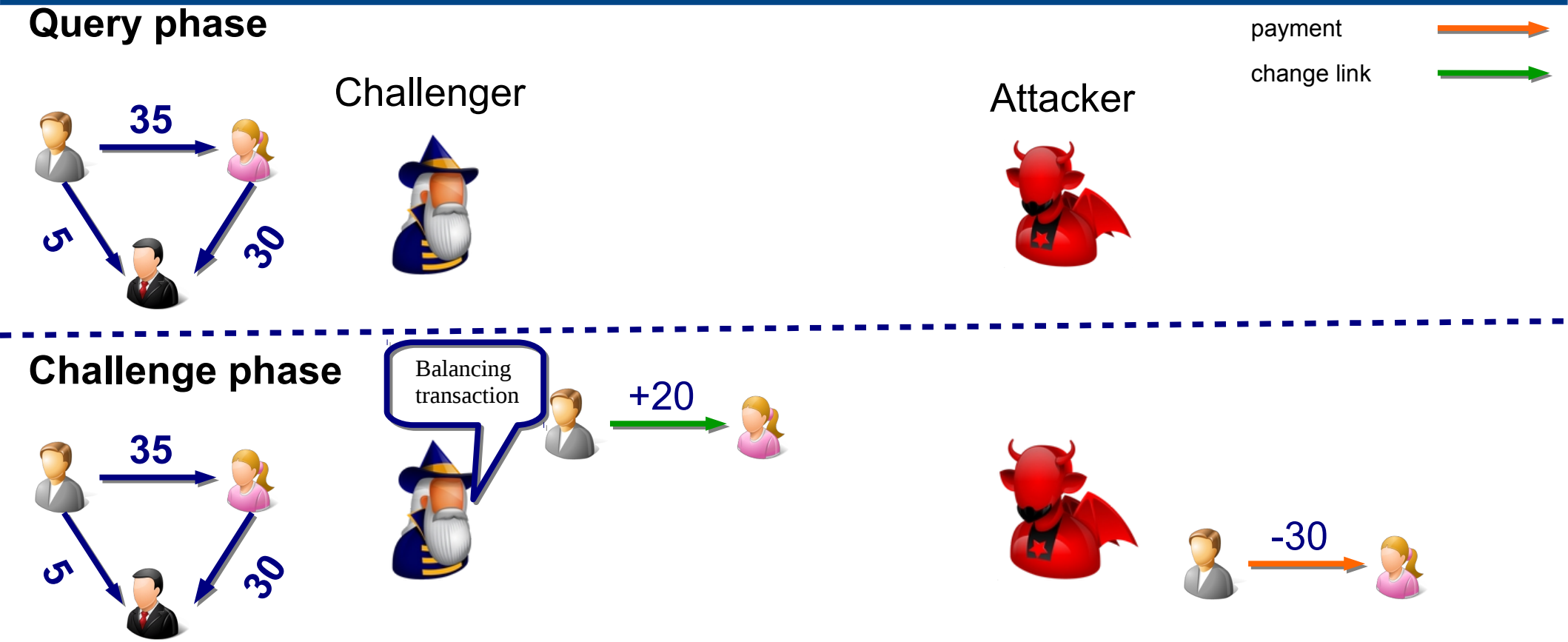

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Query phase

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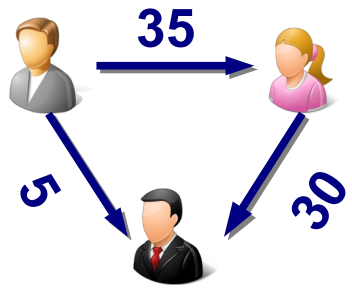

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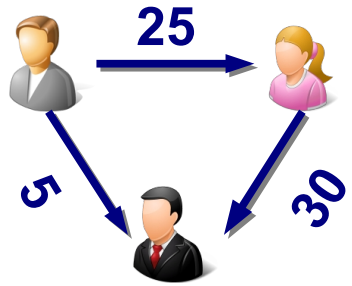
Challenge phase

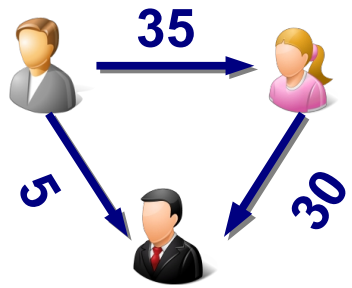


Transaction Value Privacy: Definition (I)

Query phase

payment

change link



Challenger

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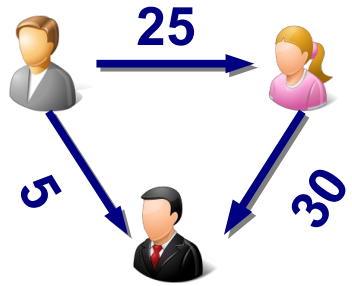
Challenge phase



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payment

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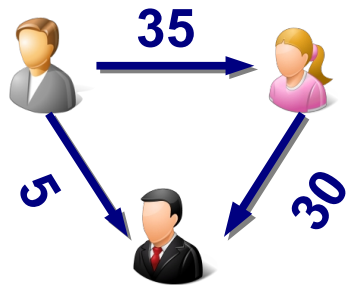

Challenger

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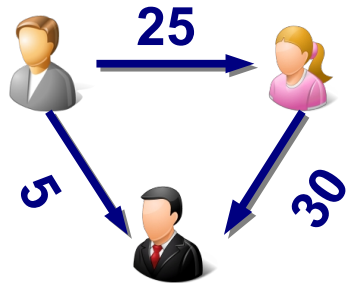
Challenge phase



Query phase

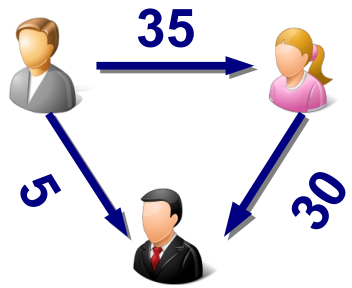
. . .

Transaction Value Privacy: Definition (I)

payment

change link

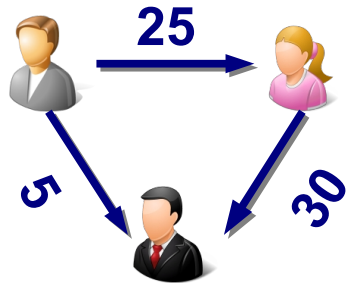
Query phase



Challenger

Attacker

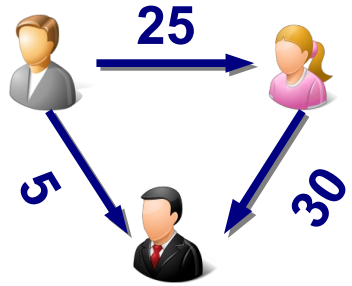
Challenge phase

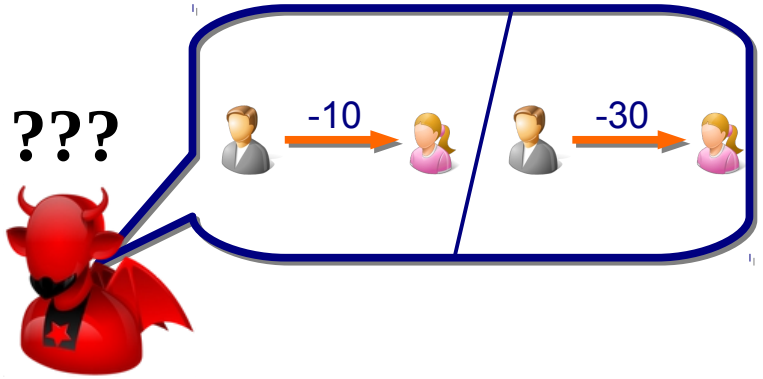


Query phase

. . .

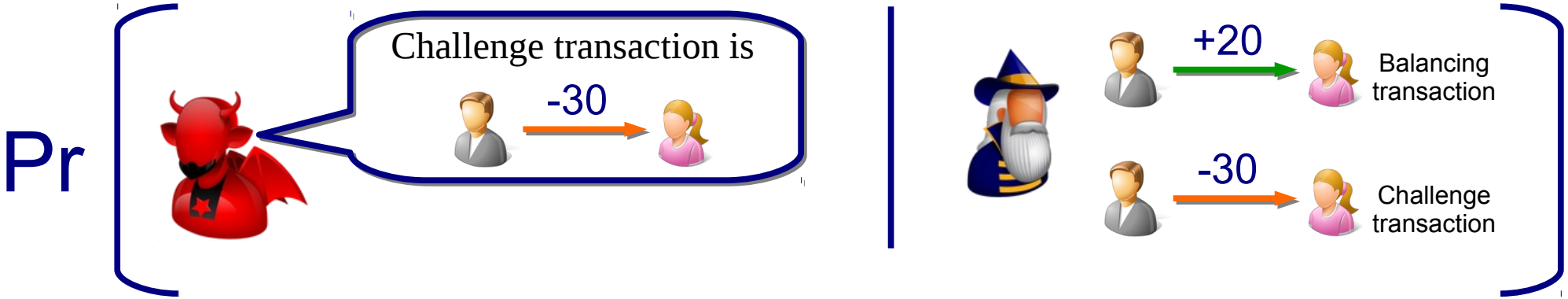
Guess phase





Transaction Value Privacy: Definition (II)

A credit network satisfies transaction value privacy if:



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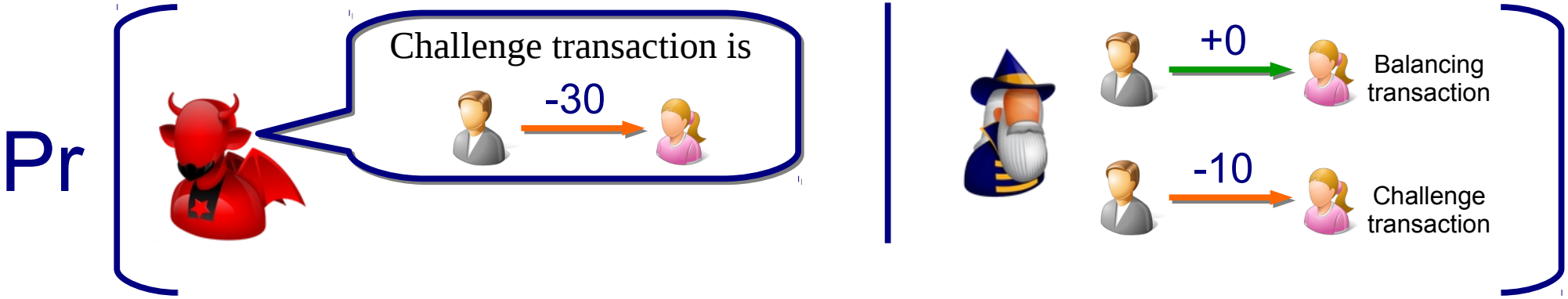
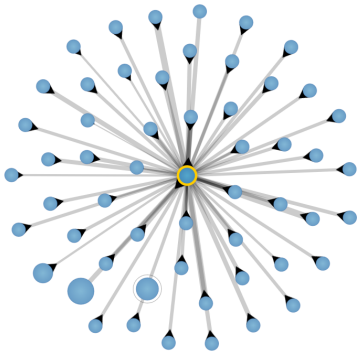


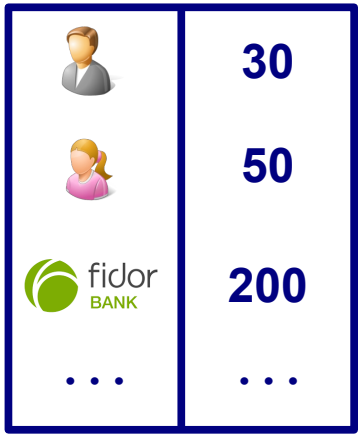
Credit Network: Privacy Challenge

Providing privacy is challenging:

- Hide transaction values → What is the paid amount?
- Hide transaction participants → Who are the sender and the receiver?

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





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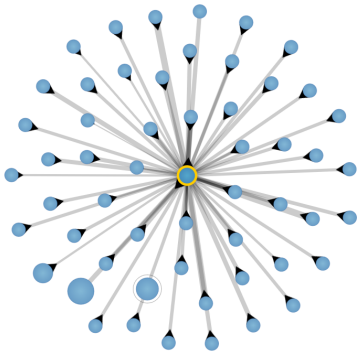
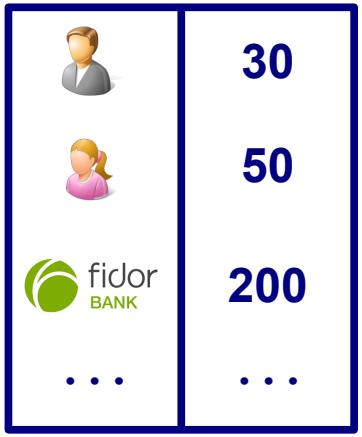
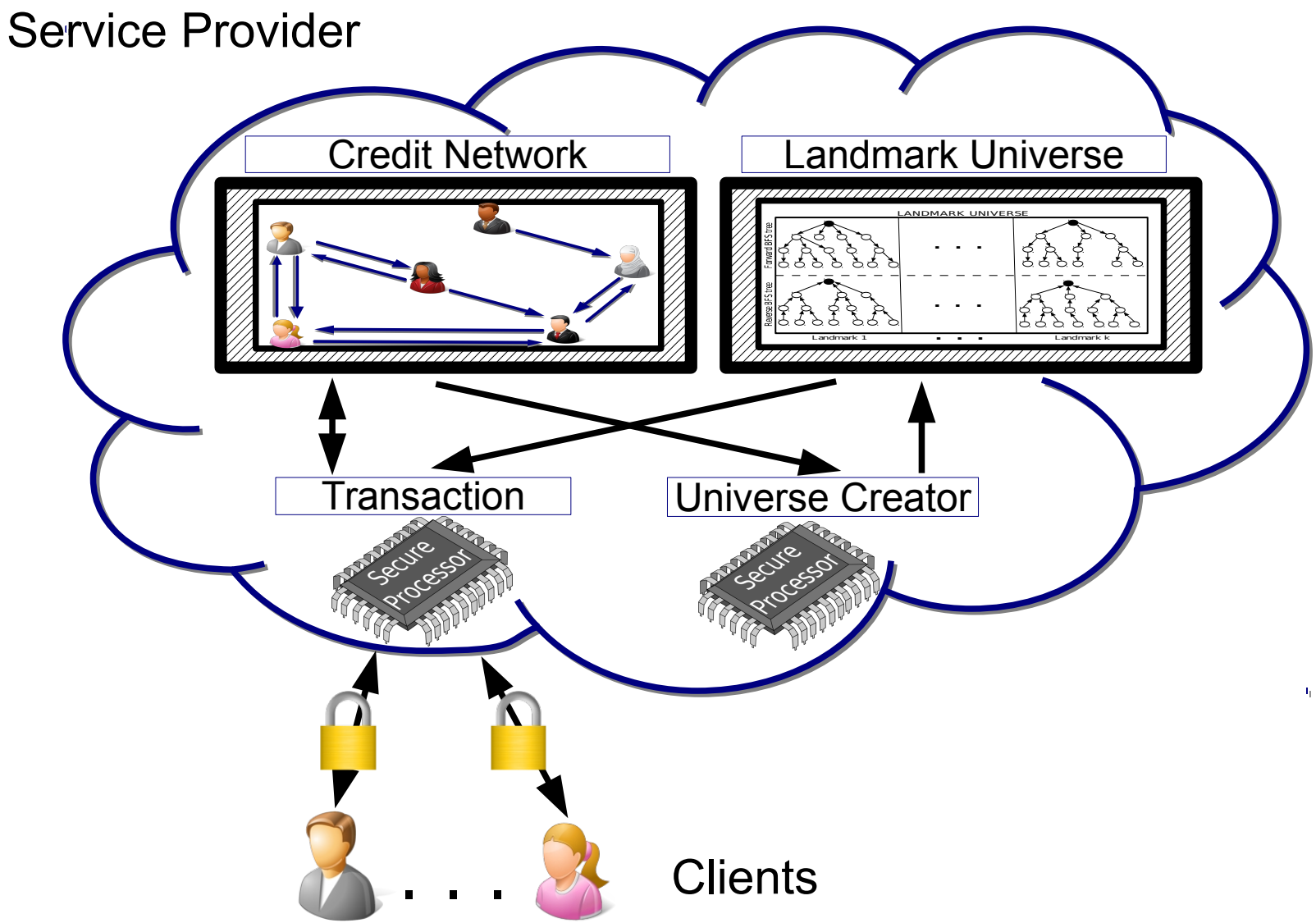
r428G9fSSmD4SYmnDra16B…	rBeToNo4AwHaNbRX2n4BNC…	0.0693402709148/CCK/rB…
rhD759dbJMrzMNL4QbvQe9…	r95pWKA1K55fy7EJWrqJ9b…	300/XRP
r42WJGvV9MJa4t5QcF8Cnx…	rBeToNo4AwHaNbRX2n4BNC…	0.0821058028231/CCK/rB…
rUnr1p7xkuSBxyAqHEopZ5…	r3H4rynDShFMRKWuJcadLY…	1129.916679154465/EUR/…
rw7UfGvzCeZwJxxUEeZHLG…	rBwgTdzzMHnouLk5DJD3xd…	100/XRP
rpVVzfSTUJX9CrKBSS2Z5W…	rDCgaaSBAWYfsxUYhCk1n2…	999.99/XRP



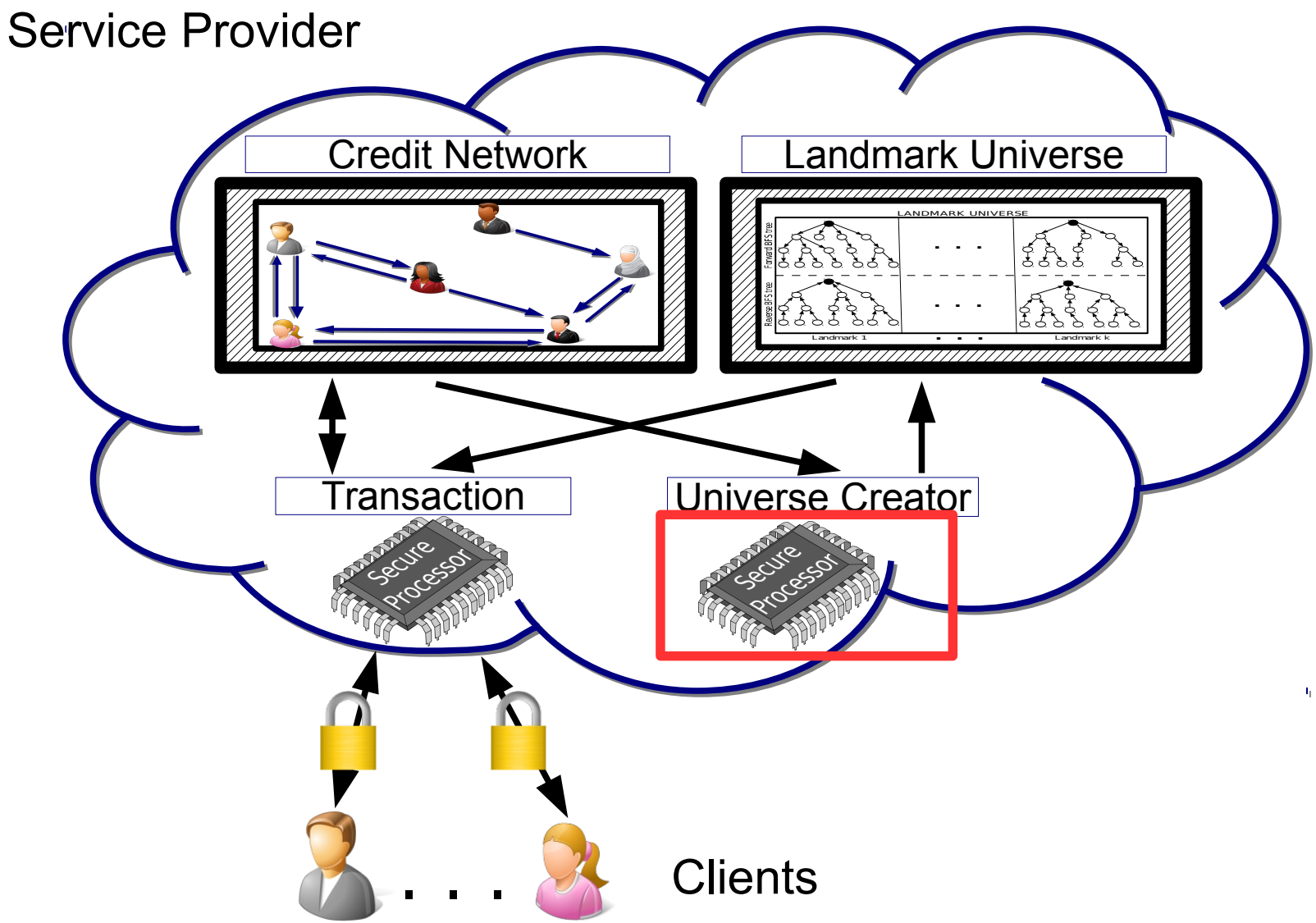


- In our approach, credit network information
  - stored on untrusted server,
  - accessed obliviously,
  - using trusted hardware

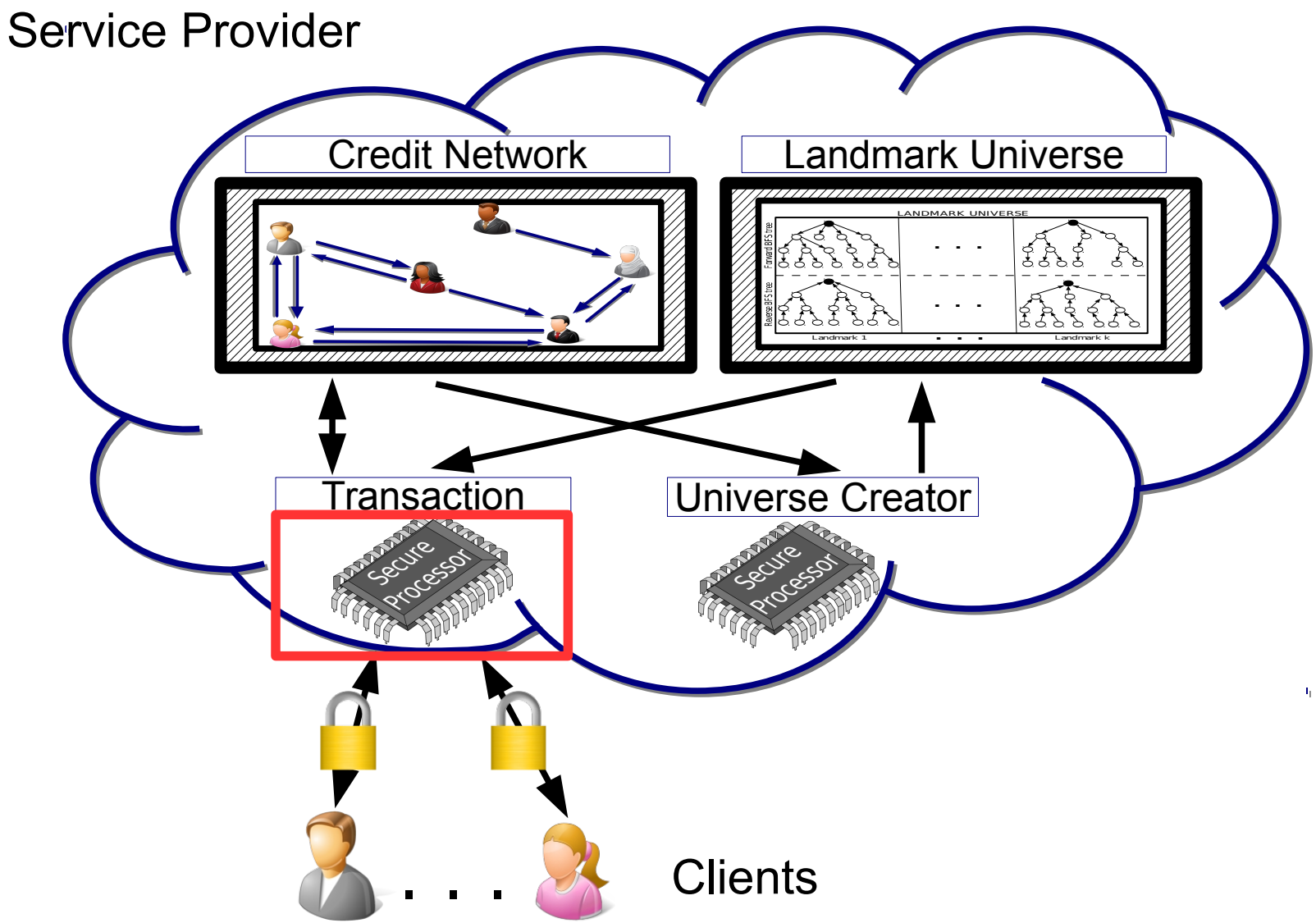
PrivPay: Overview



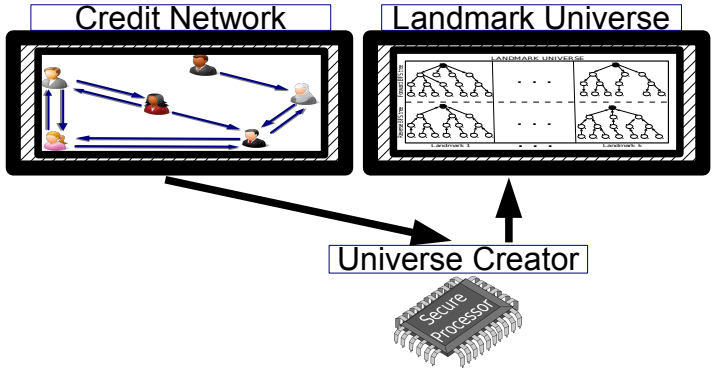
PrivPay: Overview



PrivPay: Overview



PrivPay: Universe Creator



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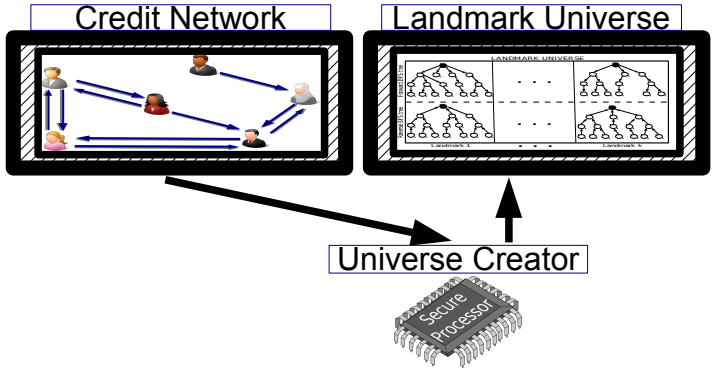

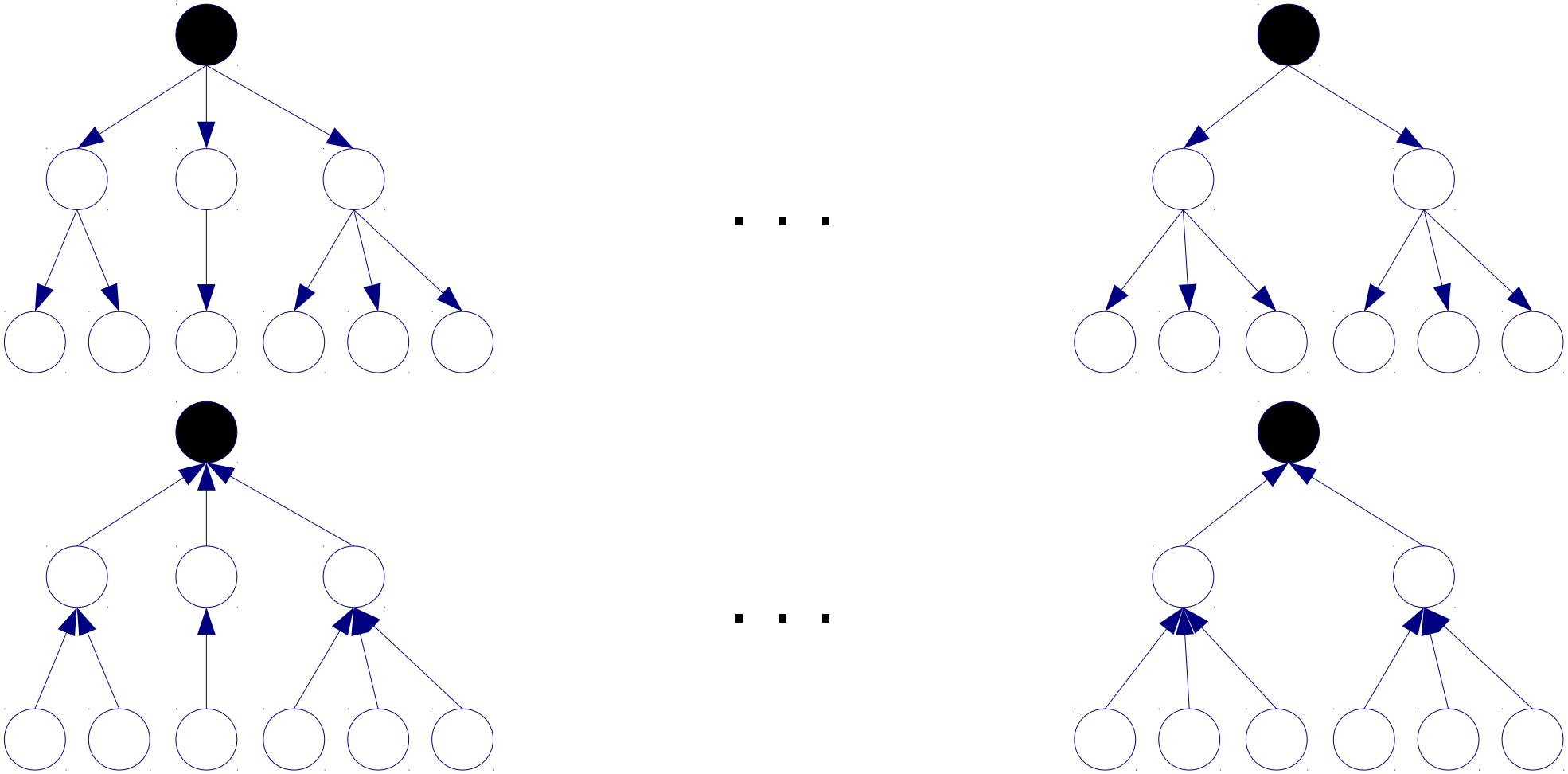

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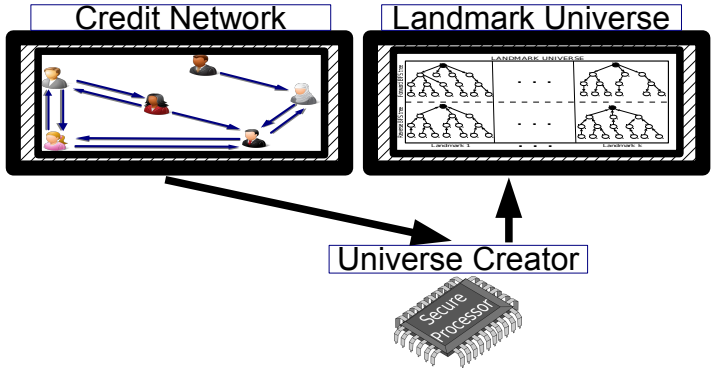
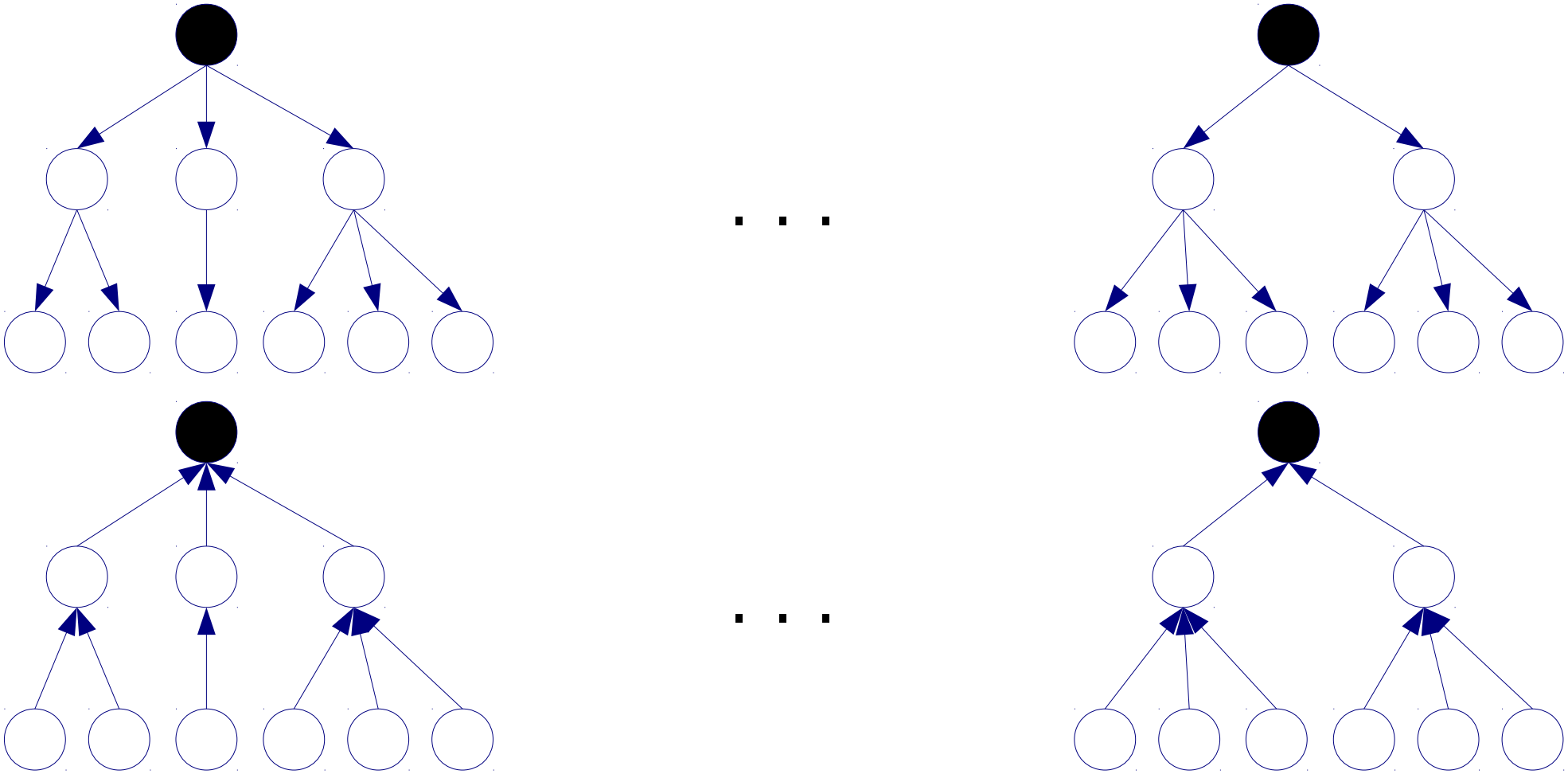


ObliBFS: Standard BFS augmented with ORAM to ensure that "**no information is leaked**"



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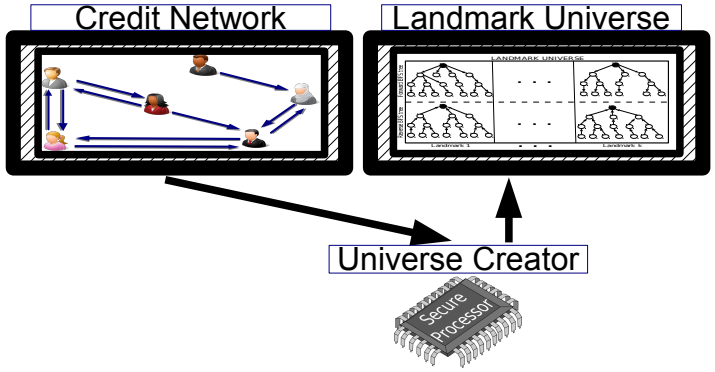

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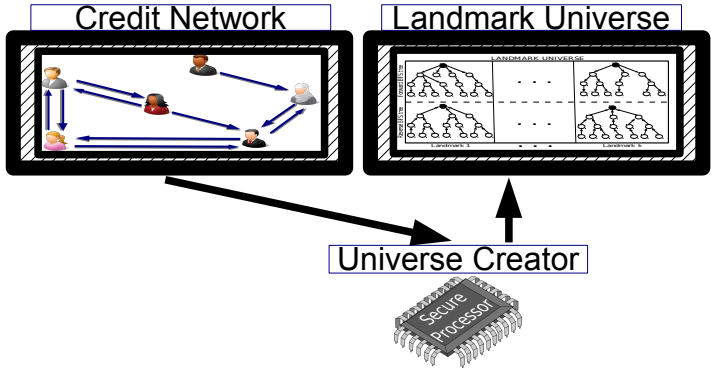

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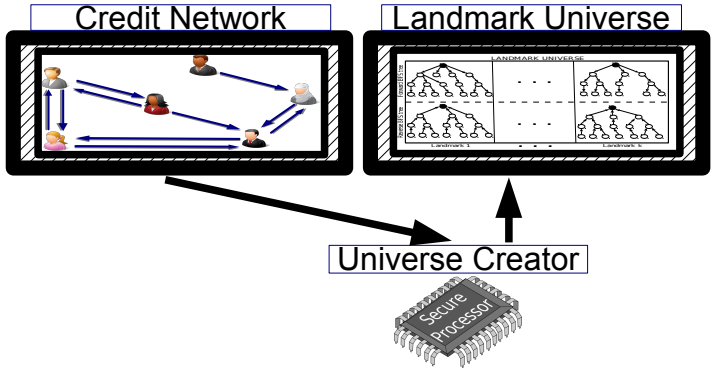

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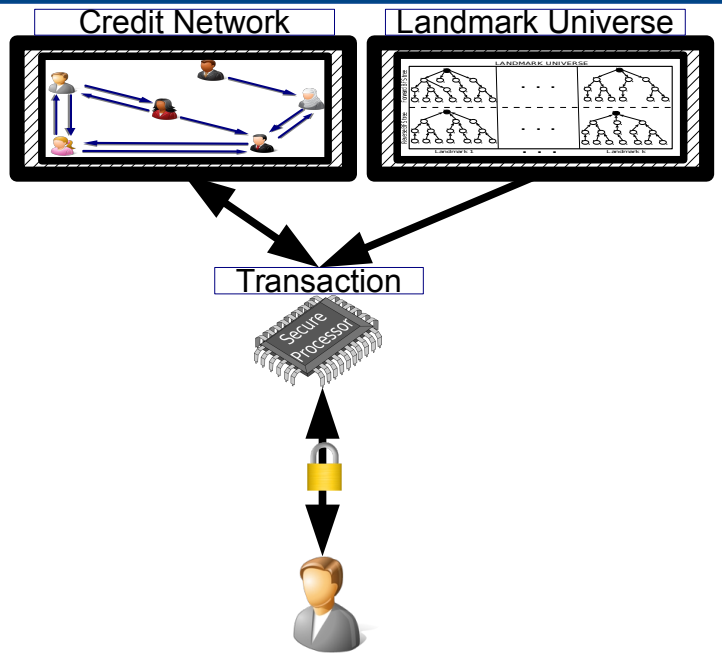

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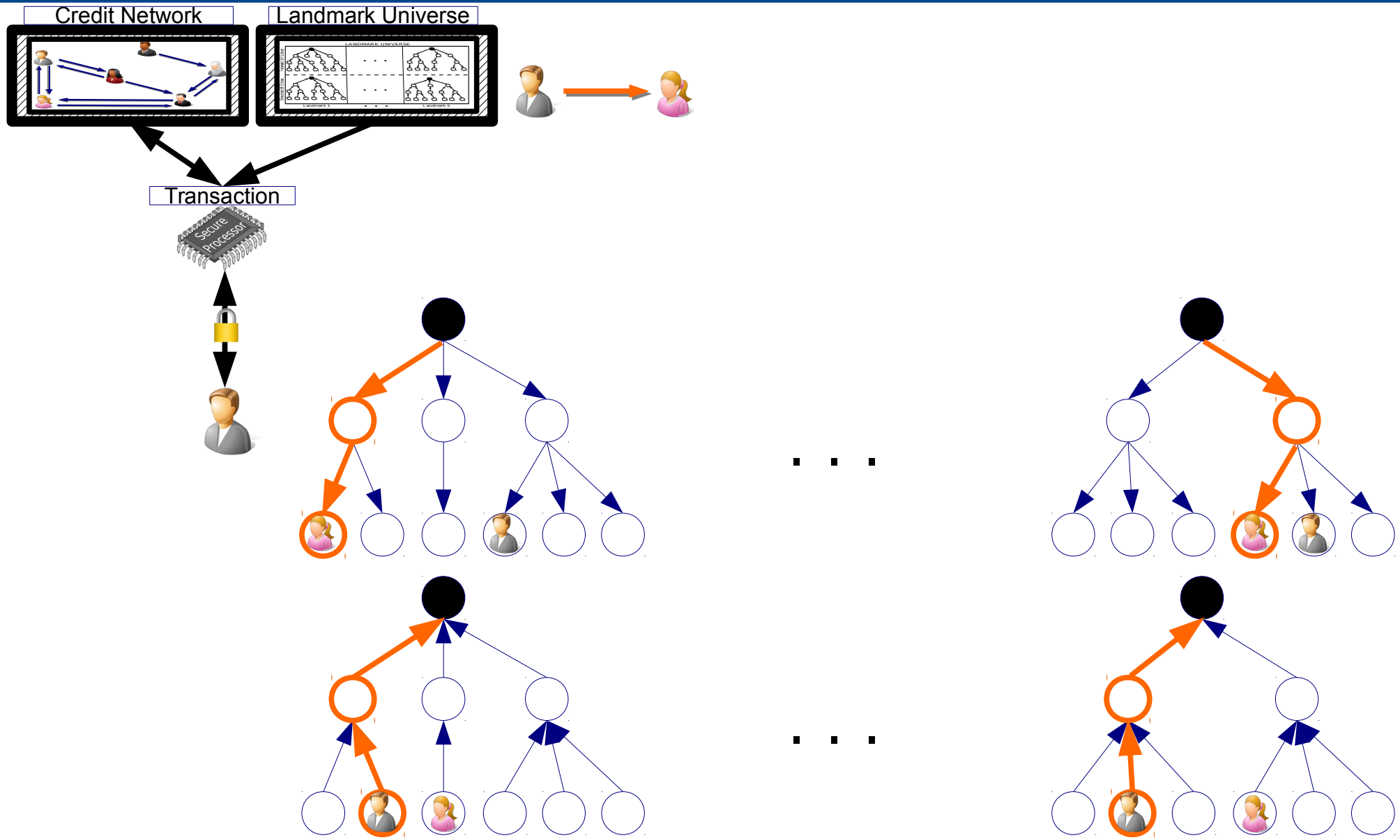

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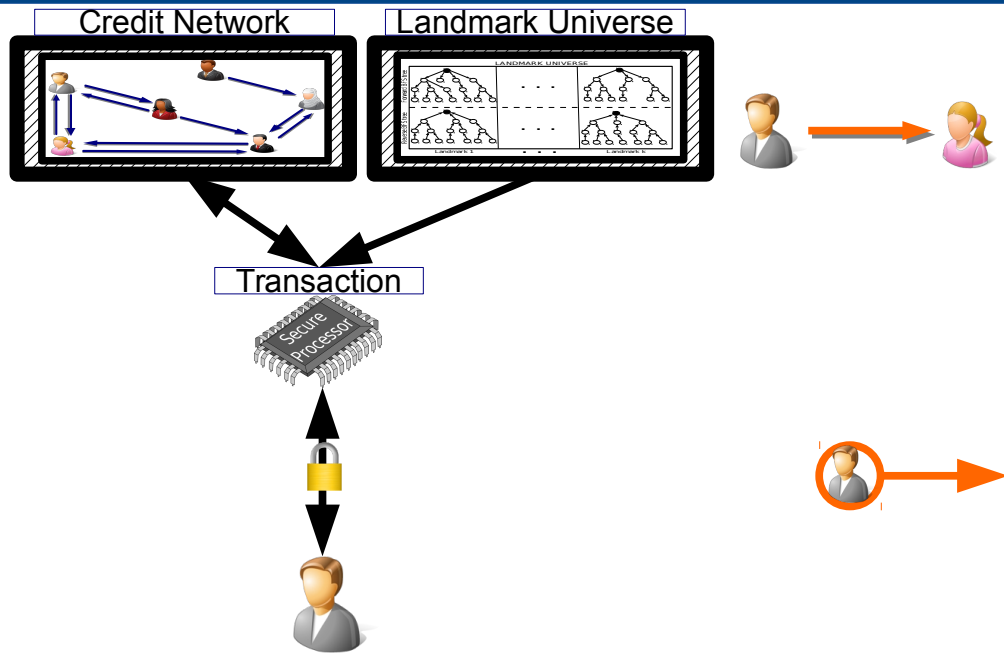

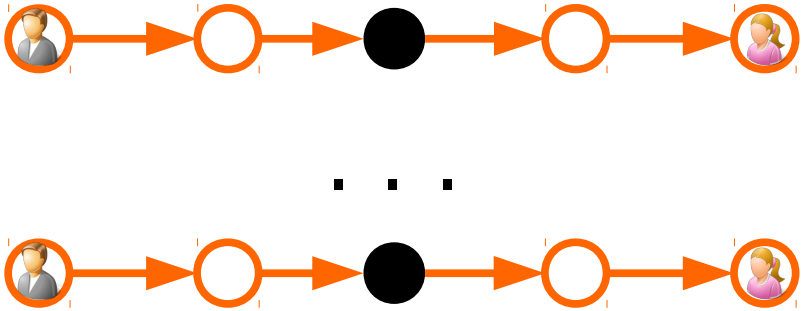

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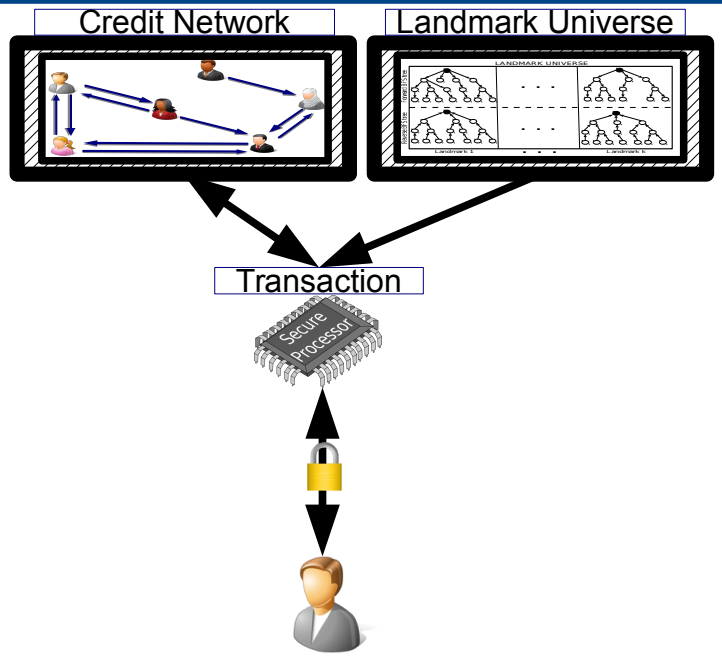

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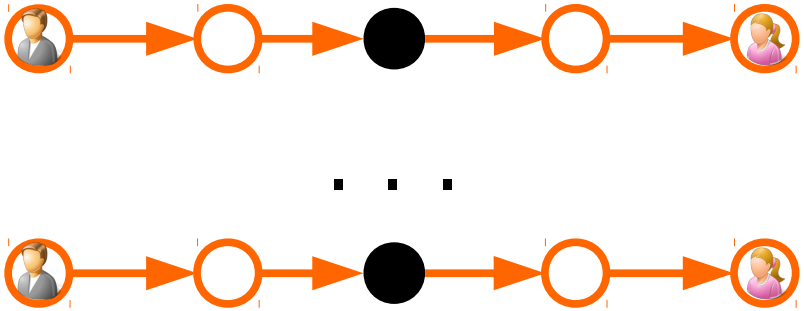

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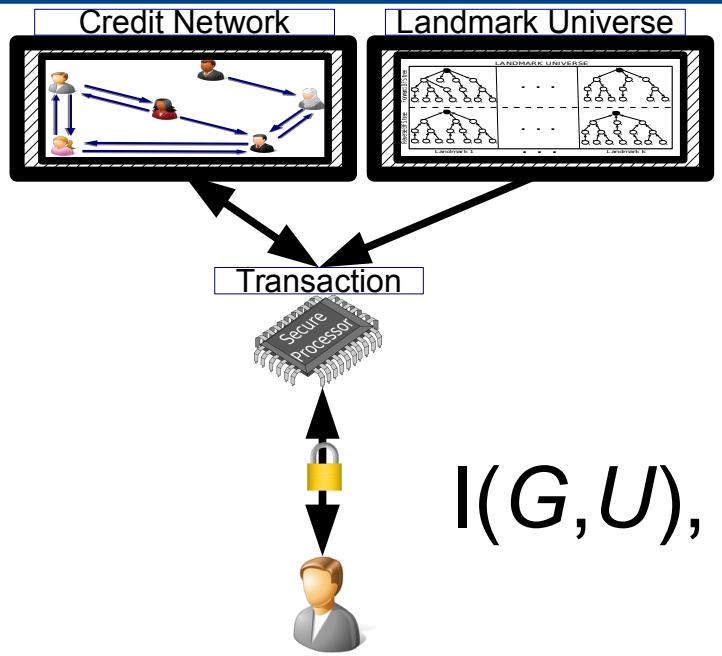

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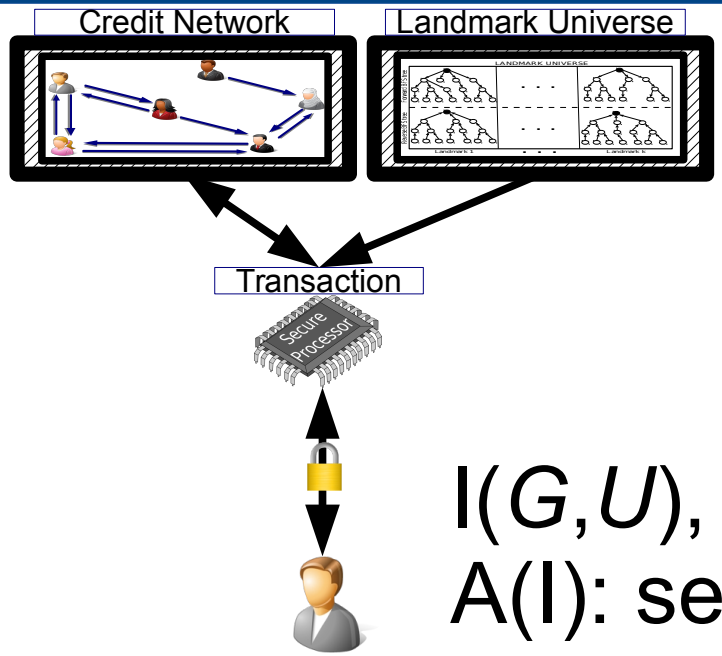

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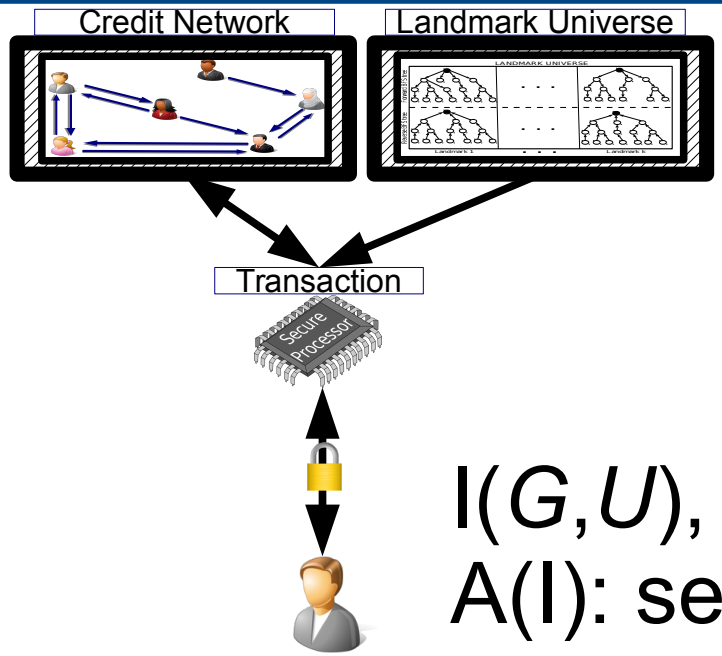

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PrivPay: Evaluation

- We have implemented PrivPay as a multithreaded C++ library
- We use Ripple transactions over a period of four months (Oct'13 – Jan'14)
  - network: 14,317 nodes and 14,176 links

	Non-Private setting [1]	PrivPay
Payment (ms)	0.078	1510
Change link (ms)	0.005	95
Oblivious BFS (ms) [Background process]	50	22000
Coverage	97%	95%

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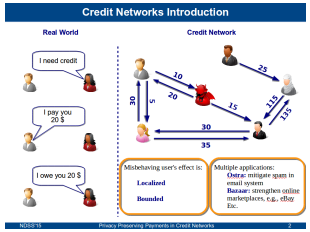
Take Home Message

- Credit networks have **interesting properties** and are used in **multiple application scenarios**



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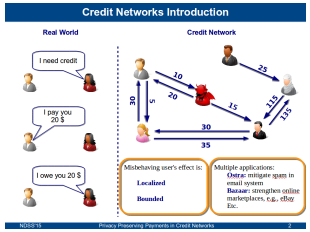

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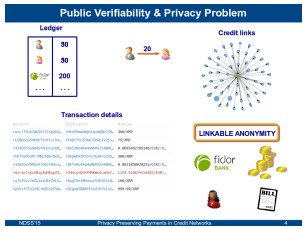

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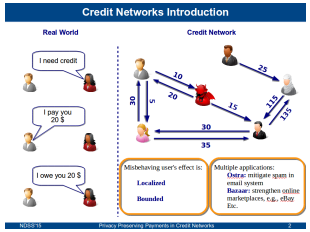
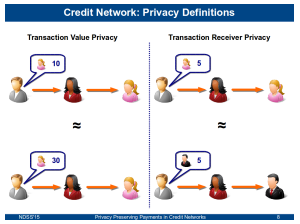


- **Define privacy properties** for credit networks



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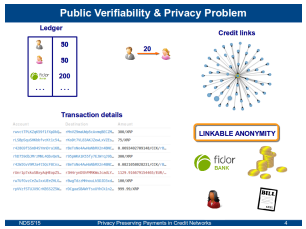

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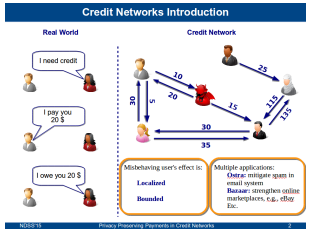

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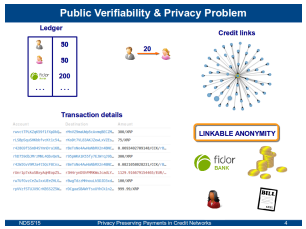

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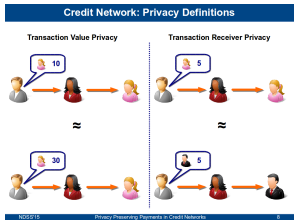

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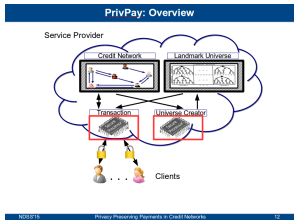

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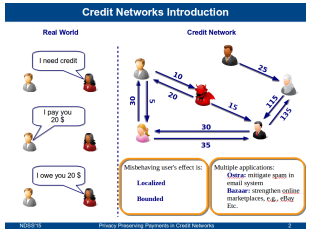

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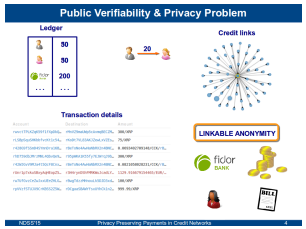

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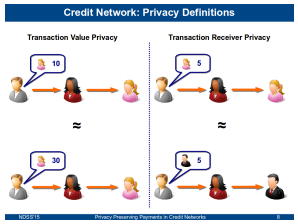

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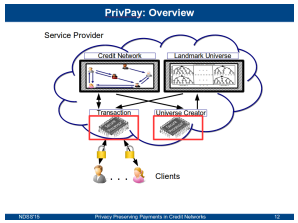
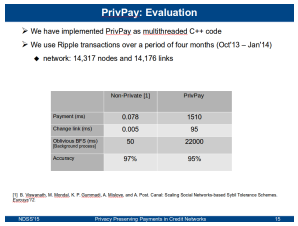


- PrivPay is **feasible to deploy** in practice



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