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Decentralized Service Registry and Discovery in P2P Networks Using Blockchain Technology

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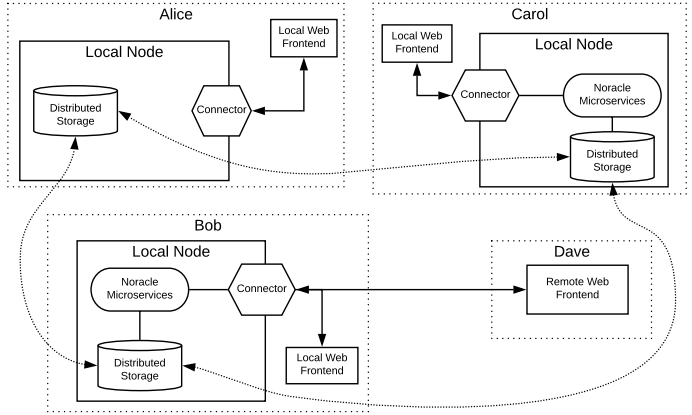
Motivation

- Communities of Practice (CoPs)[Wenger98] benefit from decentralized infrastructure
  - shared burden of hosting
  - natural scalability with community growth
  - self-governance and control over own data
- Previous work: Microservice Infrastructure for distributed CoPs[de Lange et al.18]
  - Self-hosted infrastructure for European Voluntary Service (EVS) training courses
  - Various evaluations with several communities over the course of a two year usage span



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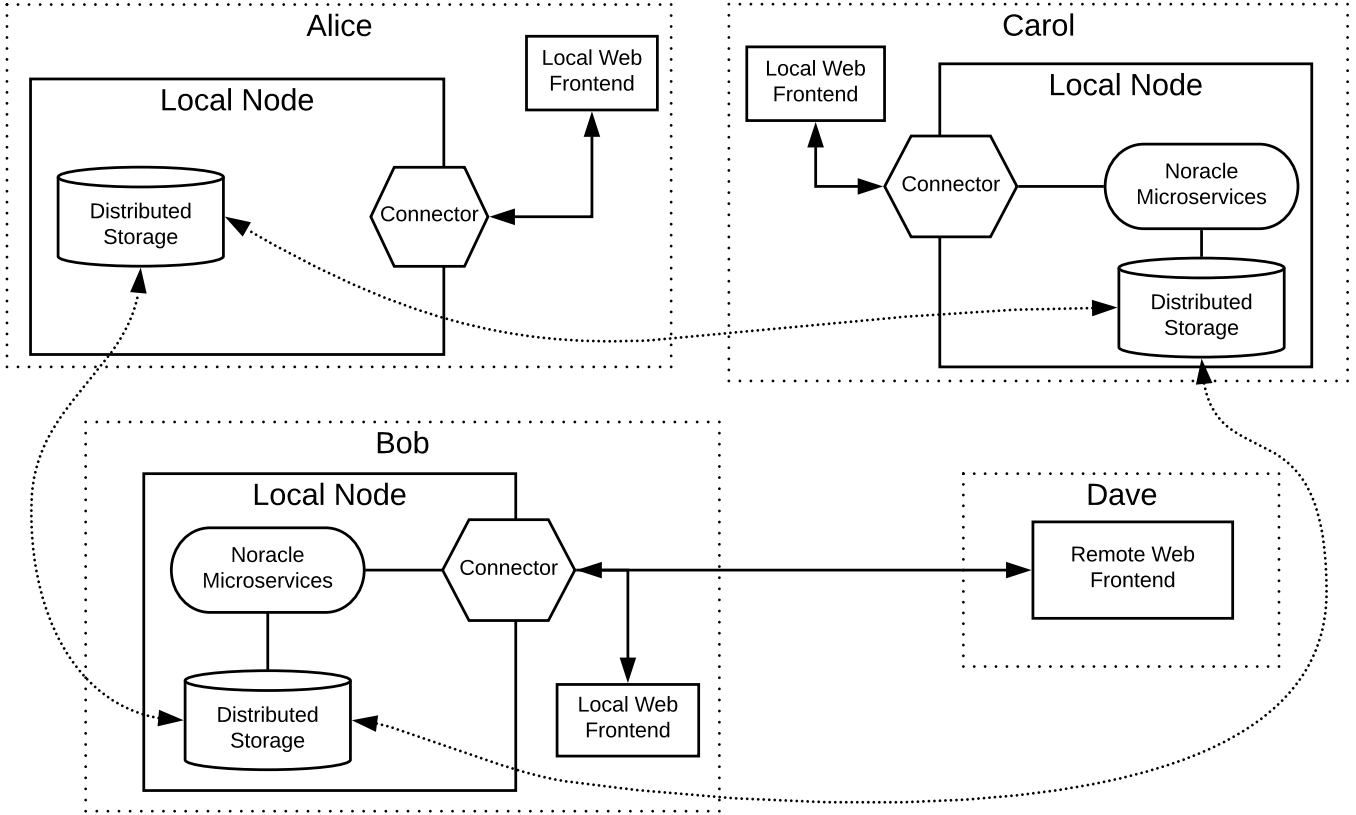
An Idealized Scenario...



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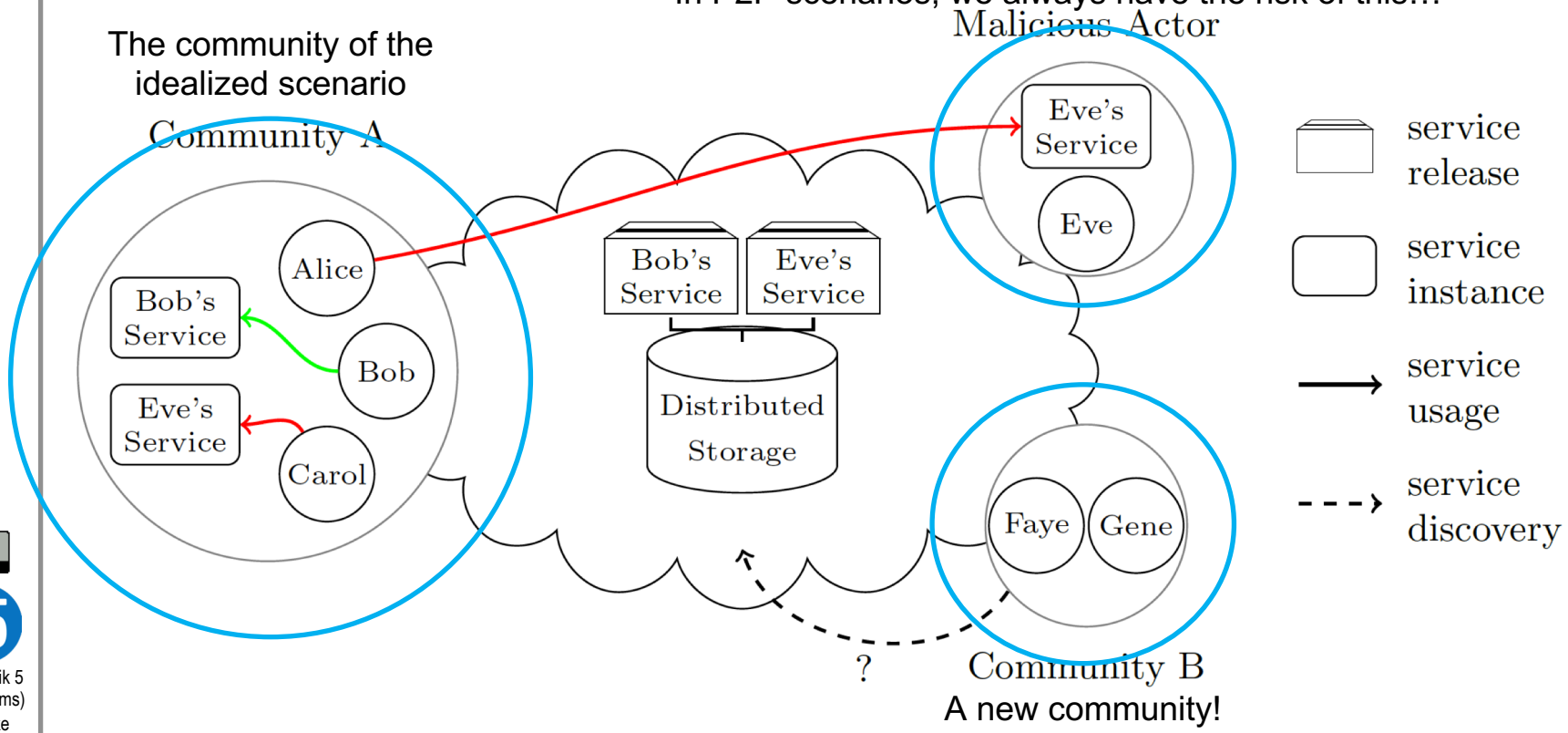
A More Realistic Scenario…

In P2P scenarios, we always have the risk of this…



Research Questions

1. How can we design a decentralized service registry that facilitates trust between service authors, users, and the published services?

2. How can we help users discover relevant services both within and beyond community boundaries?

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Thus We Need A Decentralized Service Registry That...

- Gives authors control over service update process and the ability to establish a reputation
- Lets users verify origin and history of service releases
- Enables service discovery
    1. programmatically (via an API)
    2. for humans (via Web-based node front-end)

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So Why Not Use The DHT?

- DHT lacks wildcard queriability → no search
- Sybil attacks:
  - create many “fake” identities in a network
  - influence majority decisions
- Byzantine fault:
  - nodes can exhibit arbitrary (mis-)behavior
  - misbehaving nodes can cooperate

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Blockchain

- Decentralized data structure that is robust against Sybils and Byzantine faults (if majority of computing power “behaves”)
- Proof-of-Work consensus system
  - writing requires solving a cryptographic puzzle
  - “voting power” corresponds to computing power
- Ethereum: general purpose blockchain supporting smart contracts
  - scripts stored on the blockchain
  - their functions are invoked by special transactions
  - allow us to encode rules, such as ownership of entries

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Two Smart Contracts: Decentralized Identity Management

- Secure identities are the foundation for trust
- Usernames can be registered on a first come, first served basis
- Stored on blockchain, smart contracts enforce ownership:
  - updating the entry requires private key
- Users have control over their data and can reveal as much as they like

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Two Smart Contracts: Service Registry

- Users can register service names
- The owner of a service name can then publish releases
- Releases include metadata for service discovery
  - for end-users: title, description, project URL
  - for services and developers: default class, entrypoint URL
- Running service instances are announced to the registry

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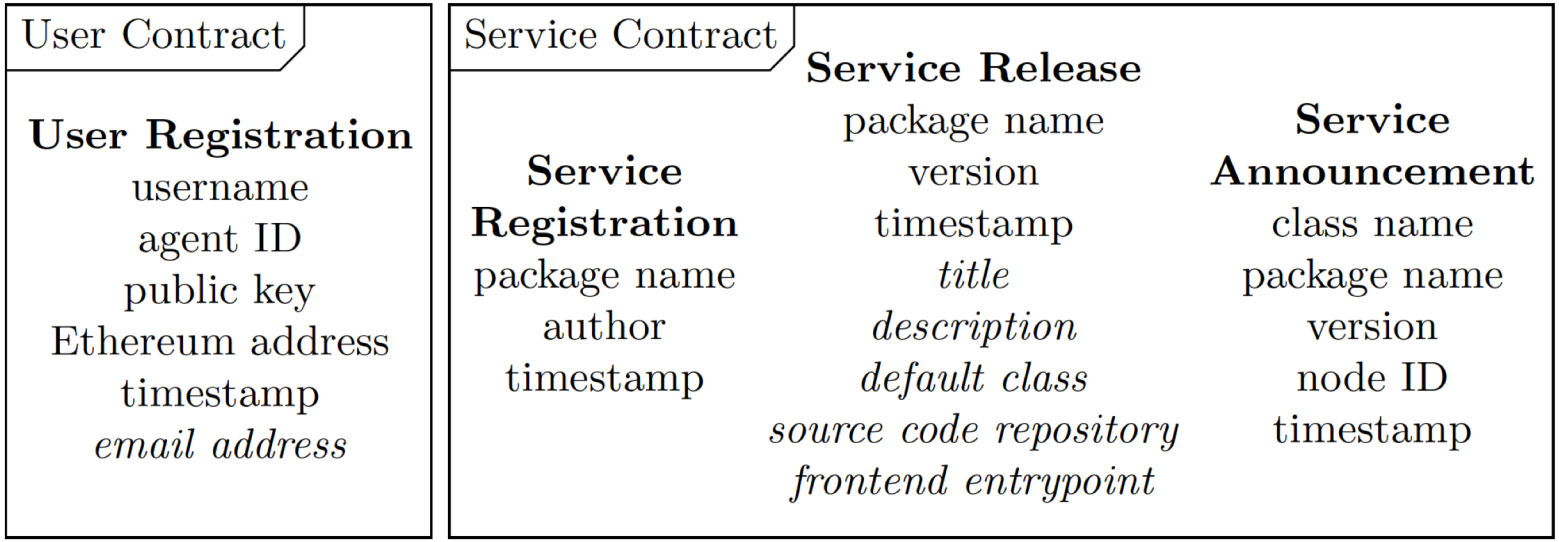
Smart Contracts



(entries in italics are stored as references to DHT)

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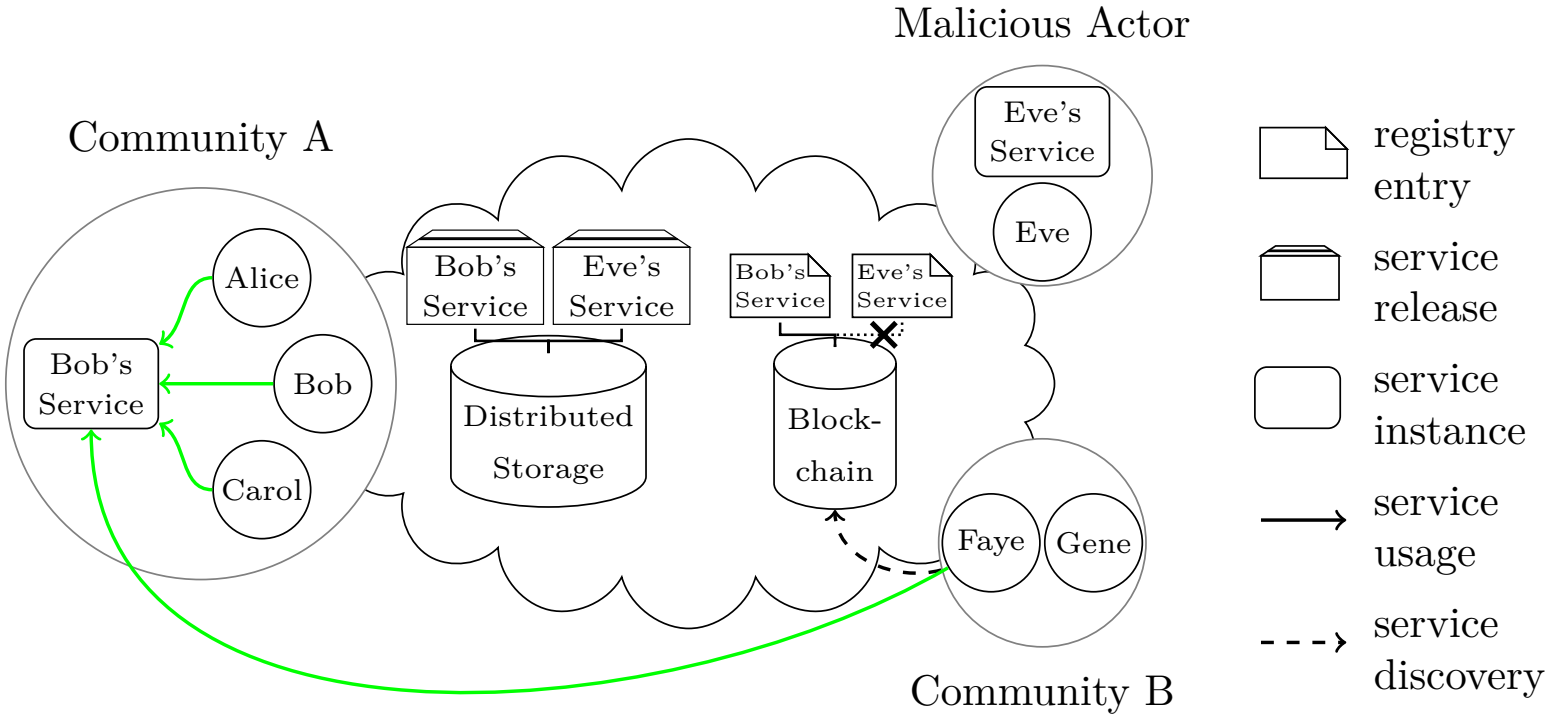
Same Use Case With BC-Service Registry



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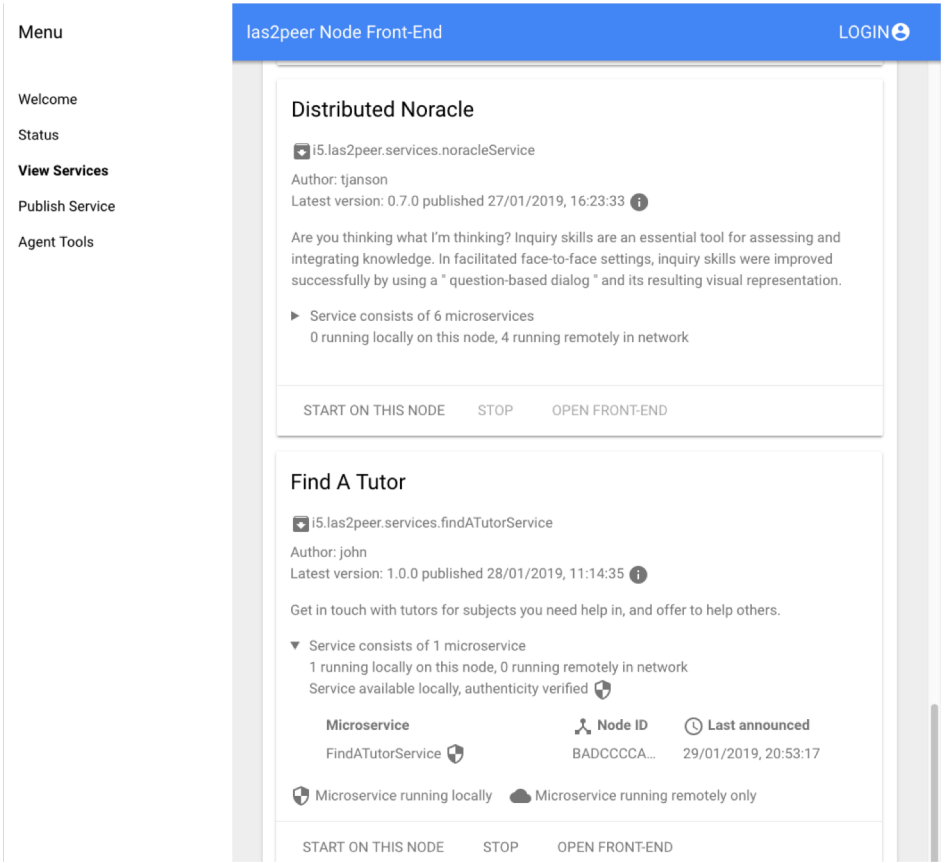
Service Explorer



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Implementation: Components & Technology

- Service registry (*Solidity – Smart contract scripting language*)
  - stores and retrieves data on/from private blockchain
- Registry gateway (*Java*)
  - middleware layer, interfacing with DHT storage and Ethereum client
  - stores data blobs in DHT, references them on blockchain
  - provides JSON-based API
- Service explorer (*LIT Element Web Component*)
  - added to existing node Web front-end

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User Evaluation

- Do users understand and appreciate the service registry concept?
- What are their motivations, how do they benefit, and what improvements do they suggest?
- Sessions
  - 11 participants using a network of 5 permanent nodes
  - hands-on tasks using the Service Explorer: explore & discover, register, start & publish a service

Decentralized Service Registry

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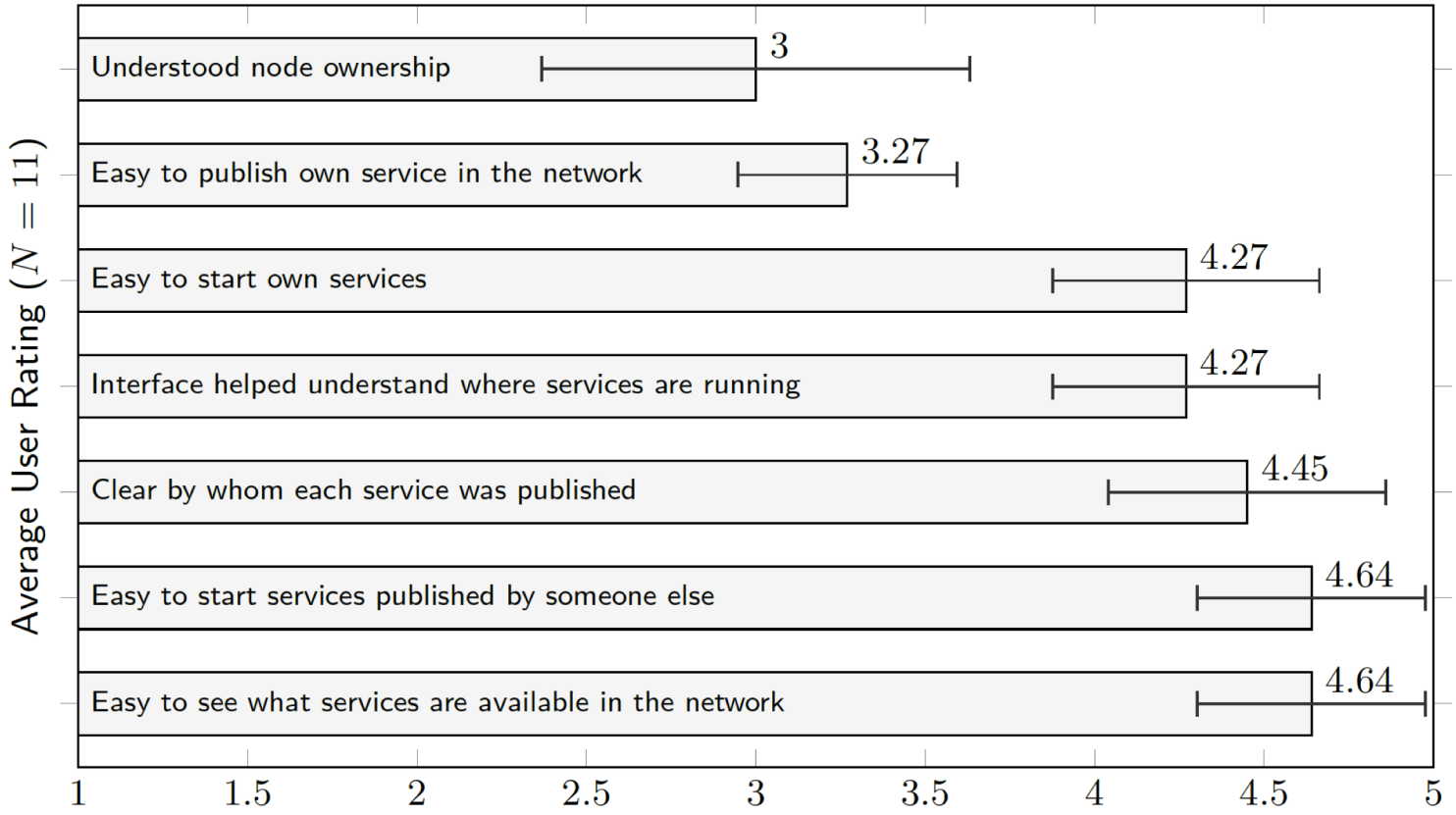
User Evaluation Results



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Outcomes And Interpretation

- Participants considered service registry useful
- Most considered verified service authorship important
- Several participants were confused by concepts like nodes
  - need to improve UI for a non-technical audience
- Acceptable response time: 10 minutes or less
  - a large minority voted for 10 seconds

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Technical Evaluation: Requirements

- Block time of < 1s used during evaluation proved infeasible
  - storage requirement too large
  - network synchronization issues
- Further evaluation yielded base storage requirements of
  - 3.7GB per year for 9.3s block time
  - 125MB per year for 271s (4.5min) block time

  → block times between 10s and 1min are feasible and would fulfill most users' expectations

Technical Evaluation: Security and Limitations

- Any attacker controlling the majority of mining power in the network can censor future transactions (e.g., exclude a particular user)
- Regardless of the blockchain-based registry, disruption of the network is easily possible by attacking the shared storage
- But: “Rewriting history” (e.g., changing ownership of a service) is quite expensive
  - an attacker twice as powerful as the existing network needs exactly one month to rewrite a block that is one month in the past

Conclusion

- Blockchain-based username and service registry is secure and feasible under realistic conditions
  - evaluation participants found the system useful
  - storage requirements are feasible, if response time requirements are not “real-time”

Future Work

- Service explorer only a first step
  - personalized recommendations, tagging, and community analysis
- Contributions, in their various forms (providing computing resources, authoring services), should be recognized and rewarded
  - blockchain cryptocurrency may form the basis of a reputation system
  - bounties could be awarded for desired contributions