P2PNS: A Secure Distributed Name Service for P2PSIP

Ingmar Baumgart

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Universität Karlsruhe (TH)
Research University • founded 1825

TeleMatics Institute of Telematics

Outline

- Decentralized VoIP (P2PSIP)
- Peer-to-Peer name service (P2PNS)
  - Architecture
  - Two-stage name resolution
- P2PNS security
  - Attacks on nodeID generation
  - Attacks on message forwarding
  - Attacks on DHT layer
- Conclusion

Peer-to-Peer SIP

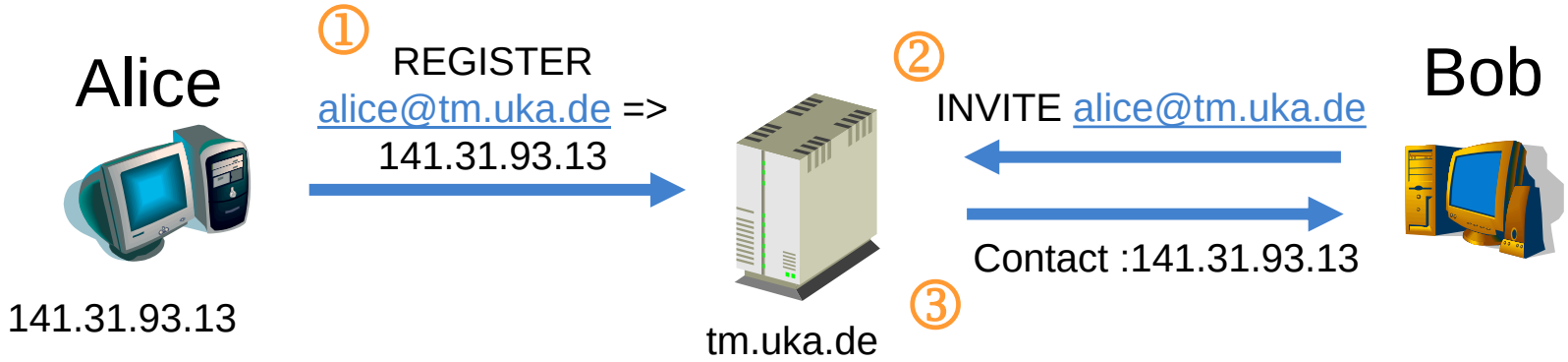
- What is P2PSIP?
  - Using a peer-to-peer network instead of centralized servers for SIP user registration and location lookup

- Why P2PSIP?
  - Cost reduction (no servers needed)
  - Scalability
  - Reliability (No single point of failure, self healing)
  - Failover for server-based SIP networks (in emergency cases)
  - NAT traversal

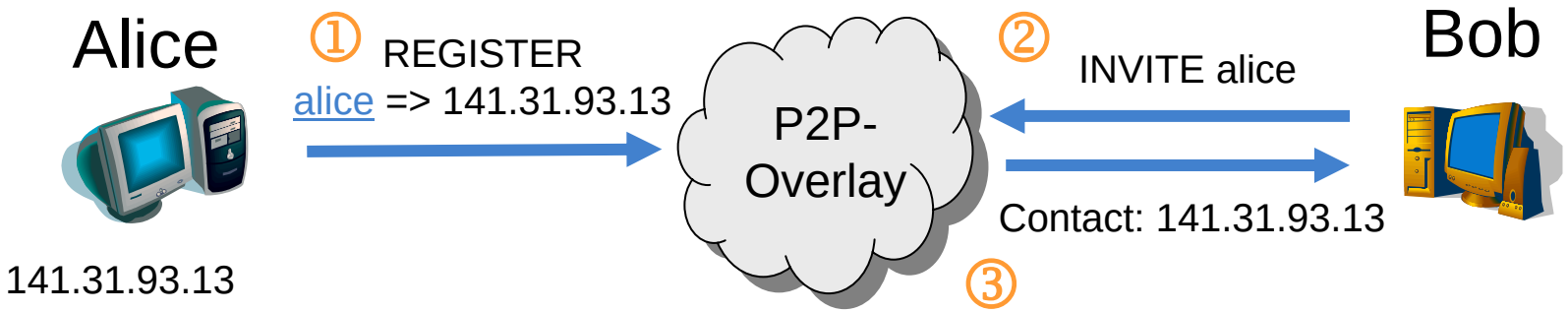
➔ Skype (largest VoIP provider in the world) also uses P2P technologies, but no open standard

Server-based SIP vs. P2PSIP

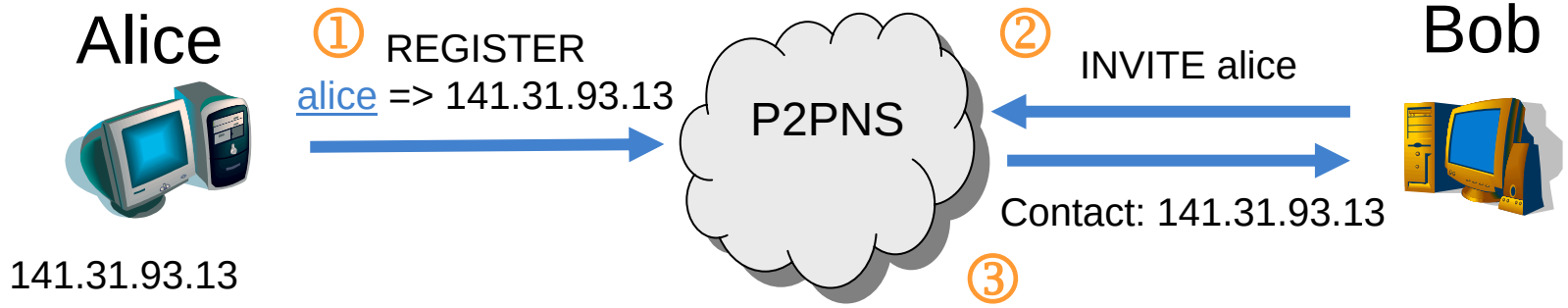
- Call setup with server-based SIP:



- Call setup with P2PSIP:



Decentralized VoIP (P2PSIP)



- Main task in P2PSIP:
  - Resolve AoR to current IP address
- Challenge: Many security issues in a completely decentralized network

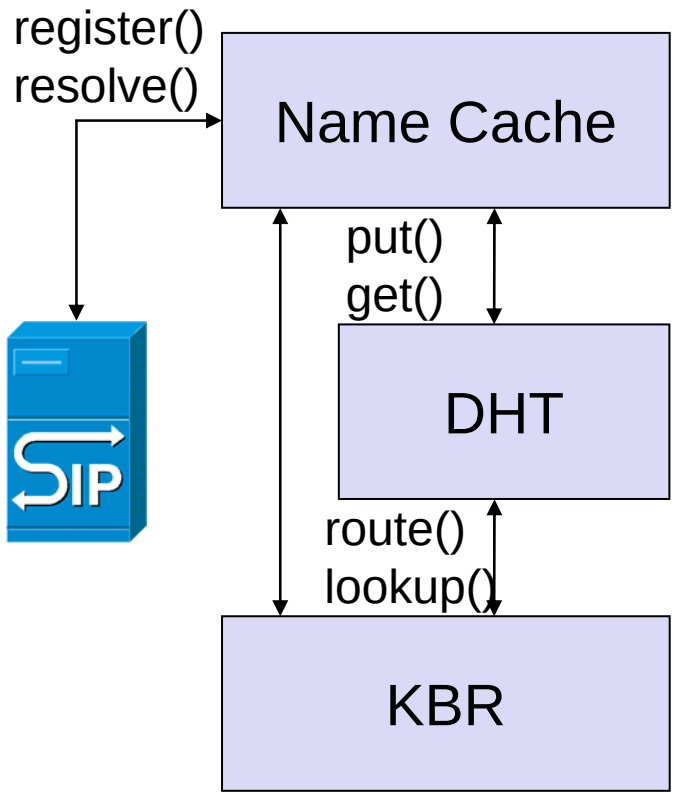
- Our approach: Generic distributed name service P2PNS *(IETF draft-baumgart-p2psip-p2pns-00)*

Peer-to-Peer Name Service (P2PNS)

- Distributed name resolution for:
  - P2PSIP, decentralized DNS, HIP, decentralized IM (XMPP)
- Same task in all scenarios:
  - Resolve a name (AoR, domain name, HIT) to the current transport address (IP, port)
- P2PNS interface:
  - register(name, transport address)
  - resolve(name)
- Name cache on top of KBR/DHT P2P layer
- Focus on security in completely decentralized networks:
  - Unique usernames
  - Prevent identity theft

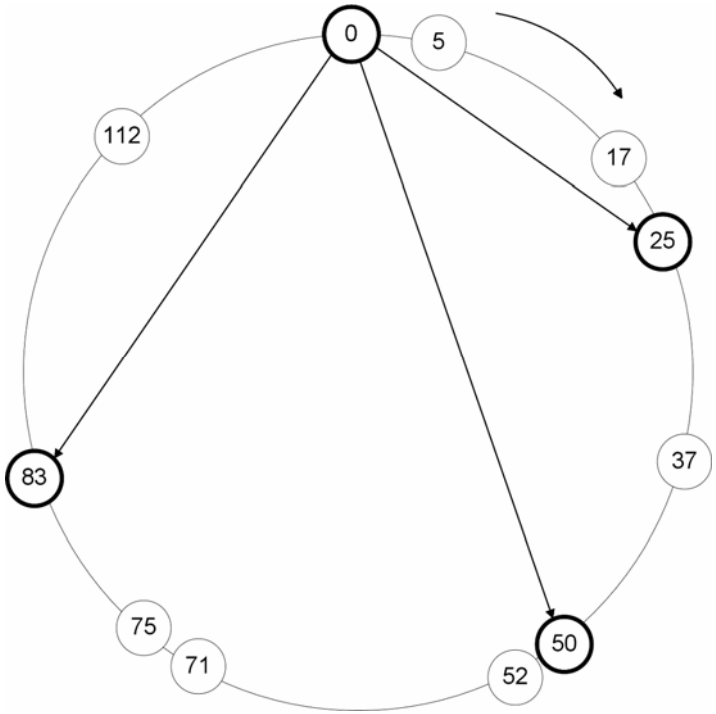
P2PNS Architecture

- Modular architecture based on Common API:
  - Key Based Routing (KBR)
    - Task: Message routing to nodeIDs
  - Distributed Hash Table (DHT)
    - Task: Distributed data storage
  - Name Cache
    - Task: Caching of AoRs
  - P2PSIP proxy:
    - Connects legacy SIP UAs to the P2PNS service



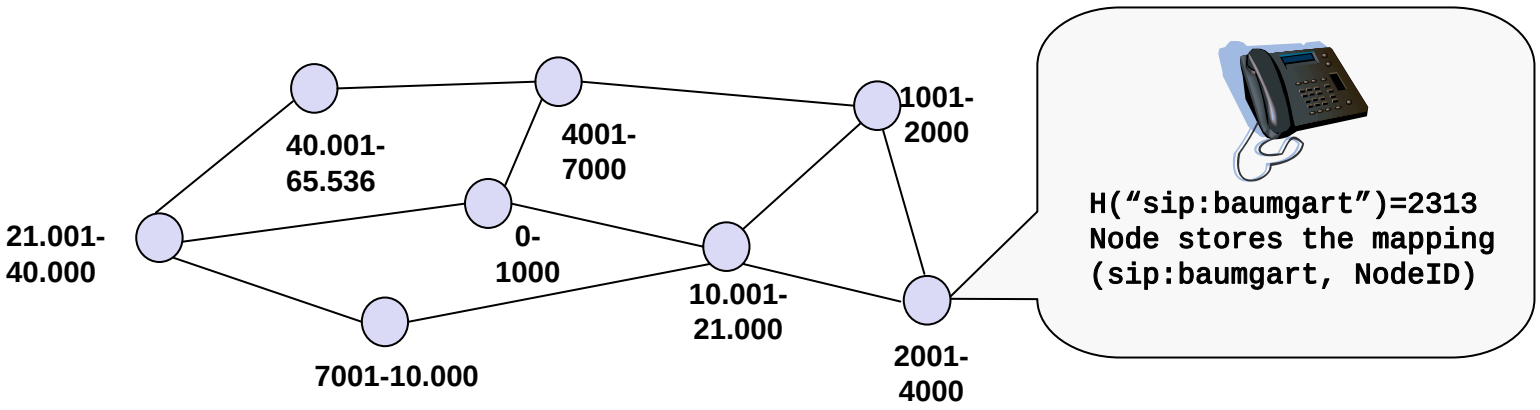
Key-based Routing (KBR)

- Message routing to nodeIDs
- Provided by structured overlay networks
  - Kademlia, Chord, Koorde, Broose, Pastry
- Main idea:
  - Each node has a nodeID
  - Overlay routing table with nodeIDs of overlay neighbours
  - Efficient lookup of keys and nodeIDs in O(log N)



Distributed Hash Table (DHT)

- Distributed storage of (key, value) tuples
- Uses the KBR layer to determine responsible nodes for data storage
  - Locate a node with a nodeID close to H(key)



DHT security is expensive

- Malicious nodes can modify or delete locally stored data items
- Countermeasure: Replicate data items on k nodes and use majority votes

➔ Modifying data items in a DHT is expensive

- DHT usage for P2PSIP
  - Usual approach:
    - DHT stores AoR→IP mapping
  - P2PNS approach:
    - Two-stage name resolution based on KBR and DHT services

Two-Stage Name Resolution

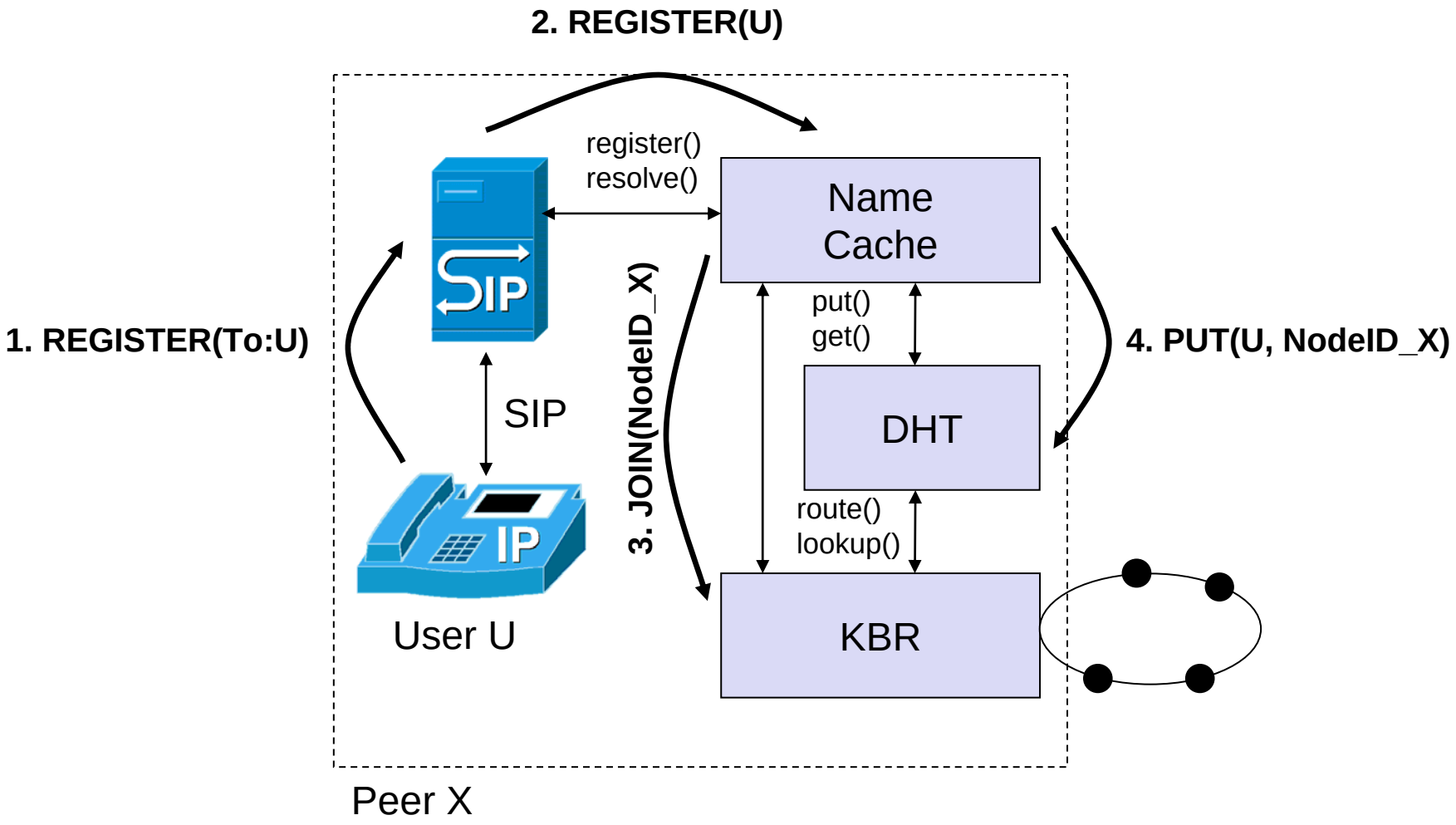
1.) Resolve AoR → NodeID (DHT layer)

2.) Resolve NodeID → IP (KBR layer)

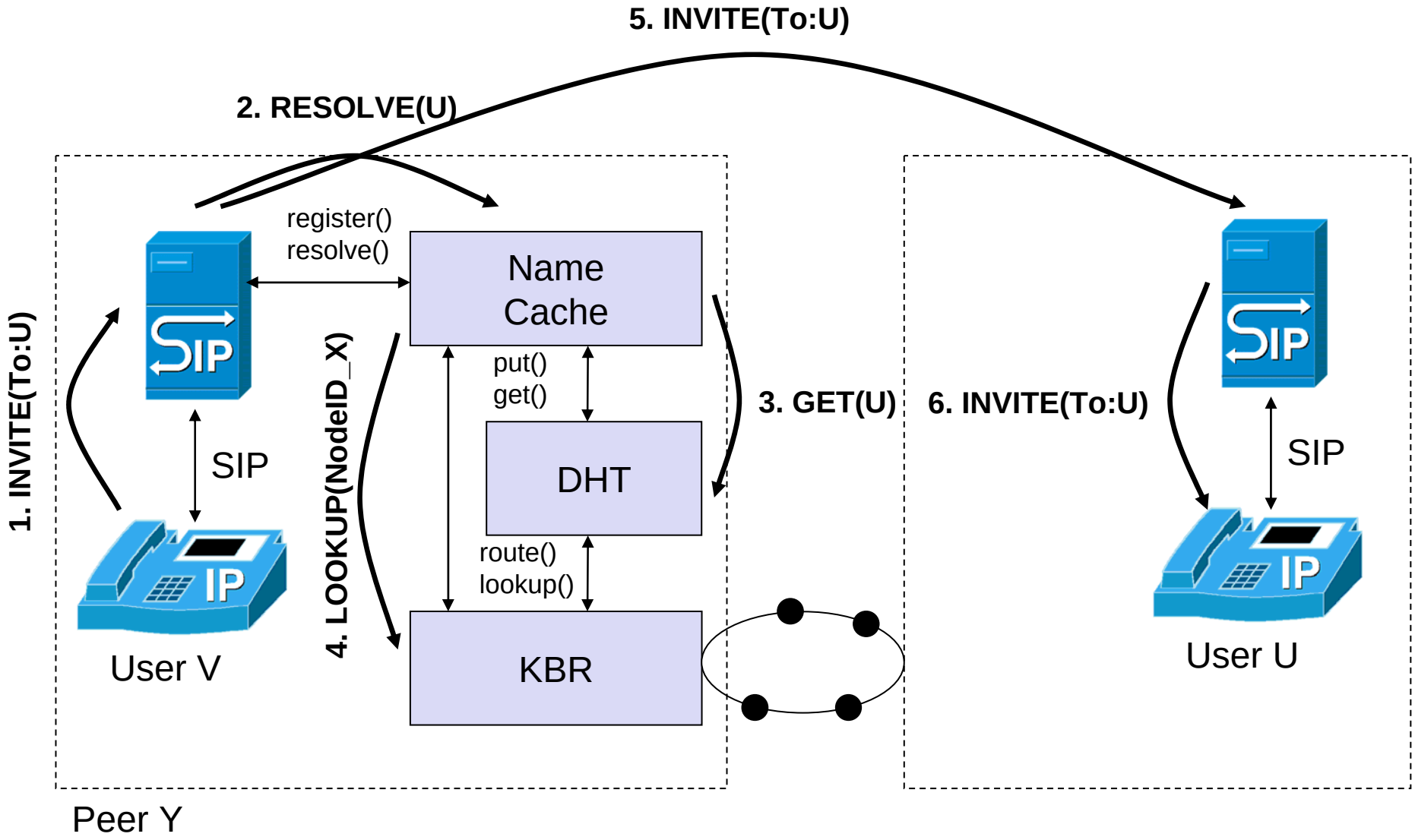
Motivation:

- Modification of data records on DHT is expensive (due to security mechanisms)
- (AoR, NodeID) binding is static: No modification needed if IP address changes (ID/Loc split)
- IP address changes are efficiently handled on KBR layer

Example: P2PNS user registration



Example: P2PNS user lookup

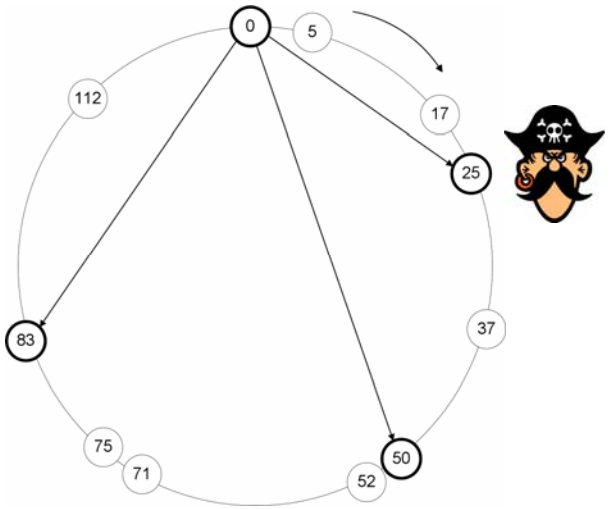


P2PNS security threats

- Attacks on routing (KBR)
  - NodeID generation
    - By carefully choosing a node ID an attacker can control access to target objects
  - Message forwarding
    - Malicious nodes along the route between sender and target node can modify or drop messages to a key
  - Routing table maintenance
    - DoS attack by distribution of faulty routing table updates
- Attacks on data storage (DHT)
  - Malicious nodes can modify or delete locally stored data items

Attacks on nodeID generation

- Eclipse attack: By carefully choosing a nodeID an attacker can control access to target objects
- Sybil attack: A single node can join the network with several nodeIDs
- Countermeasure:
  - Make nodeID generation expensive
  - Limit free nodeID selection

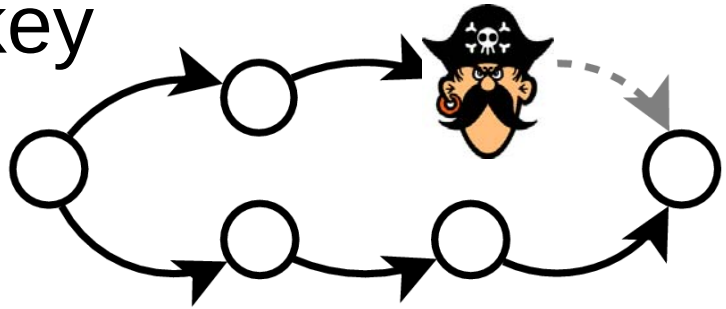


Secure NodeID generation

- Common approach: NodeID = SHA1(IP+port)
  - Problems:
    - Sybil attack still possible if an attacker controls several IP addresses
    - Constantly changing nodeIDs on dial-up connections
- Better: NodeID = SHA1(public key)
  - Public key can be used to authenticate node messages
  - Sybil attack and choose of a specific nodeID still feasible
    - Use in combination with crypto puzzles to make creation of new nodeIDs expensive
    - Use a offline CA to generate nodeIDs (if available)

Attacks on message forwarding

- Malicious nodes along the path between sender and target node can modify or drop messages to a key

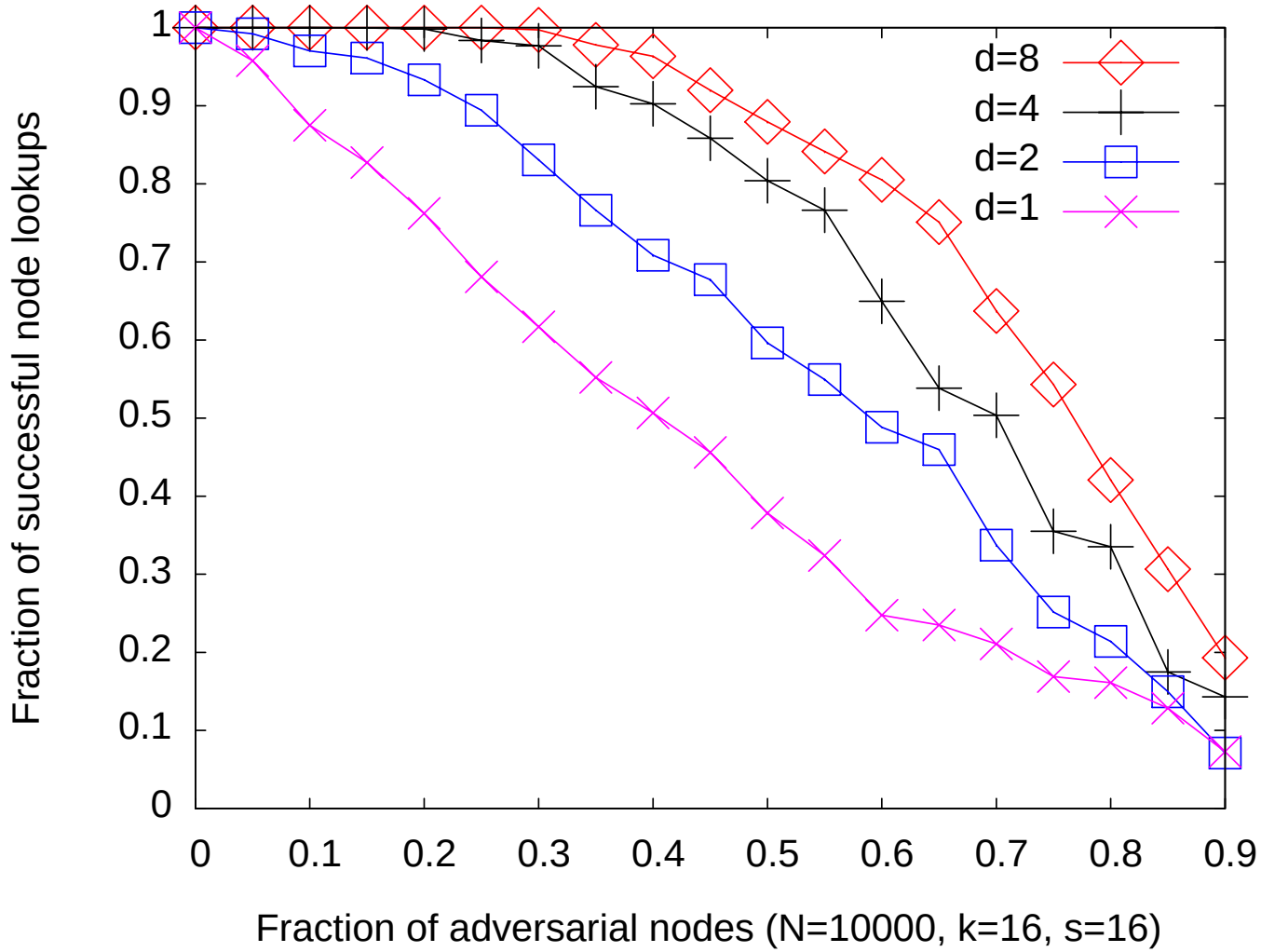


- Countermeasure: Parallel lookup over disjoint paths increases the lookup success ratio:

$$P(\text{lookup success}) = 1 - (1 - (1 - m)^h)^d$$

- Most important security properties of KBR protocols
  - Average path length h
  - Number of disjoint paths d

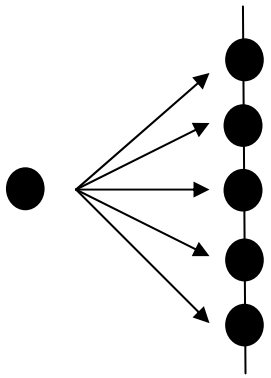
Effect of disjoint paths on lookup success



→Even with 25% adversarial nodes 99% lookups succeed in a Kademlia network with 10000 nodes

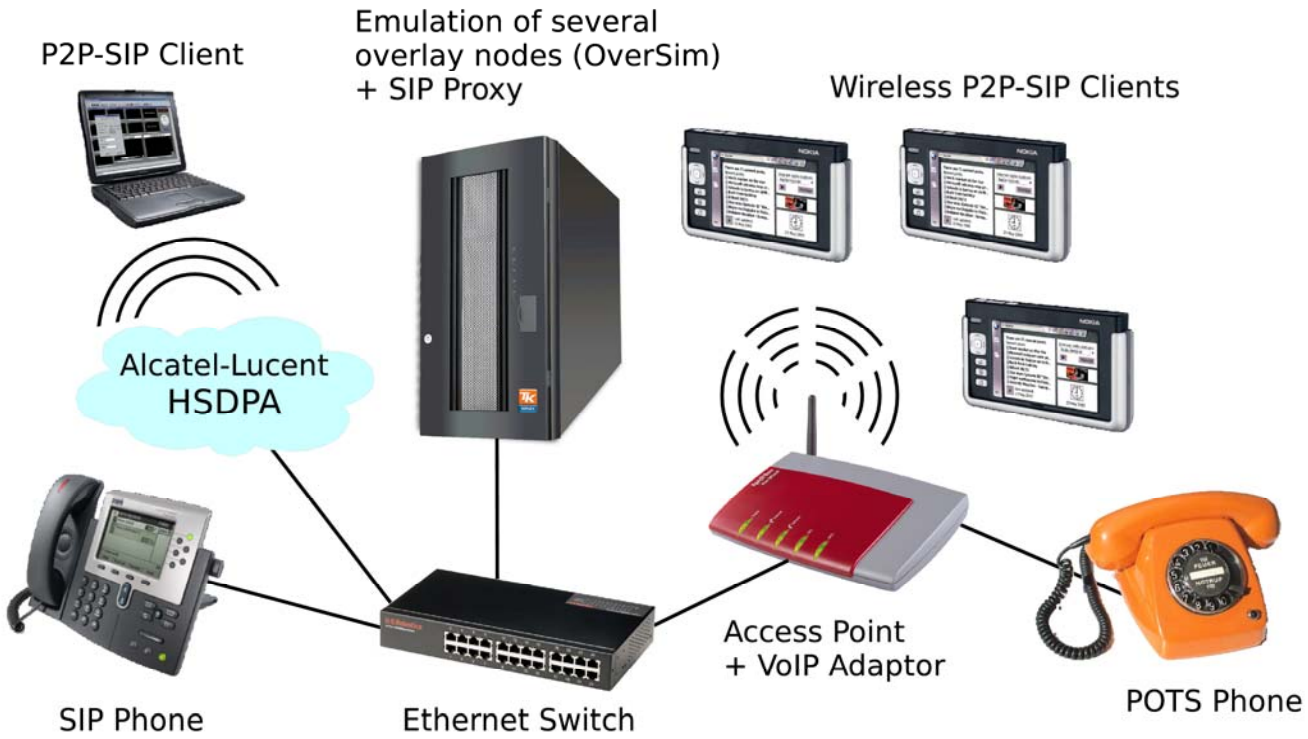
Secure DHT layer

- Data records must only be modified by the owner of a record
  - Modification requests are signed with k_{priv}
- Only store a single record for each key
  - Unique usernames
- Data records are replicated on k nodes
  - Query all replica in parallel and use majority votes
  - Joining nodes pull all replica in their key range



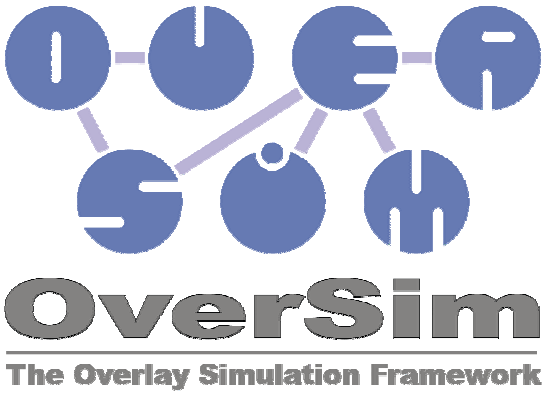
P2PNS implementation

- Unmodified SIP UAs
- Added P2PNS support to OpenSER SIP proxy
- Overlay Framework OverSim (http://www.oversim.org/)
  - Provides P2PNS service to the P2PSIP proxy



Future work

- KBR protocol selection
  - Several promising candidates:
    - Kademlia, Broose, Pastry
    - Focus on low latency and security
- Evaluation of DHT replication strategies
- Standardization
  - Generic P2P protocol
  - Common interface for KBR/DHT service
- Bootstrapping
- NAT traversal



Conclusion

- P2PNS provides generic name resolution for
  - P2PSIP, DNS, Jabber, HIP
- Modular architecture based on Common API
- Focus on security in completely decentralized environments
- Two-stage name resolution reduces communication costs in dynamic networks

Thank you for your attention!

Any questions?