A Scalable Approach for the Secure and Authorized Tracking of the Availability of Entities in Distributed Systems

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Motivation

- Proliferation of distributed systems
- Interactions predicated on knowledge of the availability of entities
  - Control messages, protocol handshakes, actions and data interchange
  - Track resources at all times
    - Load, usage patterns etc
- Remedial actions in response to failures
  - Failure suspicions, failures, shutdown

Definition of Terms

- Entity
  - Resource, service, instruments, clients etc
- Tracing
  - Process of probing, and becoming aware of, the availability of an entity
- Traced Entity
  - The entity whose availability is being probed
- Trackers
  - Entities initiating availability probes for a traced entity
- Traces
  - Messages encapsulating the state of a traced entity

Push or Pull

- Push
  - Traced entities push traces to the trackers at regular intervals
  - Receipt of such pushed traces provides info on availability
- Pull
  - Trackers poll the availability at regular intervals
  - Decisions based on the outcome of the poll

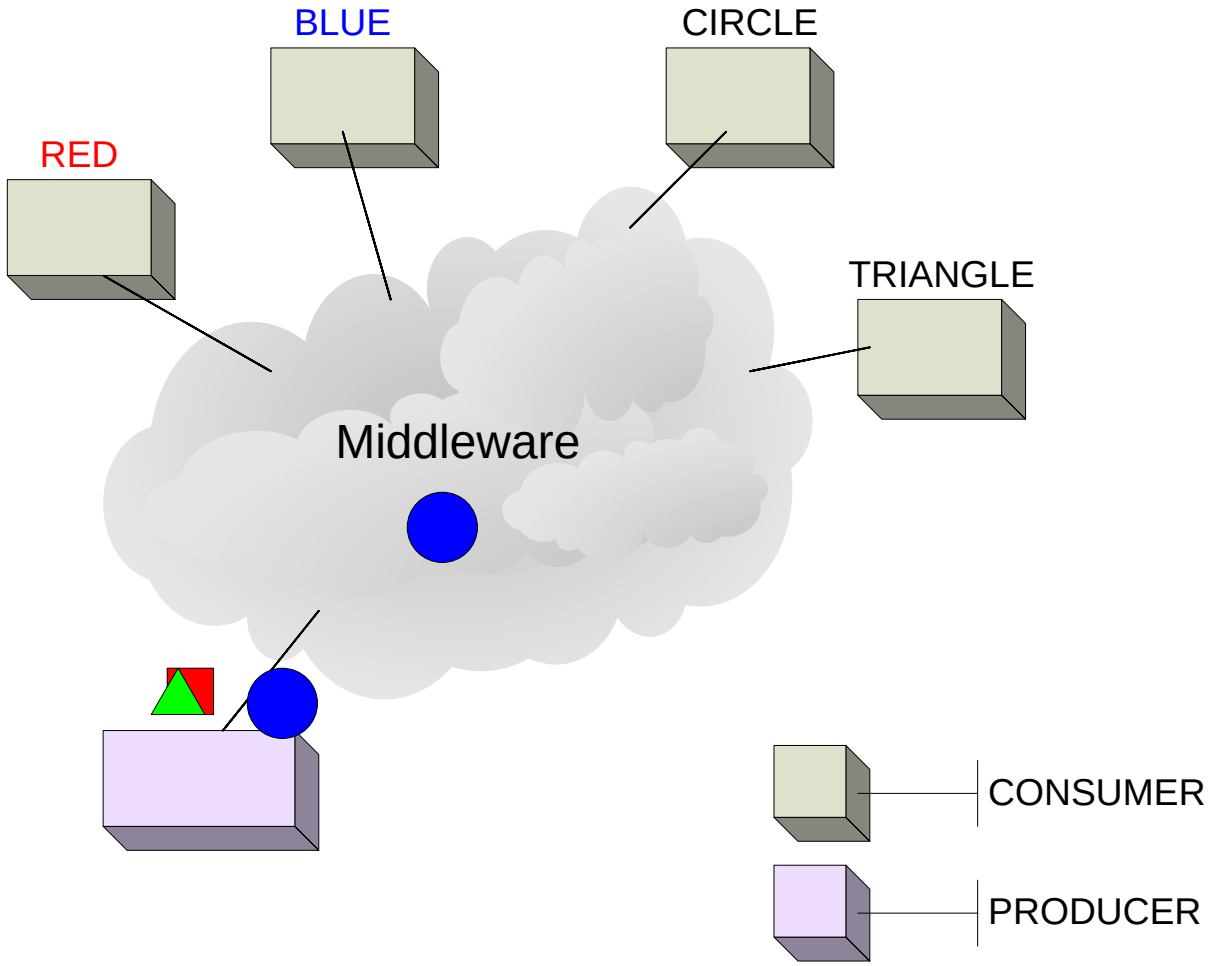
Issues in developing solution

- In simple scheme every entity issues a trace every second
  - Does not scale well
  - With increasing scale every entity is inundated with traces
- Entities operate in myriad domains
  - May deploy different transports for communications

Desired Features

- Reduction of complexity
  - Reduce the number of entities that a given entity needs to communicate with
    - Push/pull requires some entity to communicate with a rather large set
- Transport independent
- Selectivity in traces
  - For e.g. register ONLY to receive change notification traces
- Authorization
  - Restrict who is allowed to be part of the tracing process
- Security
  - Make the trace itself confidential
- Cope with some classes of DDoS attacks

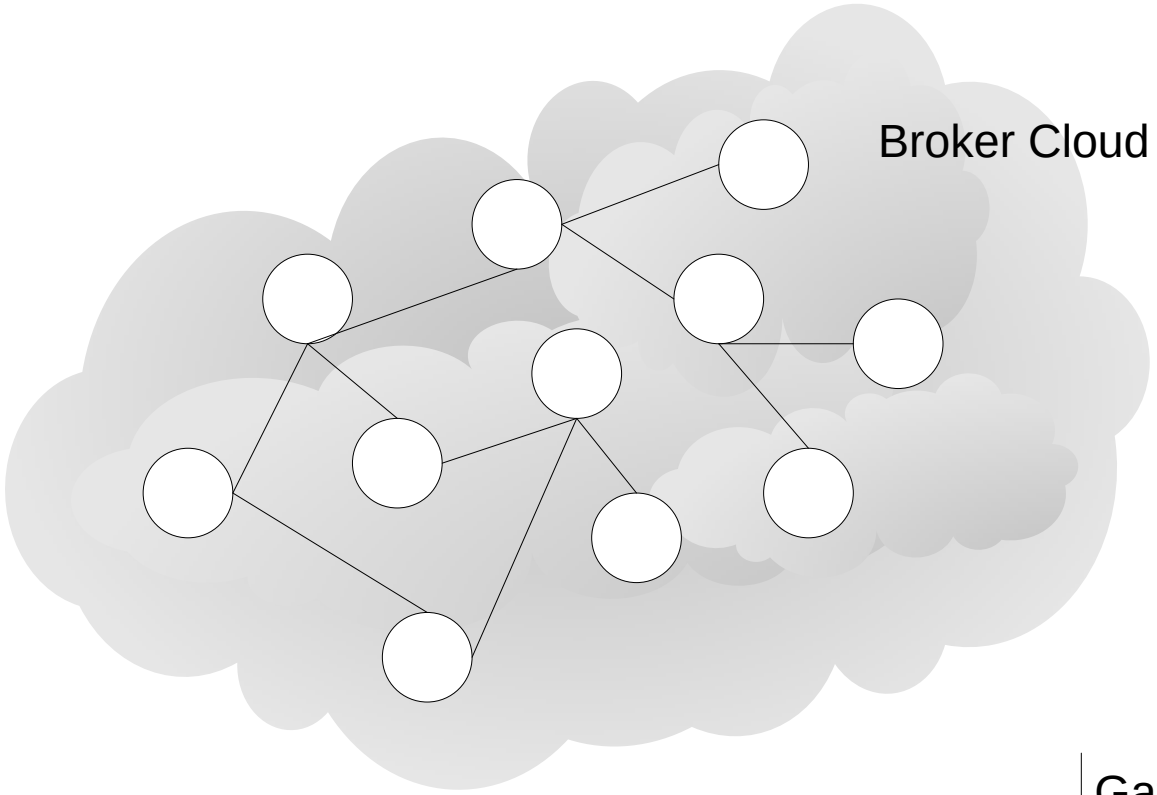
Publish/Subscribe Systems

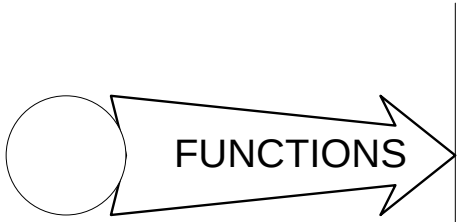


NaradaBrokering

- Provisions an enabling infrastructure for building distributed systems
  - Has services, and makes these services accessible to entities through simple invocations.
    - Processing at the service, and the infrastructure may be complicated, but this is shielded from the clients
- Dissemination is based on the pub/sub paradigm
- Open-source project http://www.naradabrokering.org
- Deployed in a wide variety of domains
  - GIS, Audio/Video conferencing, collaboration, Geoscience and Physics
- 1425 classes, 157 packages and 300,000 lines of code

The NaradaBrokering Substrate





Gateway to Services
Service multiple clients
Organize Subscriptions
Route Messages
Enforce constraints

Topic Discovery Scheme

- Create topics that are unique in space and time in a decentralized fashion
- Establish topic provenance
  - Deterministic cryptographic verification of ownership
- Restrict discovery of topics
  - Possess valid credentials
  - Specified ACL
- Establish topic life-cycle
- Manage topic collections & organization

Our scheme

- Leverage pub/sub for disseminating traces
- Facilitate **selectivity** in trace consumption by trackers
  - Different types of Traces are issued over different topics.
- Restrictions on **authorizations** related to topics over which traces are issued
  - Discovery of these topics
  - Actions associated with these topics
- Traces demonstrate authorization, tamper-evidence and source
  - Unambiguously verify this
- **Secure** the distribution of traces

Trace Topic

- Topic related to trace information related to a given entity
  - Derivative topics are constructed from this
- At creation time, the traced entity must specify who is authorized to trace it
  - ACL or based on credentials
- Register a descriptor that will facilitate discovery
  - Availability/Traces/Entity-ID

Constrained Topics

- Systems Topics
- Derivative topics managed by the broker
  - Multiple derived topics facilitates trace selectivity
- Constraints are based on
  - Limits on performed actions
  - Proof of authorization to perform action
  - Security
  - Dissemination range for the action
- Anatomy of a Constrained Topic
  - /Constrained/{Event Type}/{Constrainer}/ {Allowed Actions }/{Distribution} /{Other "/"separated Suffixes}

Registration of Trace Entity

- First create a Trace topic
- Register with broker
  - Over constrained topic that ONLY broker subscribes to
- Traced Entity needs to sign registration message
  - Verify credentials and tamper evidence
- Broker generates session identifier
  - Along with the trace topic, is used to derive a constrained topic
    - ONLY the Broker subscribes to
    - ONLY traced entity publishes to.

Broker Operations

- Responsible for failure detection
  - Must report status of traced entity to trackers
- Issues pings at regular intervals to traced entity
  - Every ping has monotonically increasing message number, and timestamp.
  - Ping responses should include both of these
    - To correlate requests and responses
  - Failure suspicions and confirmations based on lack of ping responses
- Traced entity can notify broker about
  - LOAD, Network metrics, Graceful exits and state transitions

Registering to receive traces

- Need to discover trace topic associated with a given traced entity
- Construct appropriate derived constrained topics to initiate interactions
  - Selectivity allows registering to different types of traces
- A broker generates traces ONLY if there are entities interested in traces
  - GAUGE INTEREST message issued periodically

Authorization

- Every trace message initiated by the traced entity checked for authorization (source) and tamper evidence
- Traces published by broker
  - Broker needs to demonstrate authorization to generate traces.
    - This is verified by every broker that receives it
    - Cryptographic token generated by traced entity is included

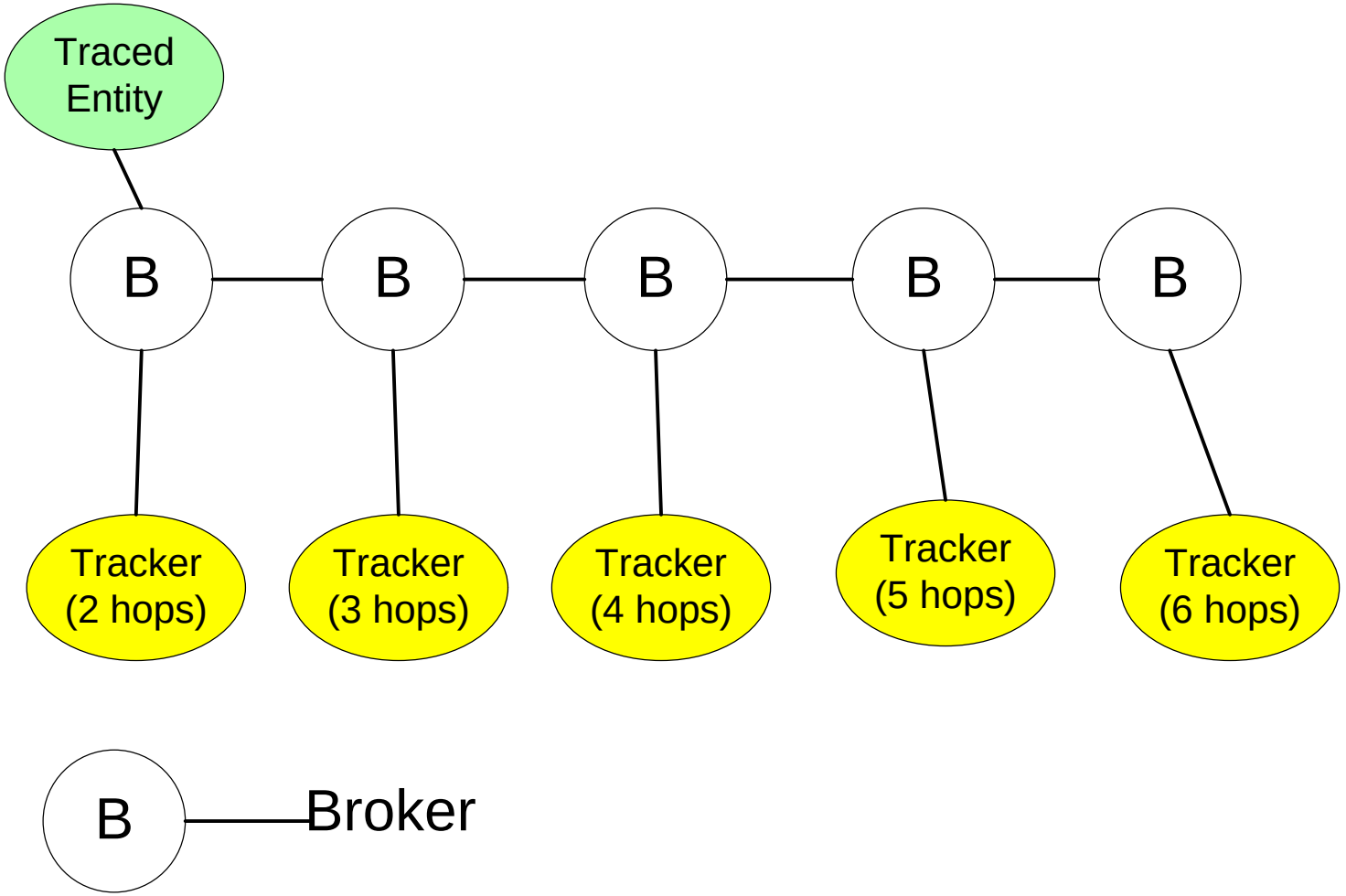
Security

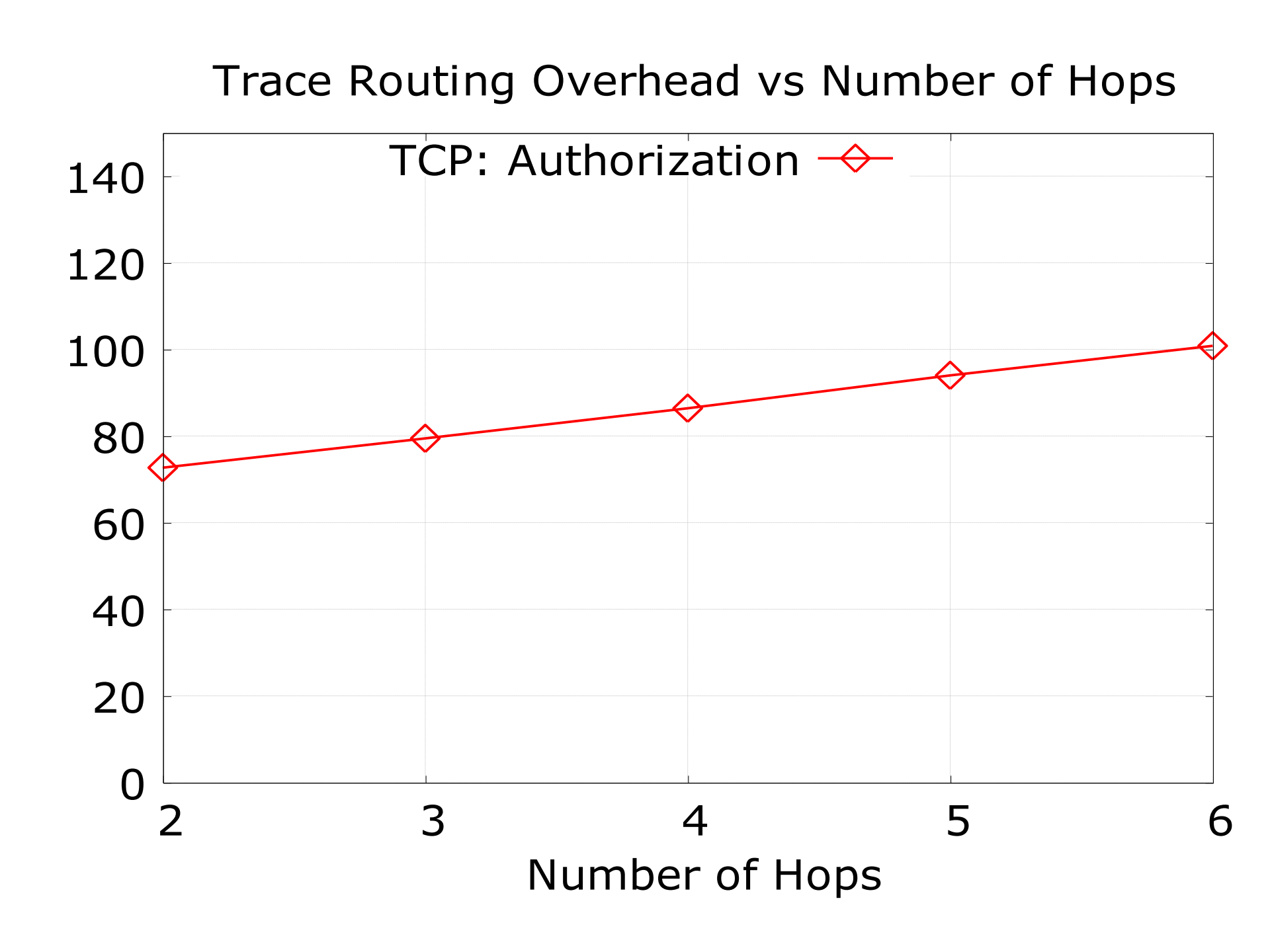
- Broker indicates that traces will be secured in the GAUGE INTEREST message.
- Trackers respond with their credentials.
- The broker secures the secret-trace-key
  - Using the tracker's credentials

Performance

- Cryptographic Profile
  - 1024-bit RSA with 160-bit SHA-1 and PKCS#1Padding.
  - Symmetric encryptions/decryptions use 192-bit AES keys
- 4 CPU Xeon, 2.4GHz, 2GB RAM
- 100 Mbps LAN
- JVM 1.4

Performance: Topology




Trace Routing Overhead vs Number of Hops
TCP: Authorization
140
120
100
80
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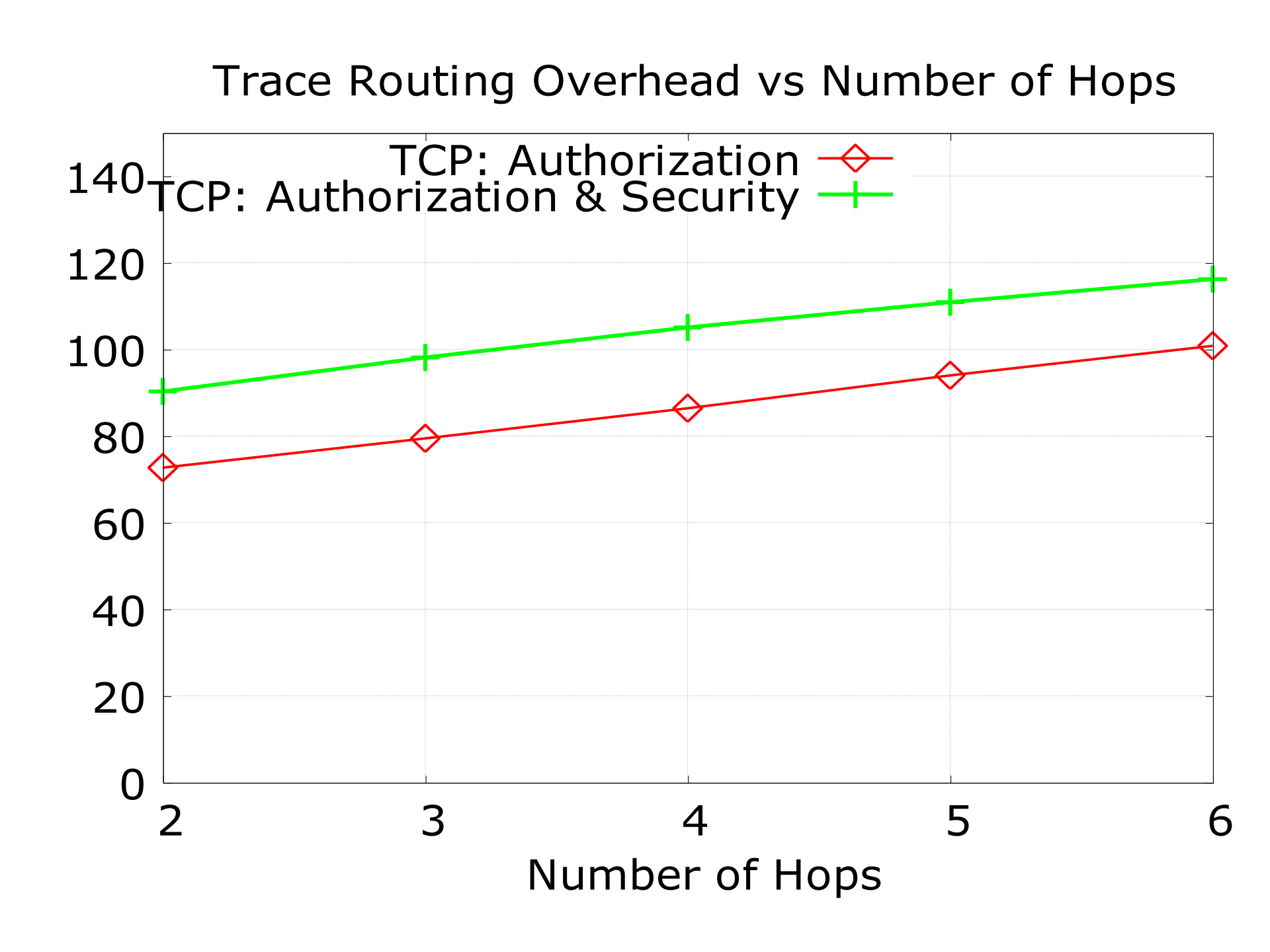
Number of Hops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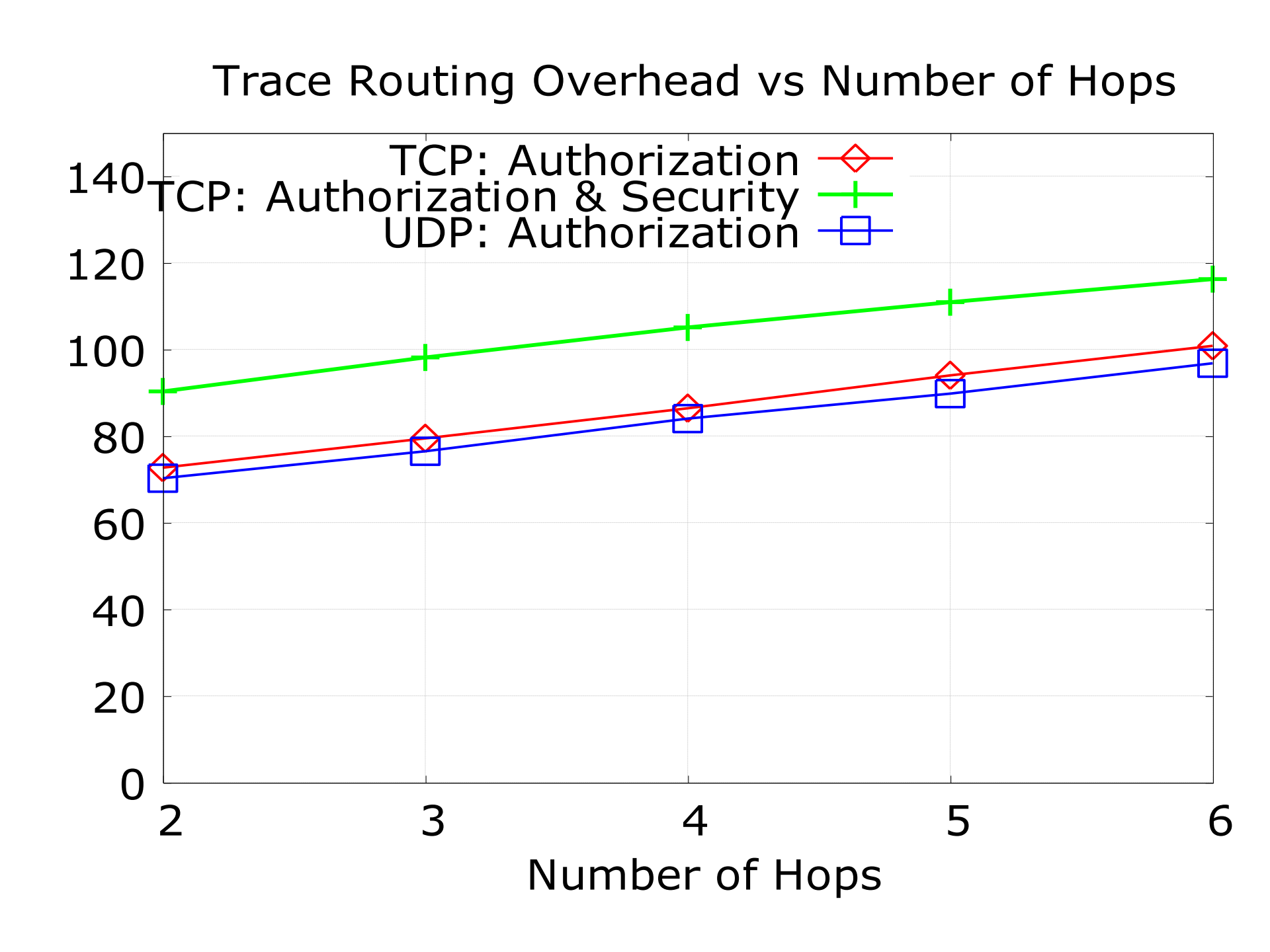
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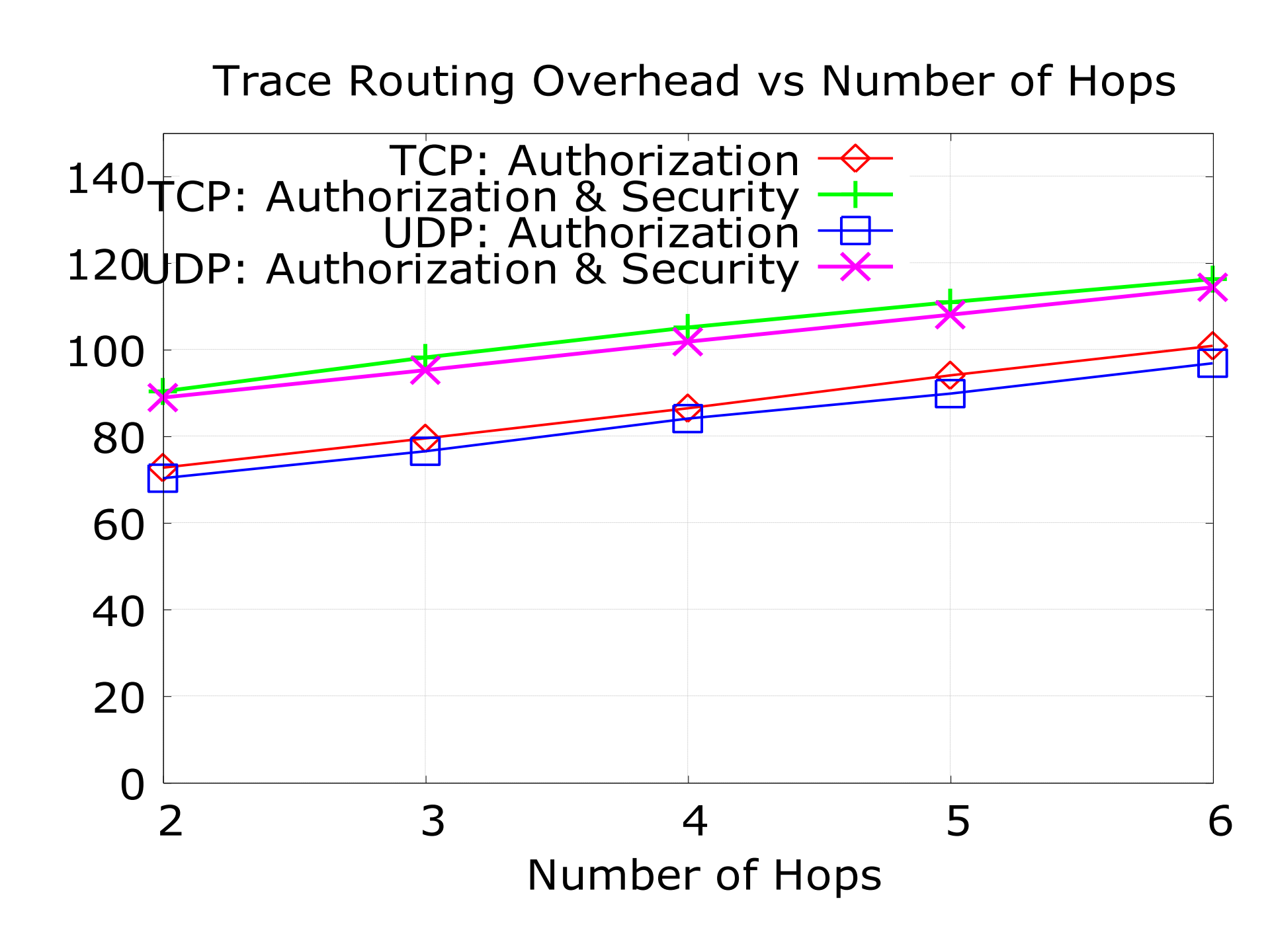
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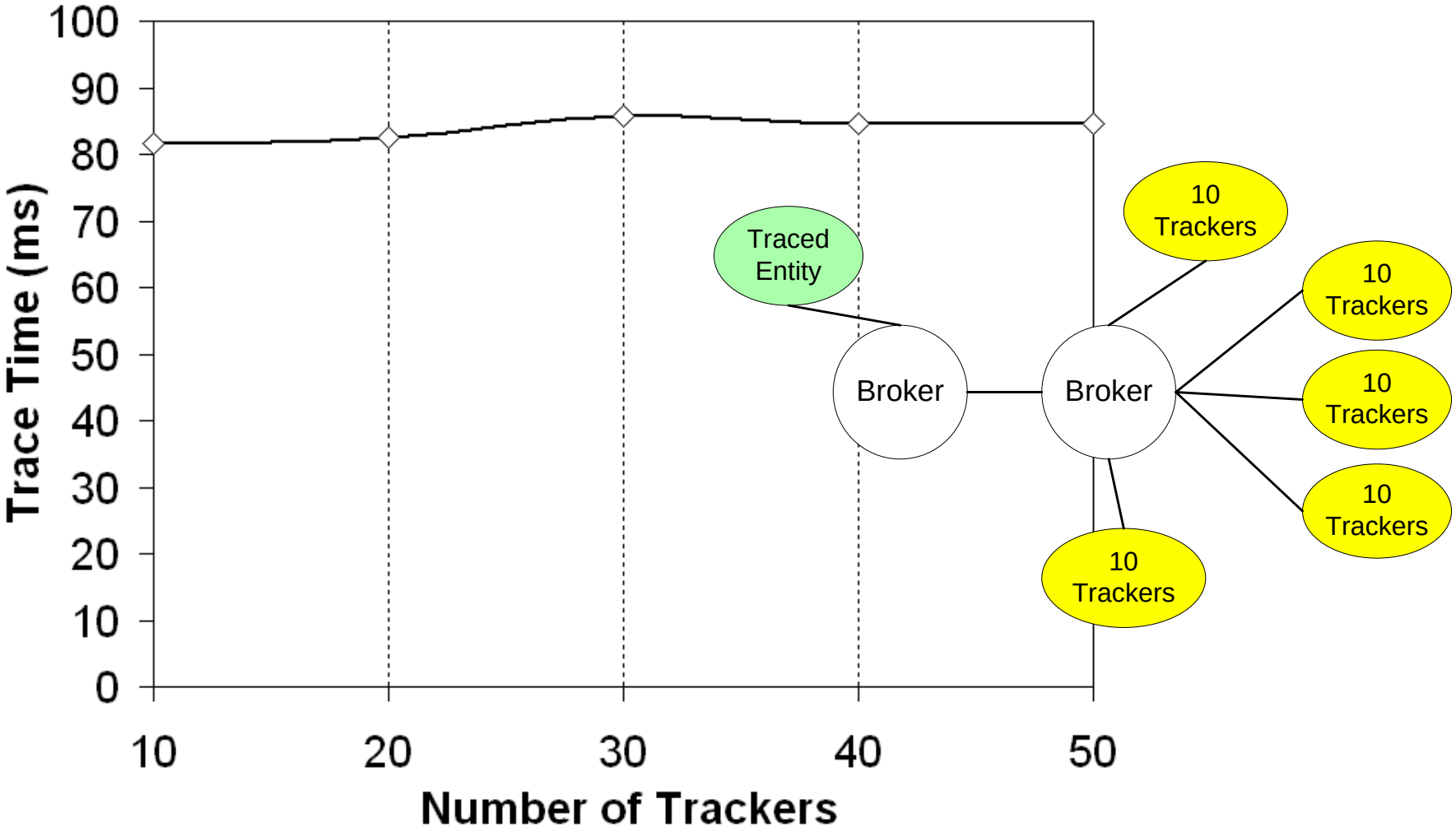
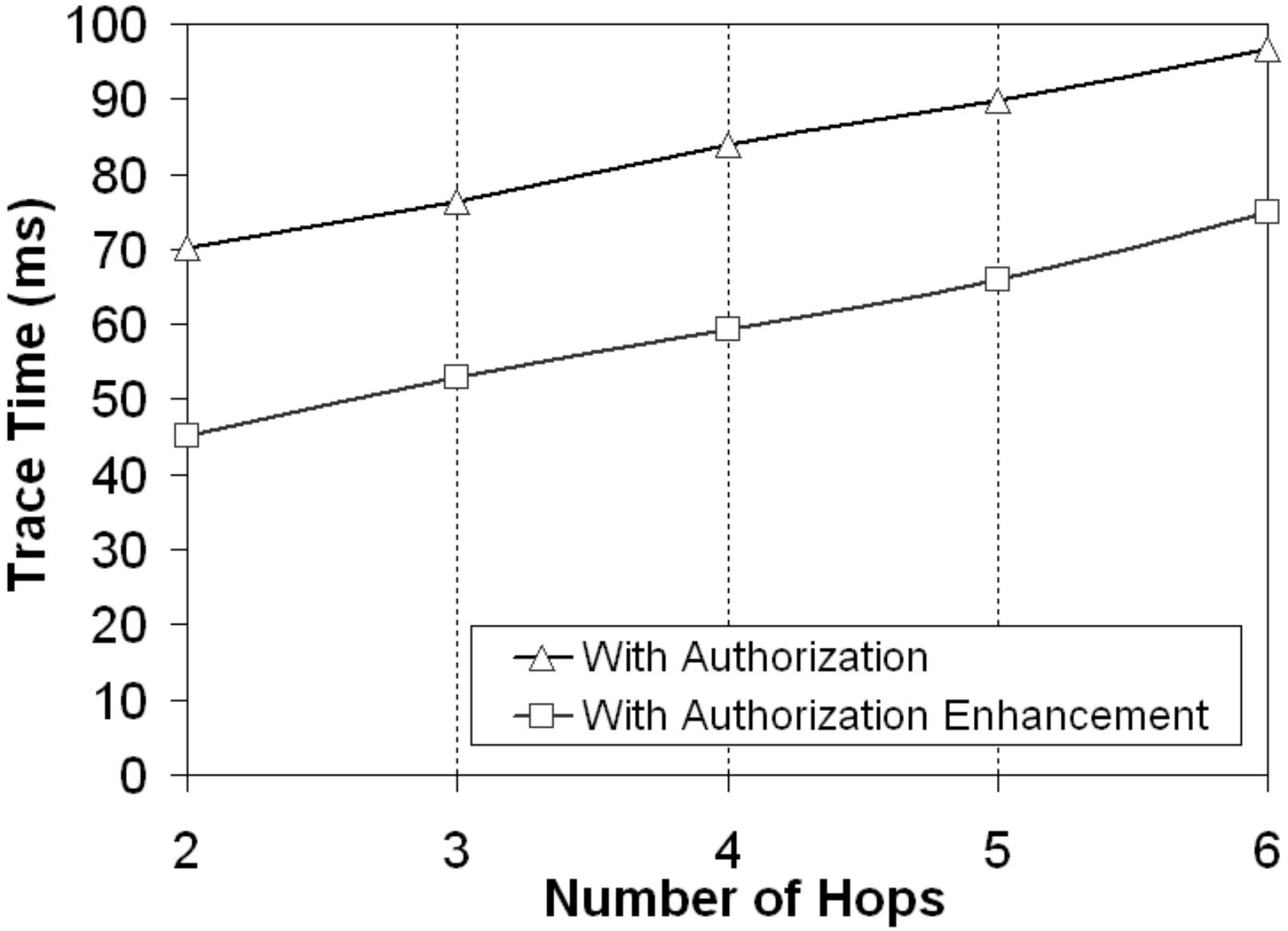
Benchmarks: Tracker Increase



Optimization: Authorization



Conclusions

- Pub/Sub provides loosely-coupled framework for the tracing scheme
- Topic provenance lays the groundwork for the trace authorization scheme
- Transport independence facilitates wider use
- The costs introduced by the secure, authorized tracing scheme are acceptable for several applications.
- System can enforce secure and authorization schemes equally well.
- Selectivity and Change notifications reduce number of messages