Design and implementation of an intentional naming system

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Environment

- Heterogeneous network with devices, sensors and computers
- Dynamism
  - Mobility
  - Performance variability
  - Services “come and go”
  - Services may be composed of groups of nodes
- Example applications
  - Location-dependent mobile apps
  - Network of mobile cameras
- Problem: resource discovery

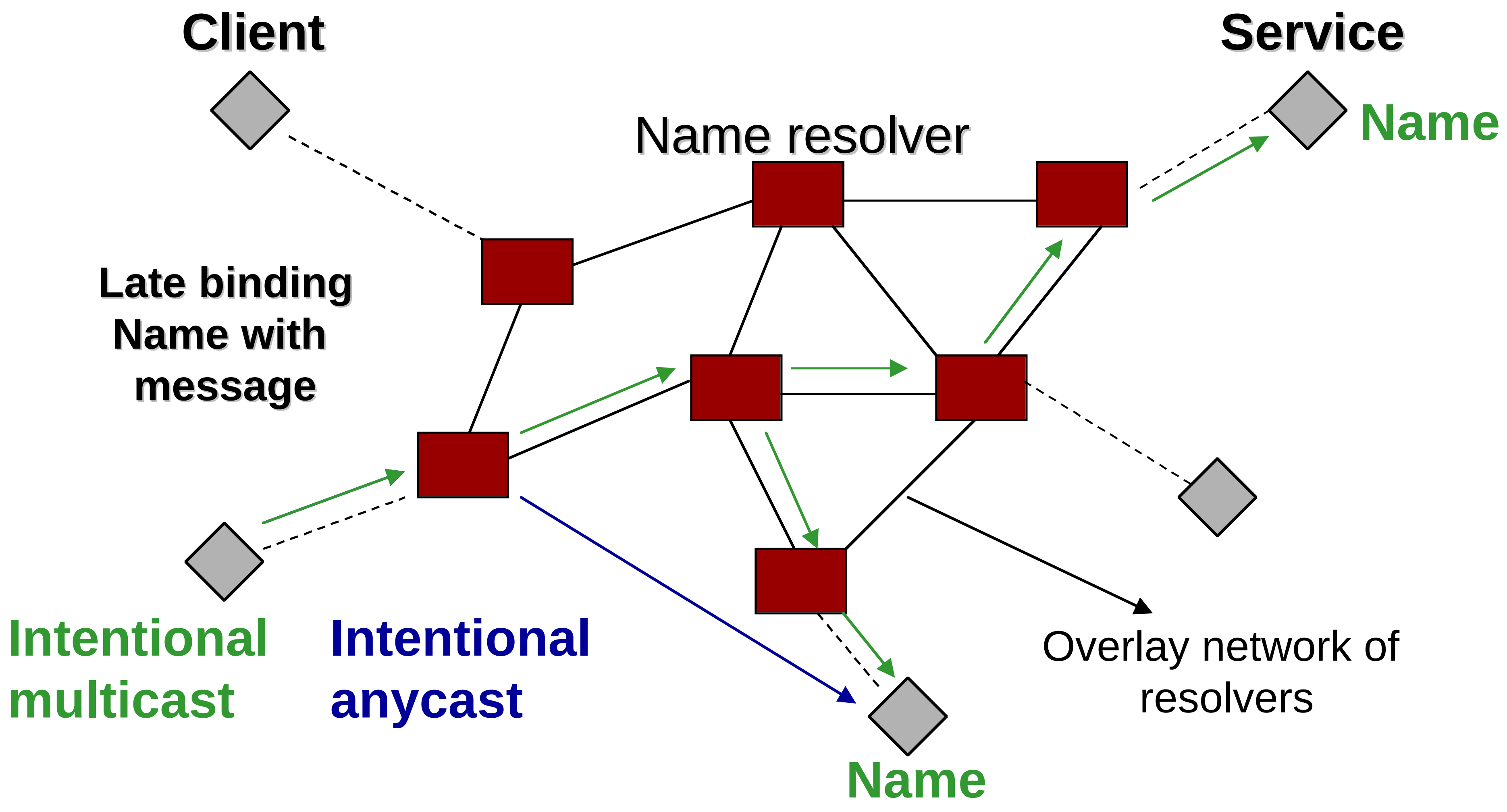
Design goals and principles

Expressiveness	➡	Names are intentional; apps know what, not where
Responsiveness	➡	Integrate name resolution and message routing (late binding)
Robustness	➡	Decentralized, cooperating resolvers with soft-state protocol
Easy configuration	➡	Name resolvers self-configure into overlay network

Naming and service discovery

- Wide-area naming
  - DNS, Global Name Service, Grapevine
- Attribute-based systems
  - X.500, Information Bus, Discover query routing
- Service location
  - IETF SLP, Berkeley service discovery service
- Device discovery
  - Jini, Universal plug-and-play
- Intentional Naming System (INS)
  - Mobility & dynamism via late binding
  - Decentralized, serverless operation
  - Easy configuration

INS architecture



Message routing using intentional names

Name-specifiers

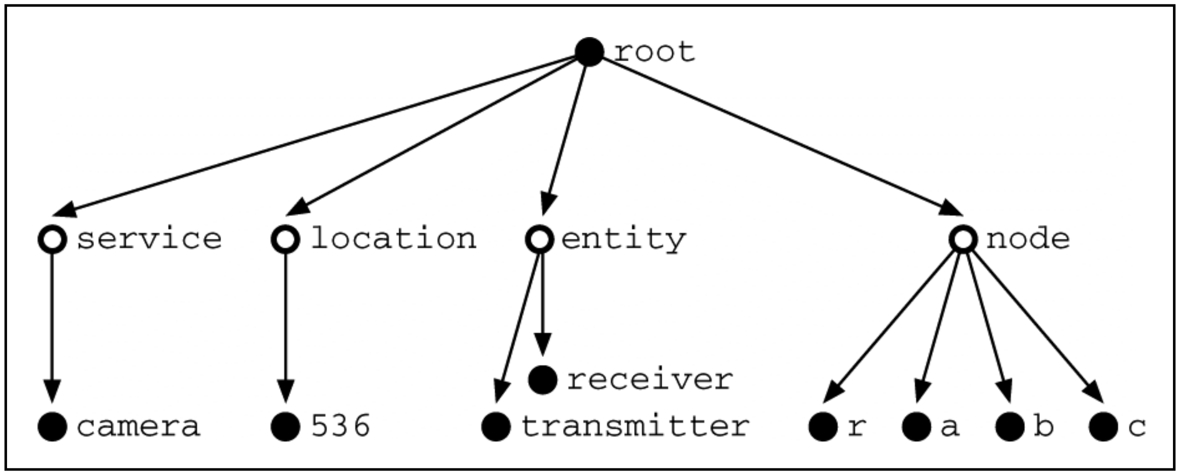
- Expressive name language (like XML)
- Resolver architecture decoupled from language
- Providers announce descriptive names
- Clients make queries
  - Attribute-value matches
  - Wildcard matches
  - Ranges

```
[vspace = lcs.mit.edu/camera]
[building = ne43
    [room = 510]]
[resolution=800x600]]
[access = public]
[status = ready]
```

```
[vspace = mit.edu/thermometer]
[building = ne43
     [floor = 5
       [room = *]]
[temperature < 60⁰F]
```

```
data
```

Name lookups



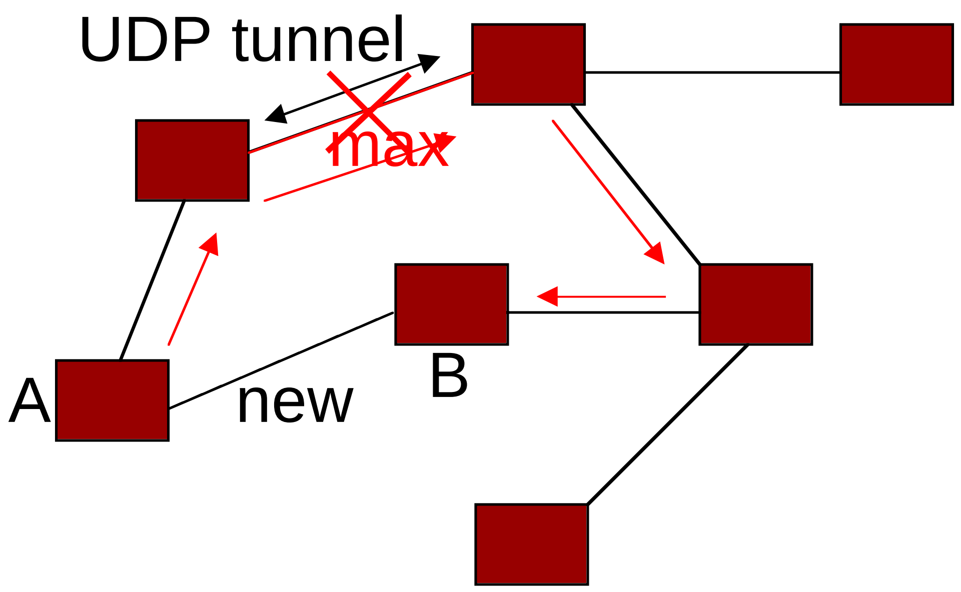
- Lookup
  - Tree-matching algorithm
  - AND operations among orthogonal attributes
- Polynomial-time in number of attributes
  - O(n^d) where n is number of attributes and d is the depth

Resolver network

- Resolvers exchange routing information about names
- Multicast messages forwarded via resolvers
- Decentralized construction and maintenance
- Implemented as an “overlay” network over UDP tunnels
  - Not every node needs to be a resolver
  - Too many neighbors causes overload, but need a connected graph
  - Overlay link metric should reflect performance
  - Current implementation builds a spanning tree

Spanning tree algorithm

- Loop-free connectivity
- Construct initial tree; evolve towards optimality
  - Select a destination and send a discover_bottleneck message along current path



Late binding

- Mapping from name to location can change rapidly
- Overlay routing protocol uses triggered updates
- Resolver performs lookup-and-forward
  - lookup(name) is a route; forward along route
- Two styles of message delivery
  - Anycast
  - Multicast

Intentional anycast

- lookup(name) yields all matches
- Resolver selects location based on advertised service-controlled metric
  - E.g., server load
- Tunnels message to selected node
- Application-level vs. IP-level anycast
  - Service-advertised metric is meaningful to the application

Intentional multicast

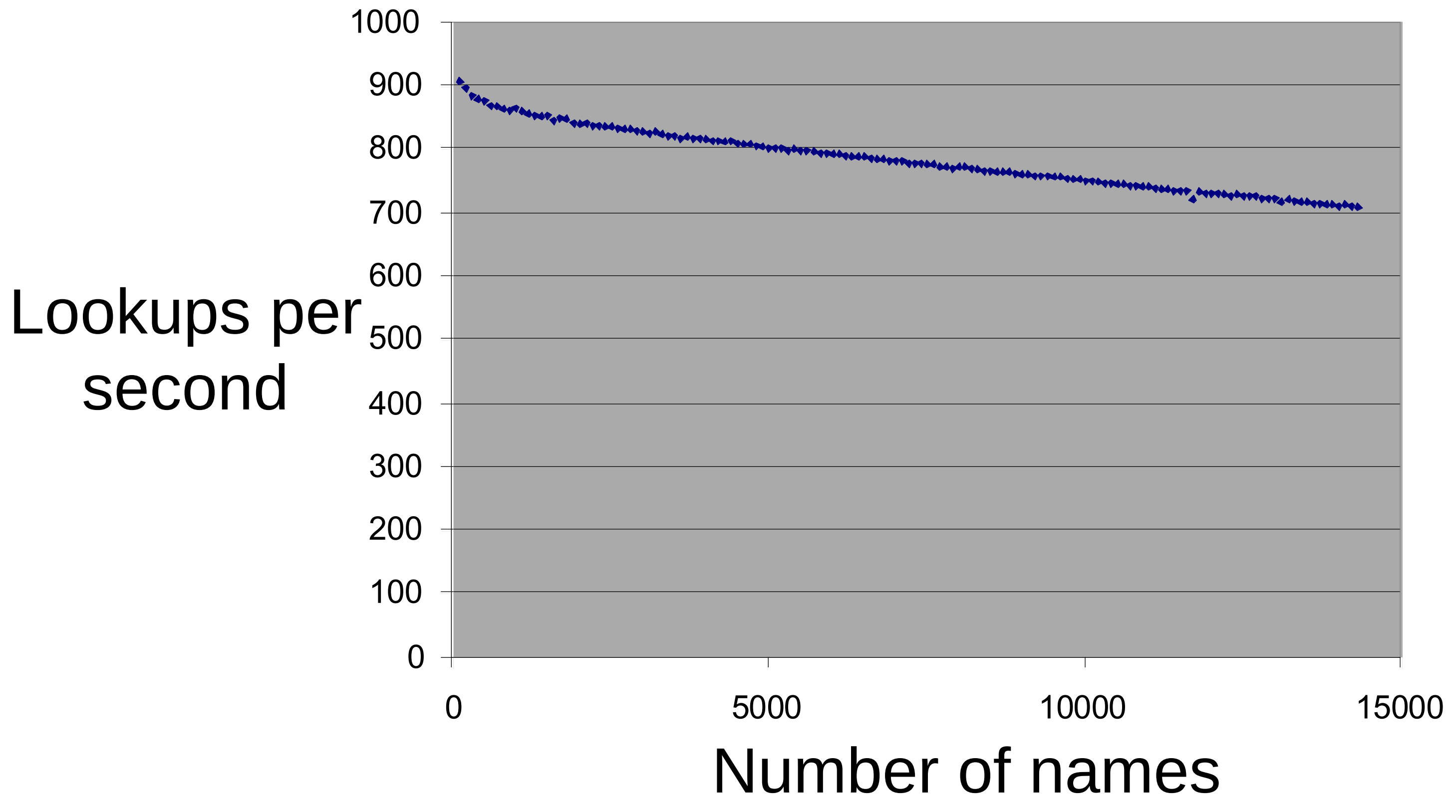
- Use intentional name as group handle
- Each resolver maintains list of neighbors for a name
- Data forwarded along a spanning tree of the overlay network
  - Shared tree, rather than per-source trees
- Enables more than just receiver-initiated group communication

Robustness

- Decentralized name resolution and routing in “serverless” fashion
- Names are weakly consistent, like network-layer routes
  - Routing protocol with periodic & triggered updates to exchange names
- Routing state is soft
  - Expires if not updated
  - Robust against service/client failure
  - No need for explicit de-registration

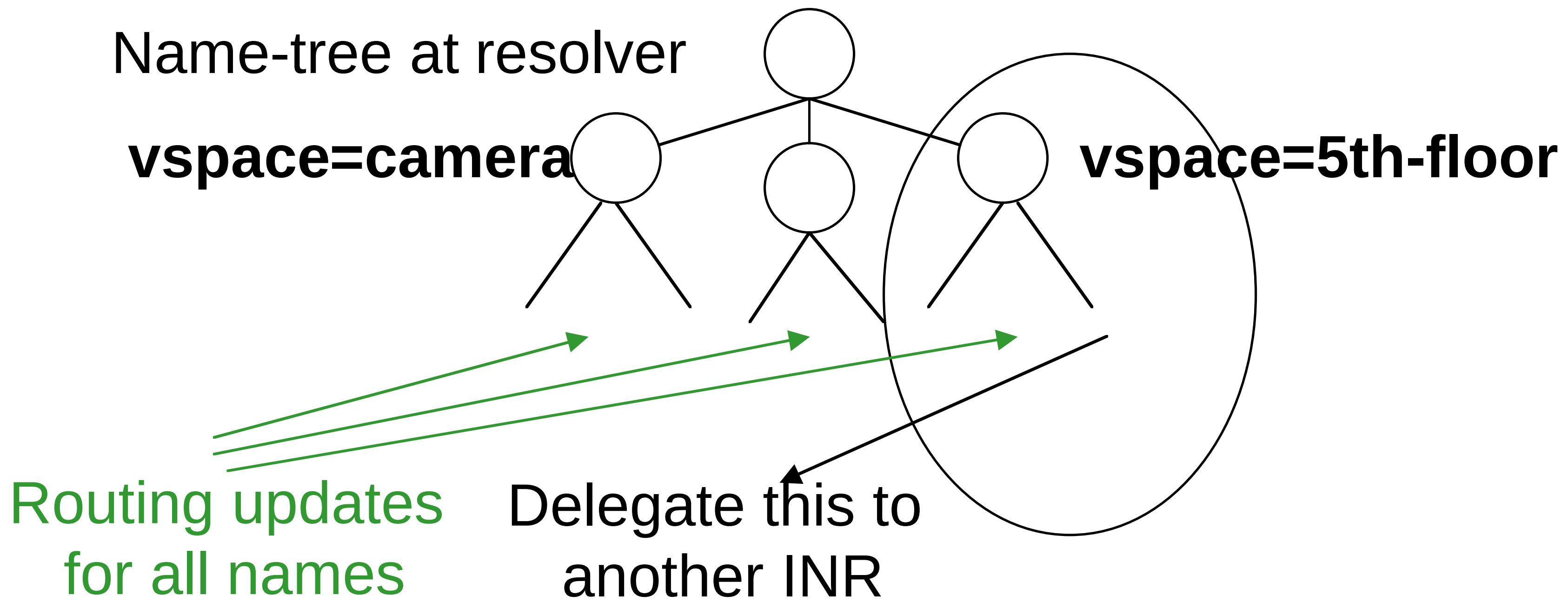
Performance and scalability

- Lookup performance



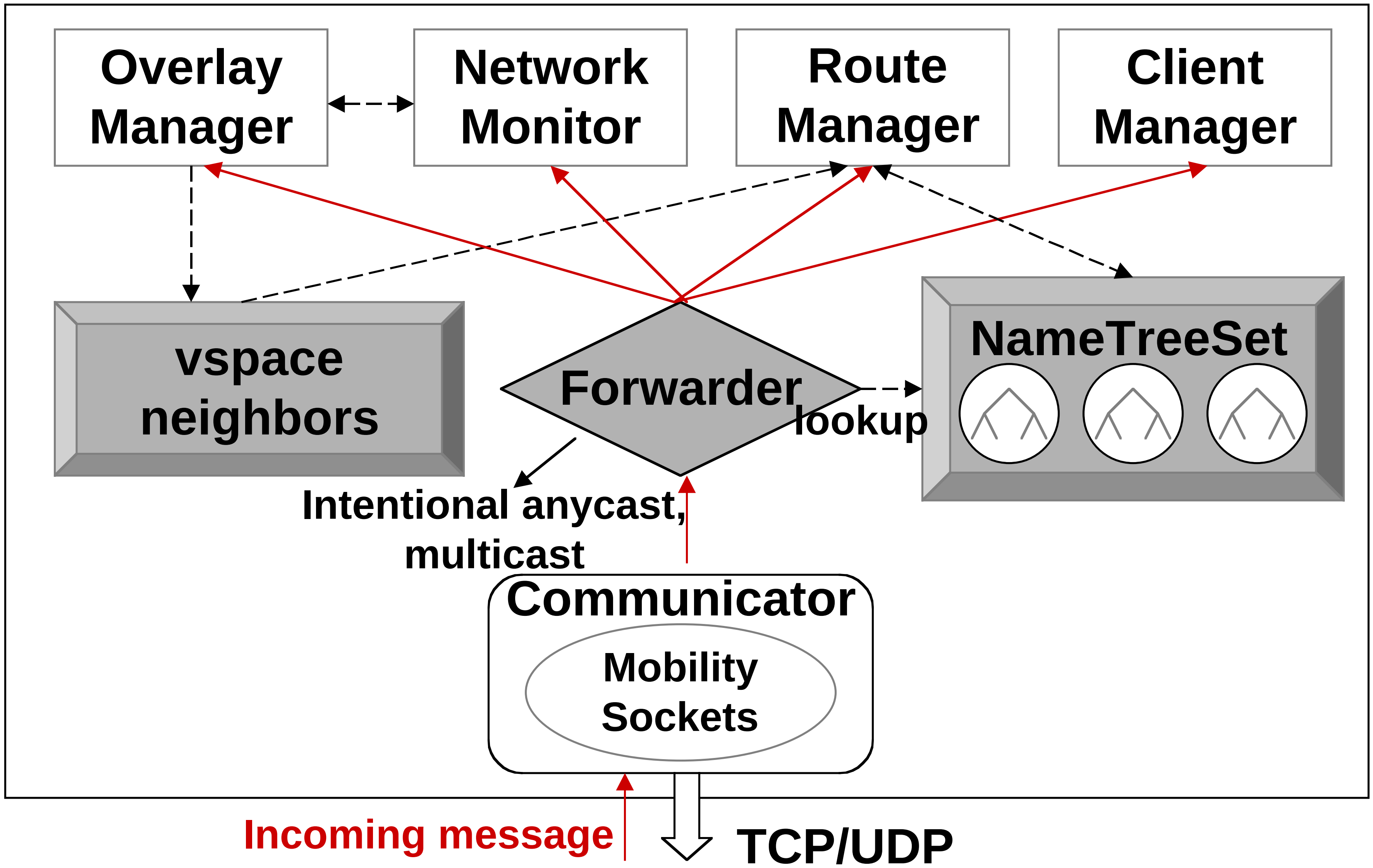
- Spawn INR on a new node to shed load

Routing Protocol Scalability



- vspace = Set of names with common attributes
- Virtual-space partitioning: each resolver now handles subset of all vspaces

INR Implementation



Applications

- Location-dependent mobile applications
  - Floorplan: An map-based navigation tool
  - Camera: A mobile image/video service
  - Load-balancing printer
  - TV & jukebox service
- Sensor computing
- Network-independent “instant messaging”
- Clients encapsulate state in late-binding applications

Status

- Java implementation of INS & applications
  - Several thousand names on single Pentium PC; discovery time linear in hops
  - Integration with Jini, XML/RDF descriptions in progress
- Scalability
  - Wide-area implementation in progress
- Deployment
  - Hook in wide-area architecture to DNS
  - Standardize virtual space names (like MIME for devices/services)

Conclusion

- INS is a resource discovery system for dynamic, mobile networks
- Expressiveness: names that convey intent
- Responsiveness: late binding by integrating resolution and routing
- Robustness: soft-state name dissemination with periodic refreshes
- Configuration: resolvers self-configure into an overlay network