Intentional Naming System

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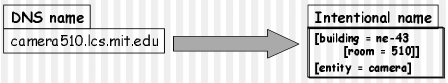
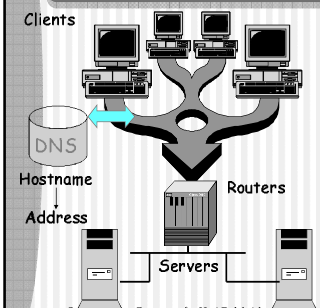


Today



- Mostly static topology & services
  - Hard to maintain
  - Adding new hosts is hard
- Deploying new services cumbersome
- Applications cannot learn about network
- Failures are common!
- High management cost

Resource discovery

- Why is this hard?
  - Dynamic environment (mobility, performance changes, etc.)
  - No pre-configured support, no centralized servers
  - Must be easy to deploy (“ZERO” manual configuration)
  - Heterogeneous services & devices
- Approach: a new naming system & resolution architecture

Terms

- INR - Intentional Name Resolver
- Name Specifier - the intentional name of each resource
- AV Pair - Attribute\Value
- Late\Early binding

INS principles

- Names are intentional, based on attributes
  - Apps know WHAT they want, not WHERE
- INS integrates resolution and forwarding
  - *Late binding* of names to nodes
- INS resolvers replicate and cooperate
  - Soft-state name exchange protocol with periodic refreshes
- INS resolvers self-configure
  - Form an application-level overlay network
  - Nodes can add/drop from network

Benefits of INS

- Heterogeneous network
- 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 principle

Expressiveness ➡	Names are intentional; apps know <u>what</u>, not <u>where</u>
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

Ad hoc configuration

- Static configuration impossible
- DHCP-like configuration undesirable
  - Over wireless, pre-configured subnetworks and broadcasts problematic
- Solution: Distributed, randomized address assignment

Name-specifiers

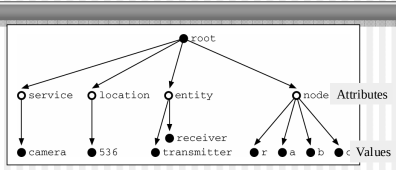
- Expressive name language (like XML)
- Resolver architecture decoupled from language
- Providers announce descriptive names
- Clients make queries
  - Attribute-value matches
  - Wildcard matches
  - Ranges

```
[vspace = camera]
[building = ne-43
    [room = 504]]
[resolution=800x600]]
[access = public]
[status = ready]
```

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

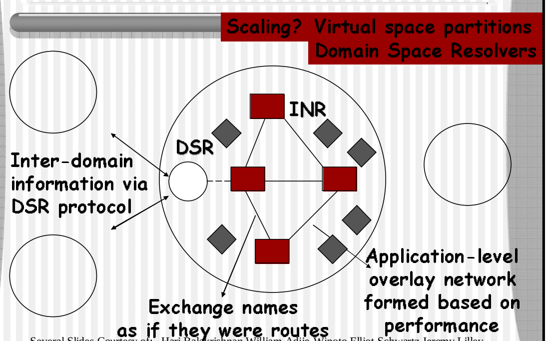
```
[vspace = mit.edu/thermometer]
[building = ne43
    [floor = 5
        [room = *]]
[temperature < 60°F]
data
```


Name lookups

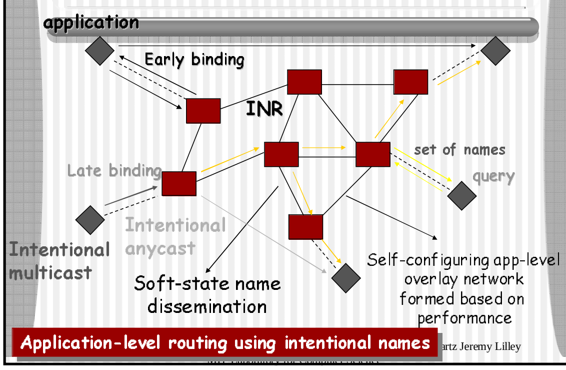


- Lookup
  - Tree-matching algorithm
  - AND operations among orthogonal attributes
- Polynomial-time in number of attributes
  - $O(n^d)$ where n is number of attributes and d is the depth

How does it work?



INS Architecture



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 - INR returns 1 location (metric based)
  - 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

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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

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Routing Topology

- Routing information
  - Triggered, Periodic updates to other INRs
- Each update contains:
  - IP Address + name specifiers + port number
  - Port numbers allow early binding
  - Application defined metric
  - Next hop INR + INR's RTT
  - Announcer ID
    - Unique to each instance of a service

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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

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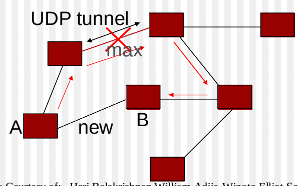
Spanning tree algorithm

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



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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

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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

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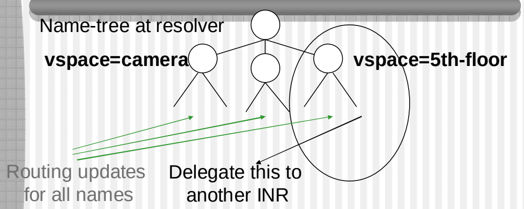
Routing Protocol Scalability



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

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Scaling issues

- Two potential problems
  - Lookup overhead
  - Routing protocol overhead
- Load-balancing by spawning new INR handles lookup problem
- Virtual space partitioning handles routing protocol problem
  - Just spawning new INR is insufficient

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Conclusion

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

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Questions?

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