Wireless Networks of Devices

Resource Discovery

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Application: Location-dependent wireless service

- Spontaneous networking
- Automatically obtain map region & discover device services and people ther
- Access, control services communicate with them
- Handle mobility & group communication
- Locate other useful serv (e.g., nearest café)

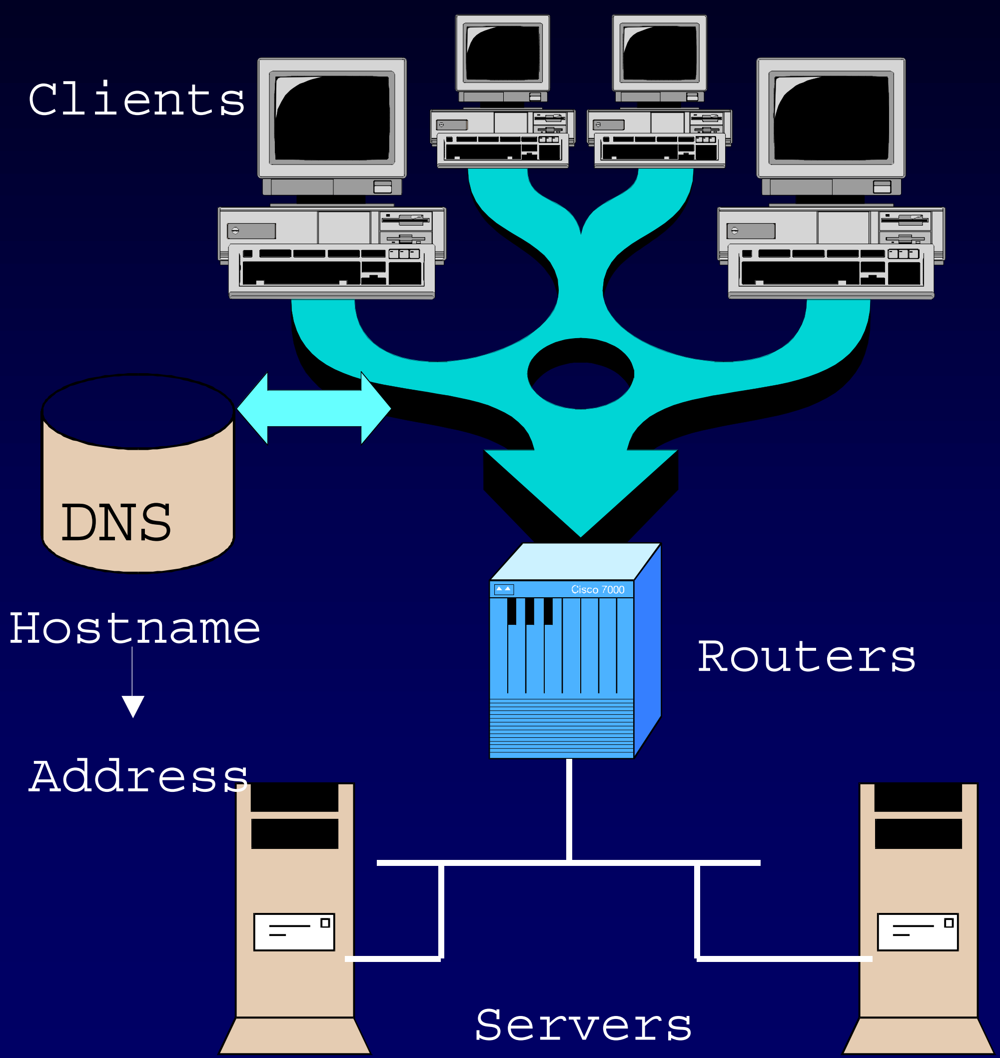
App should be able to conveniently specify a resource and access it

Challenges

- Configuration
- Routing
- Discovery
- Adaptation
- Security & privacy

Dynamic, mobile environment with no pre-config
support for internetworking or service loc

Today



- Mostly static topol
  & services
- Deploying new servi
  cumbersome
- Applications cannot
  learn about network
- Failures are common
- High management cos

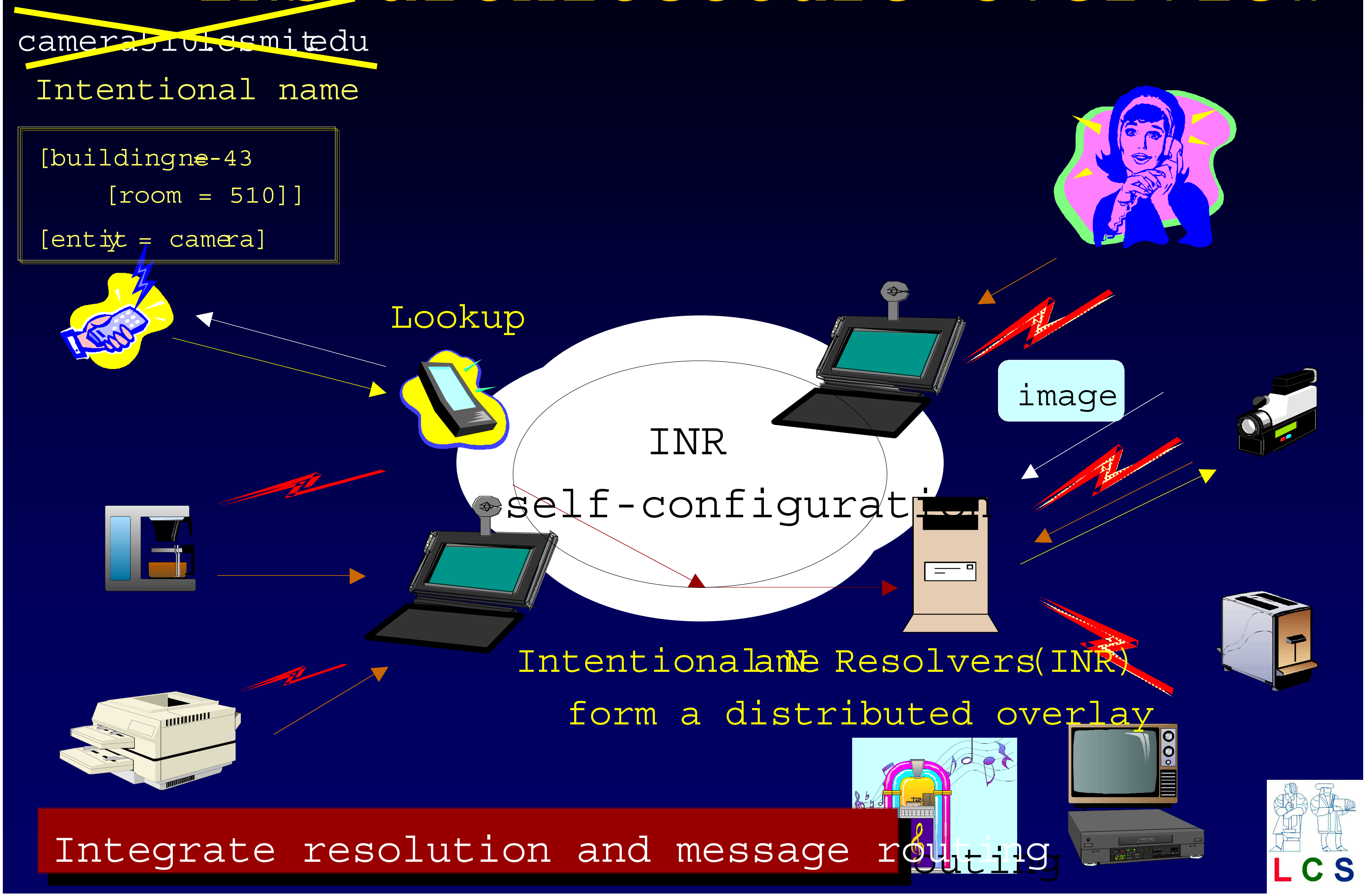
Resource discovery

- 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 using intentional naming

Design goals

Expressiveness	Names must be descriptive signifying application intent
Responsiveness	Name resolvers must track rapid changes
Robustness	System must overcome resolver and service failu
Easy configuration	Name resolvers must self-configure

INS architecture overview



Integrate resolution and message routing

Intentional Naming System (IN
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 period
    refreshes
- INS resolvers self-configure
  - Form an application-level overlay network

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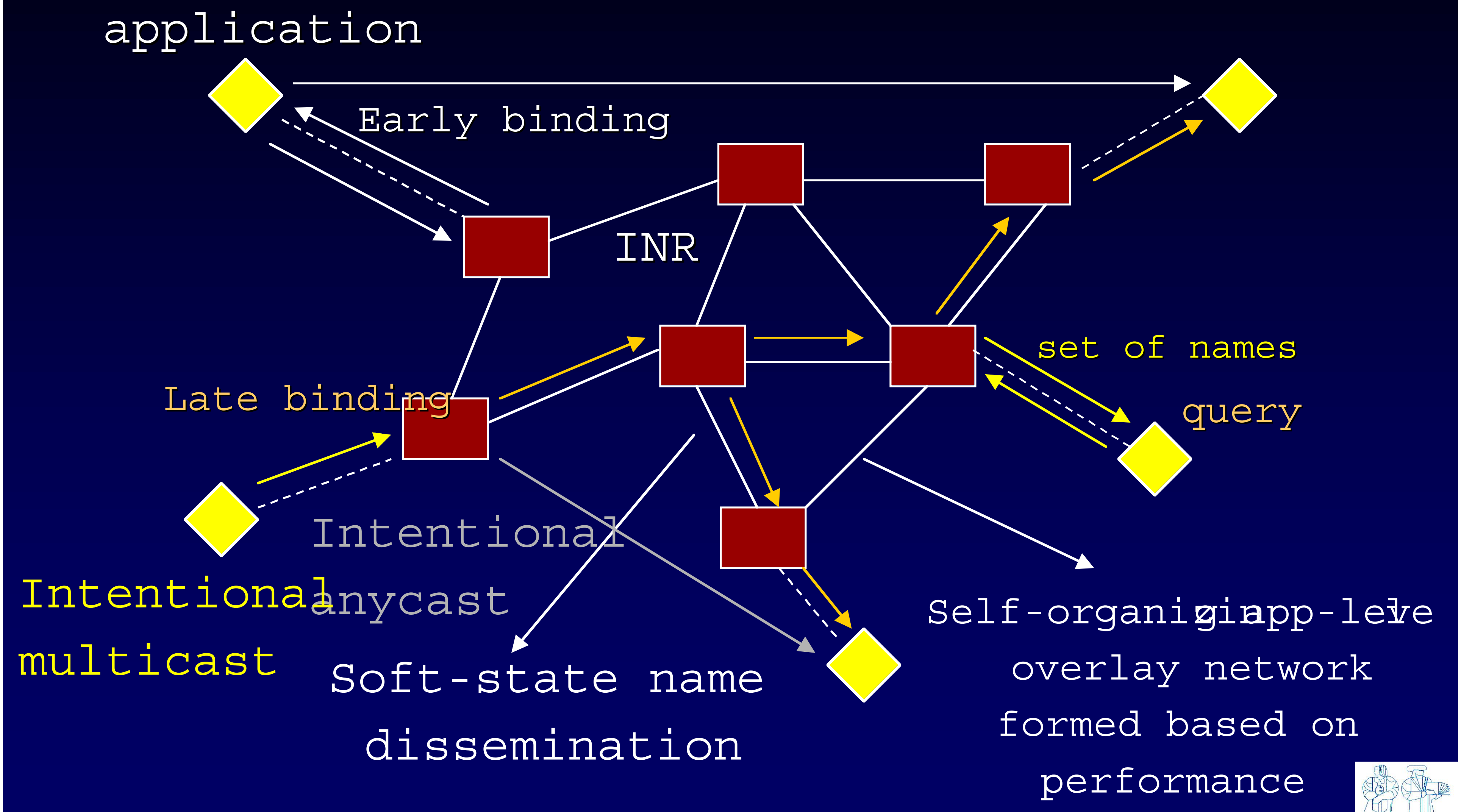
INS service model



What's in a name?

- Expressive name language (like XML)
- Resolver architecture decoupled from language

- Names are descriptive
  - Providers announce names
- Names are queries
  - Attribute-value matches
  - Range queries
  - Wildcard matches

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

```
[vspace = netgroup]
[department = arch-lab
     [state = oregon
       [city = hillsboro]]]
```

data

```
[vspace = thermometer]
[building = ne-43
    [room = *]]
```

data

Responsiveness: Late bindin

- Mapping from name to location(s) can change rapidly
- Integrate resolution and message routing to track change
  - INR resolves name by lookup-and-forward, not by returning address
  - *lookup(name)* is a route
  - Forward along route
- A name can map to one location (“anycast”) or to many (“multicast”)

Late binding services

- Intentional anycast
  - INR picks one of several possible locations
  - Choice based on service-controlled metric [contrast with IP anycast]
  - Overlay used to exchange name-routes
- Intentional multicast
  - INR picks all overlay neighbors that "express interest" in name
  - Message flows along spanning tree
  - Overlay used to transfer data too

Robustness: Names as soft-sta

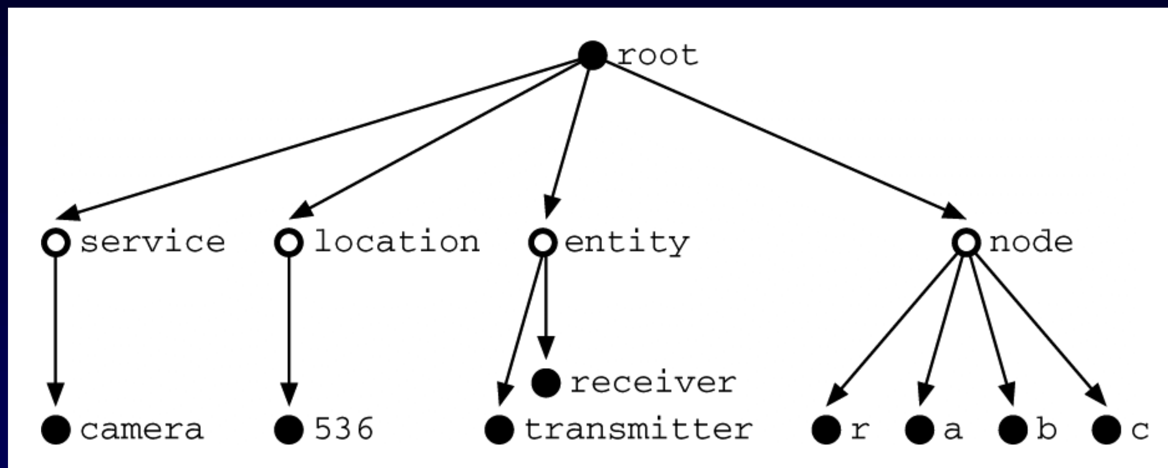
- Resolution via network of replicated resolvers
- Names are weakly consistent, like network-layer routes
  - Routing protocol to exchange names
- Fate sharing with services, not INRs
  - Name unresolved only if service absent
- Soft-state with expiration is robust against service/client failure
  - No need for explicit de-registration

Self-configuring resolvers

- INRs configure using a distributed topology formation protocol
- DSR (DNS++) maintains list of candidate and active INRs
- INR-to-INR "ping" experiments for "link weights"
- Current implementation forms (evolving) spanning tree
- INRs self-terminate if load is low

Efficient name lookups

- Data structure



- Lookup
  - AND operations among orthogonal attributes
  - For values pick the value(s) satisfying the lookup
- Polynomial-time worst case

Scaling issues

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

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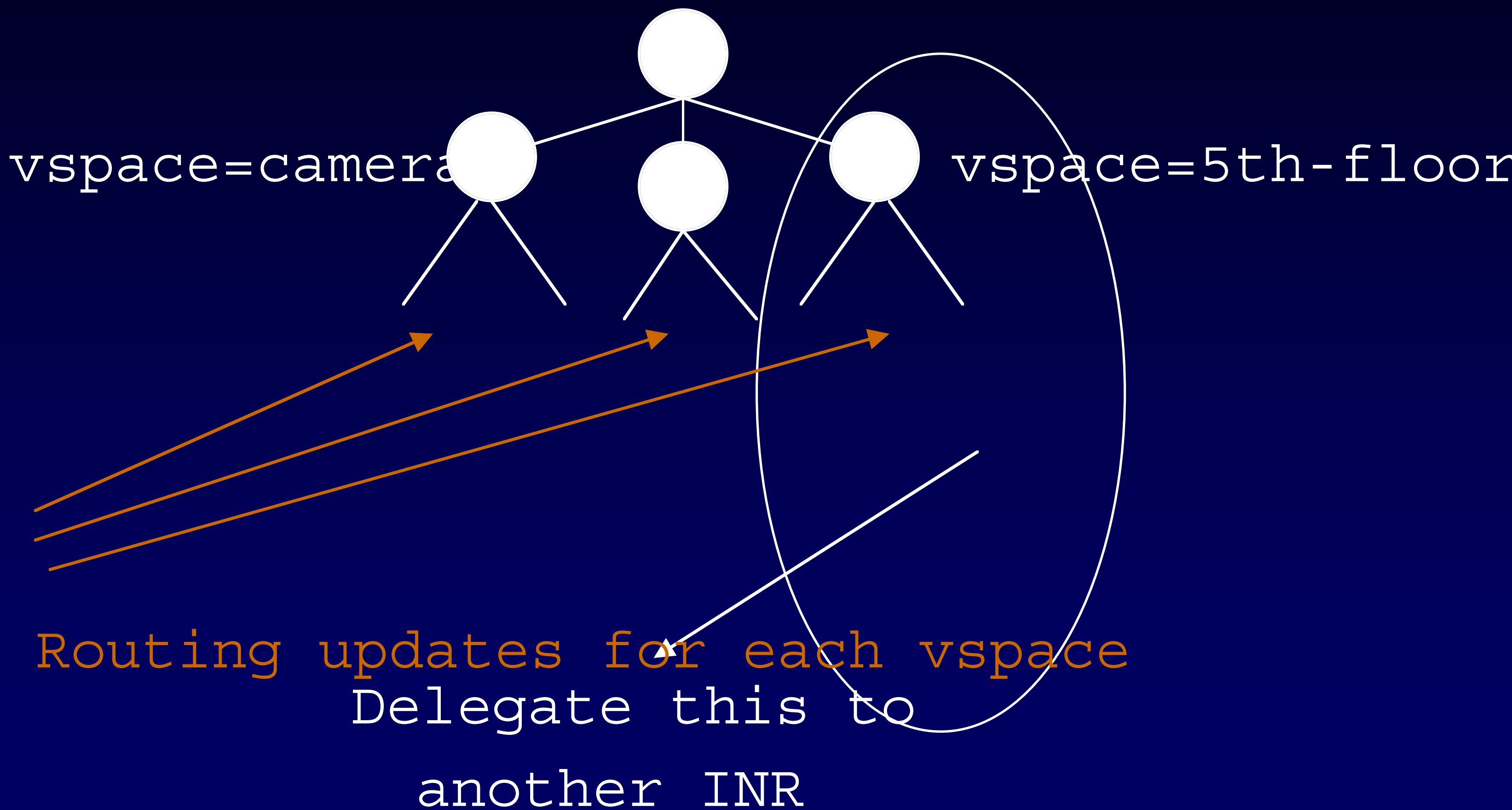
Virtual space partitioning



WIND Applications

- Location-dependent mobile applications
- Floorplan: A navigation & discovery
- Camera: An image/video service
- Printer: A smart print spooler
- TV & jukebox
- Location-support system based on intelligent beacons

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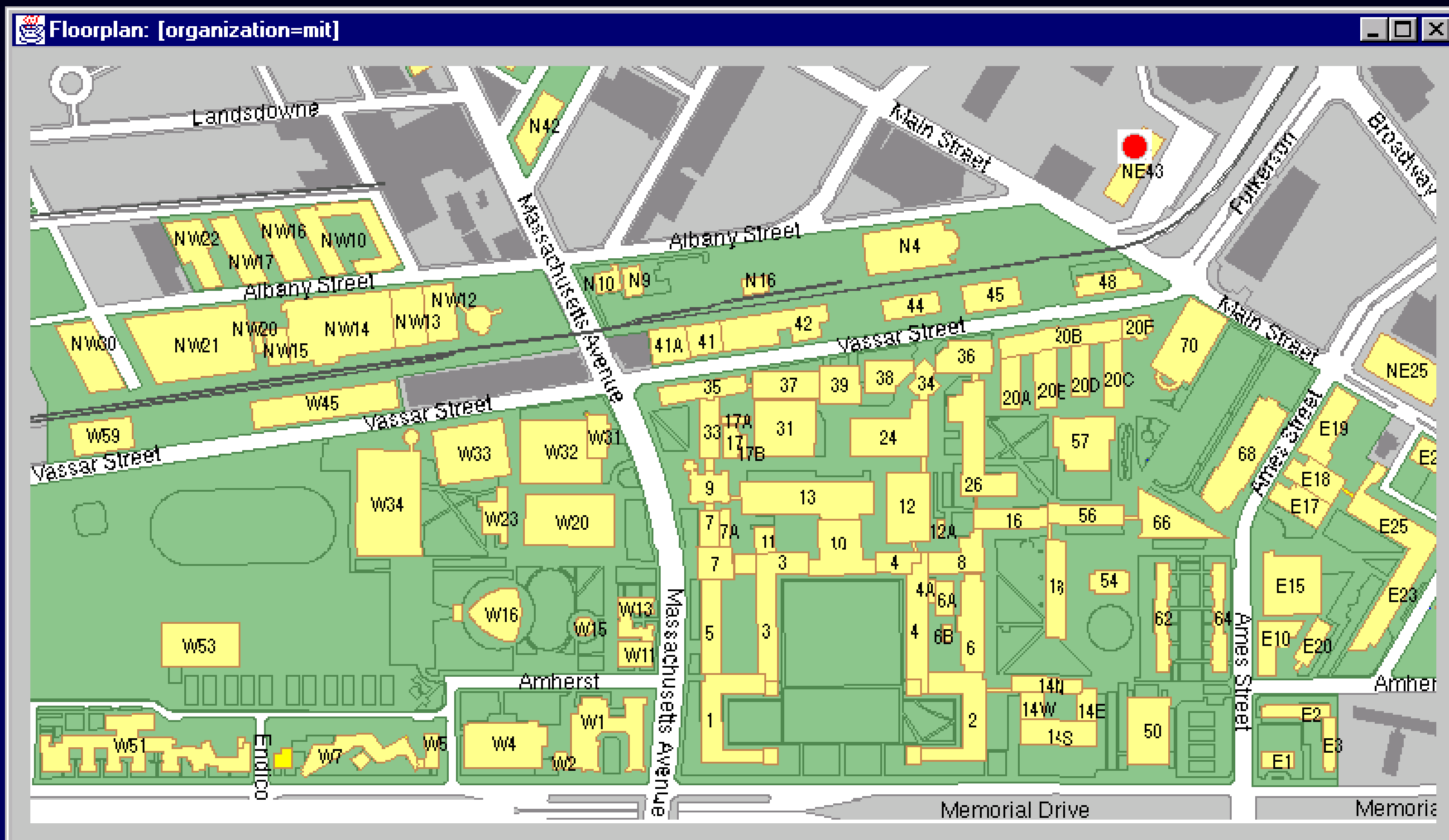
Floorplan: [organization=mit]
Landsdowne
Main Street
Albany Street
Vassar Street
Massachusetts Avenue
Fulkerson
Broadway
Ames Street
Amherst
Endicott
Memorial Drive
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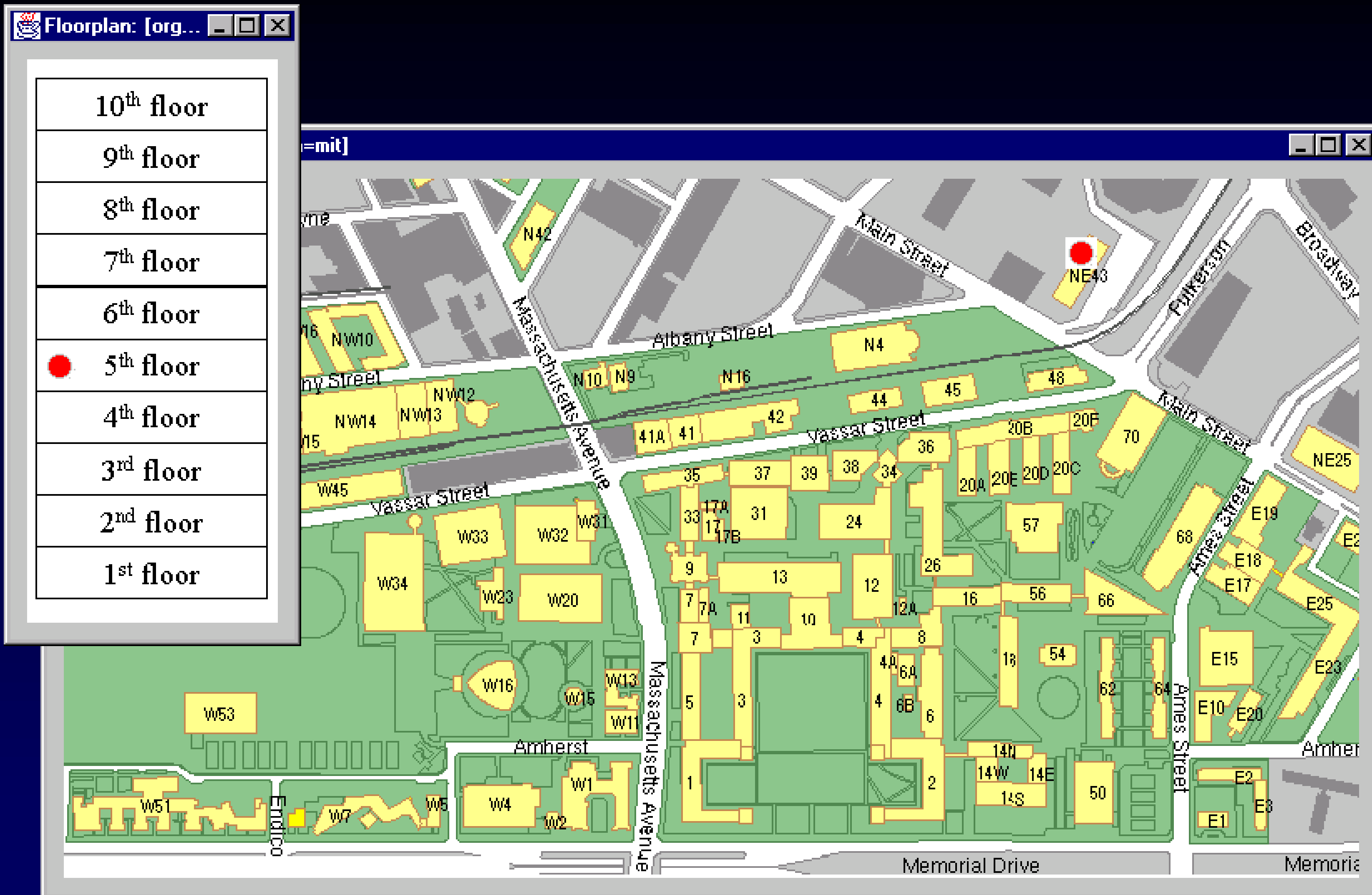

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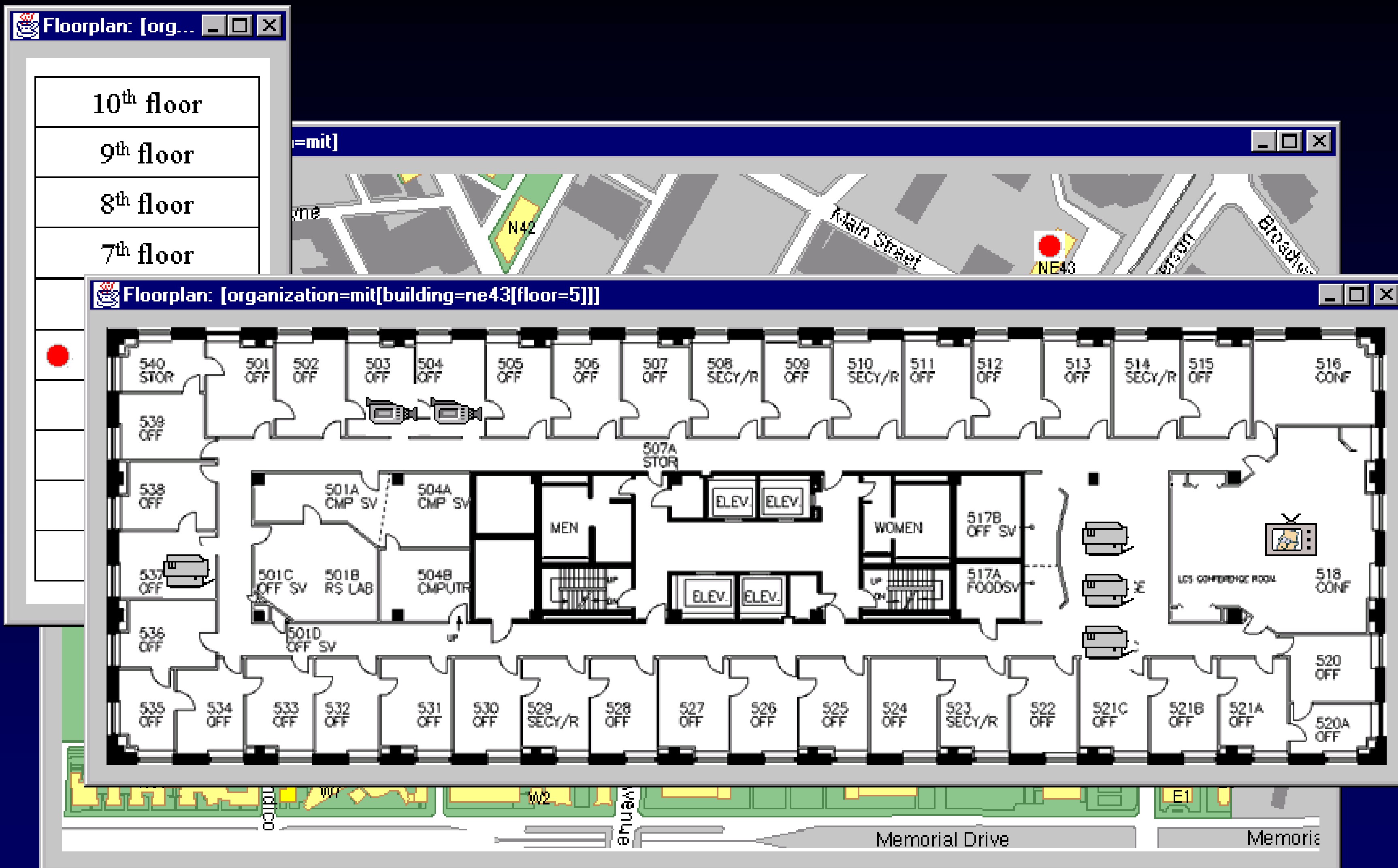

Floorplan: [org...
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E1
Floorplan: [organization=mit[building=ne43[floor=5]]]
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504B CMPUTR
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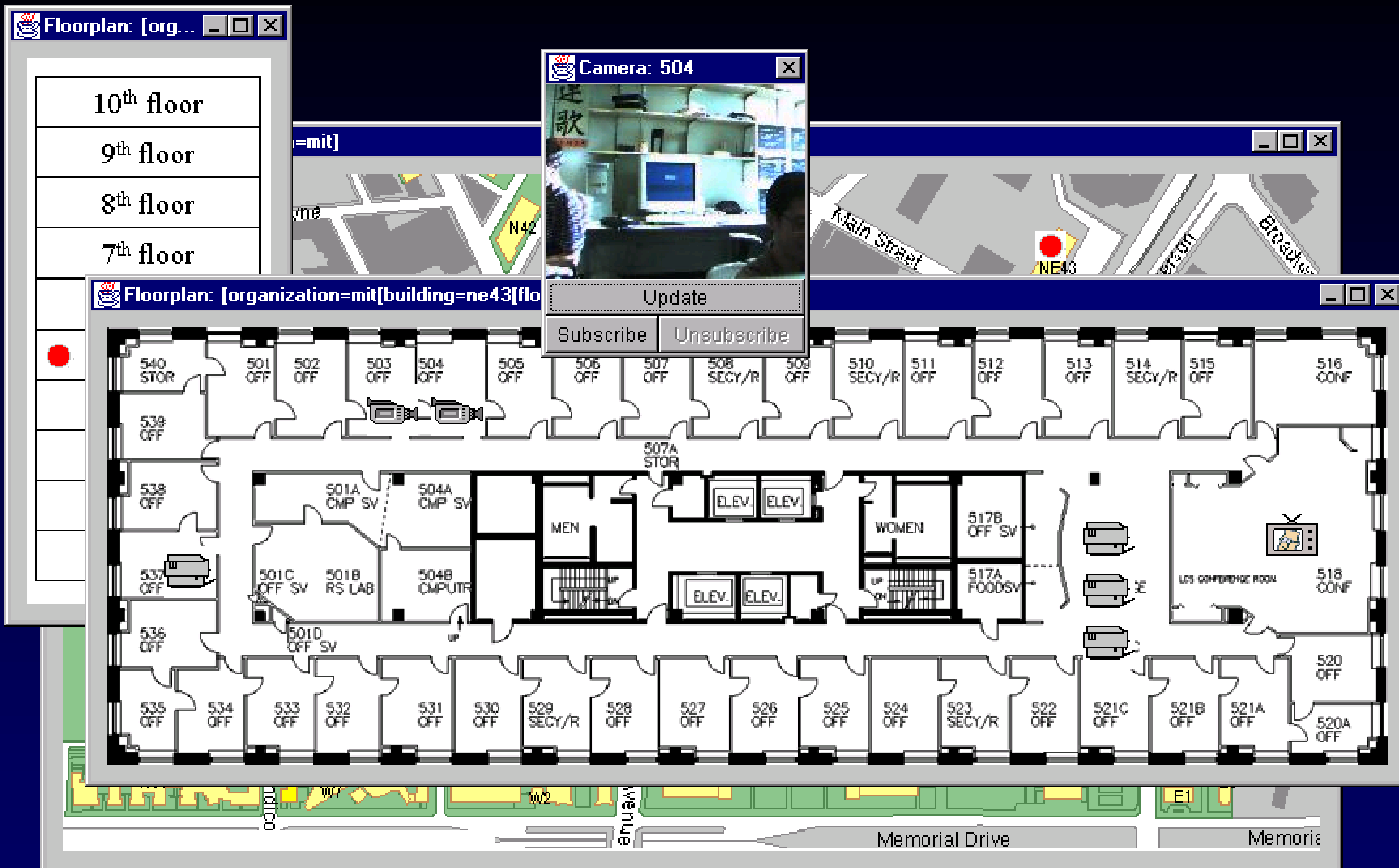
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LPR Client: pastrami @ room 537
Printer Error: may need attention! (Not Responding for 2
Rank Owner Job Files
active robcheng 5 (standard input)
1st wfang 6 /usr/tmp/figures.ps.Z3484
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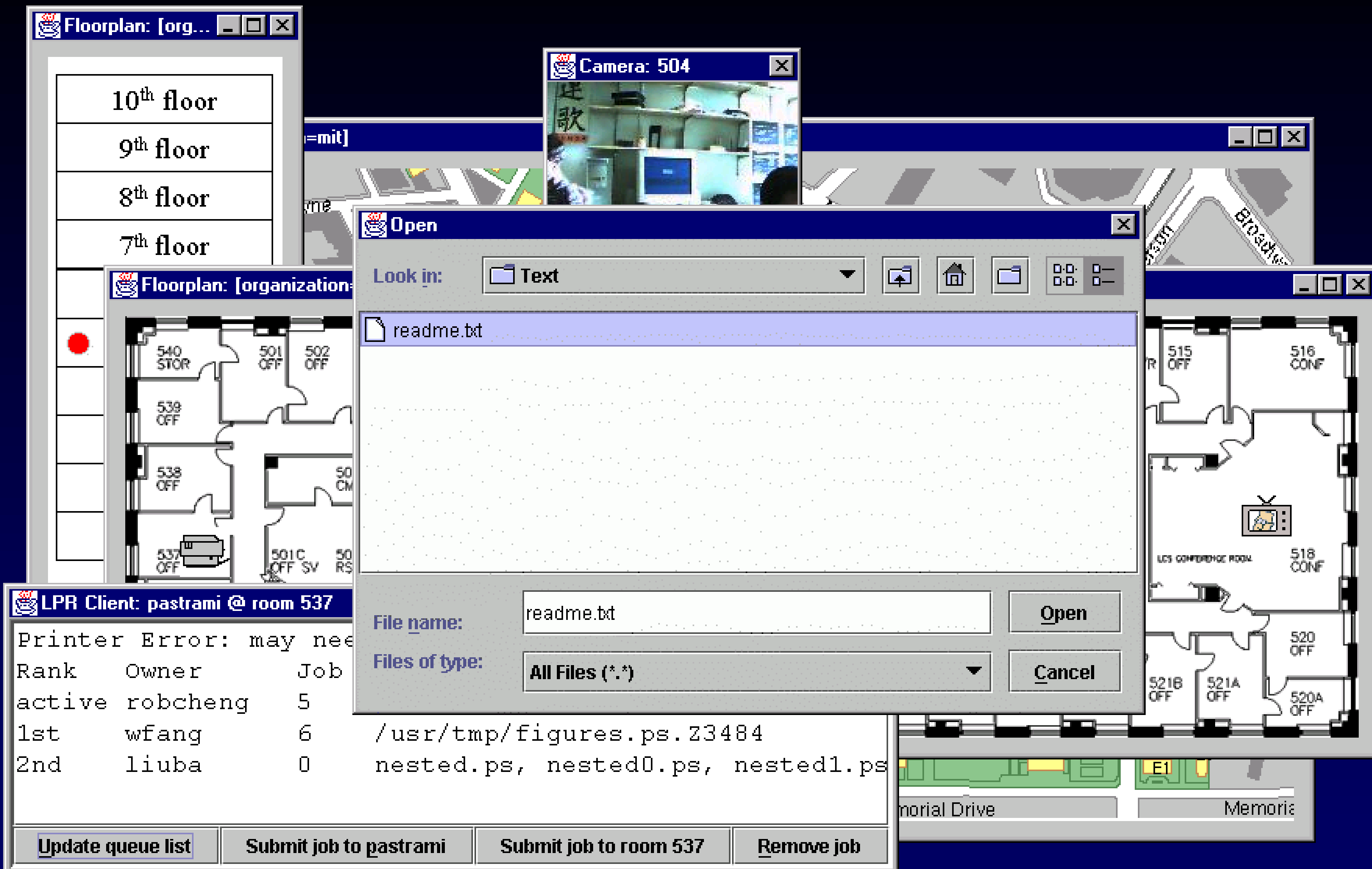

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File name:
readme.txt
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Files of type:
All Files (*.*)
Cancel
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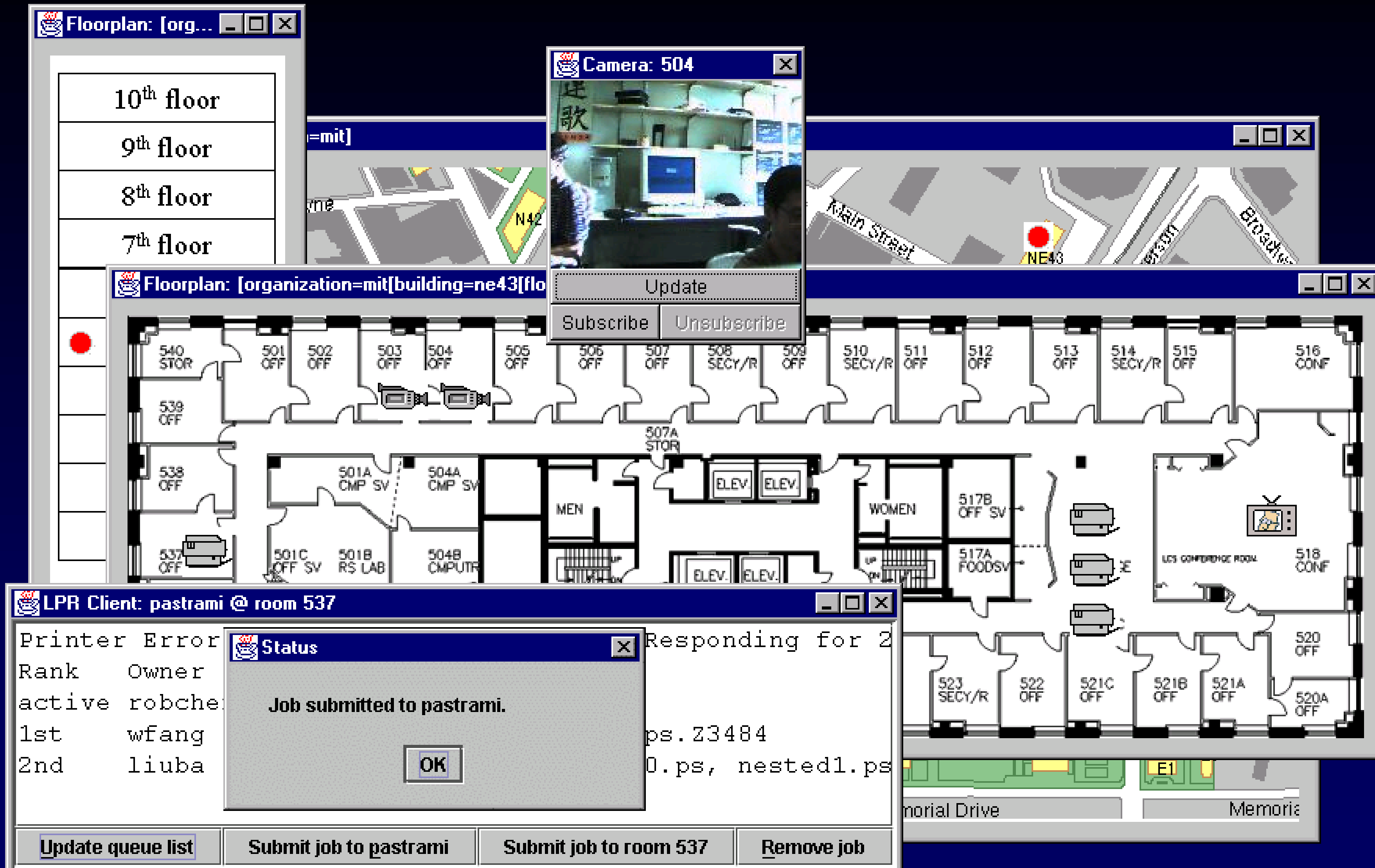
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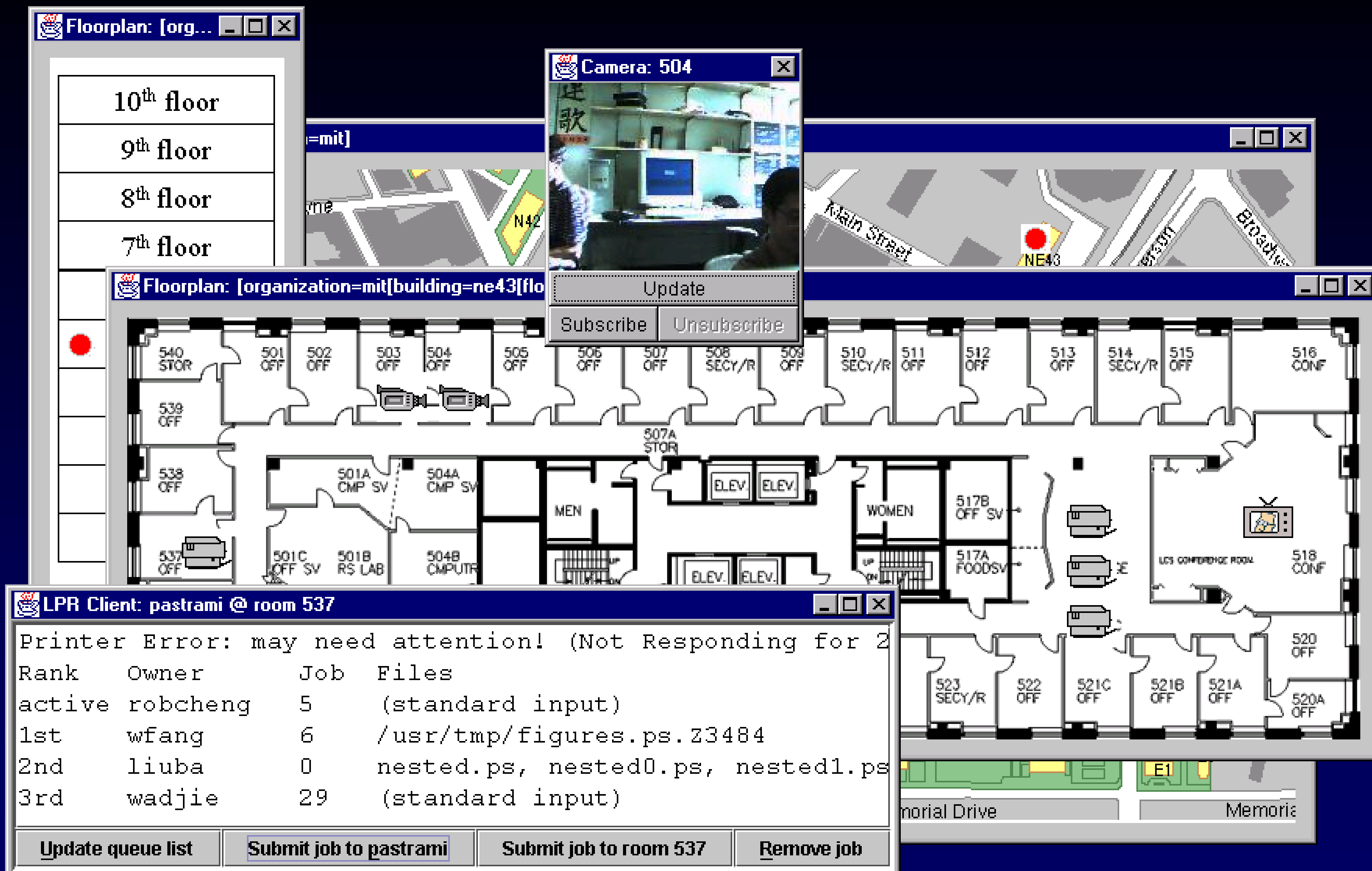
Submit job to pastrami
Submit job to room 537
Remove job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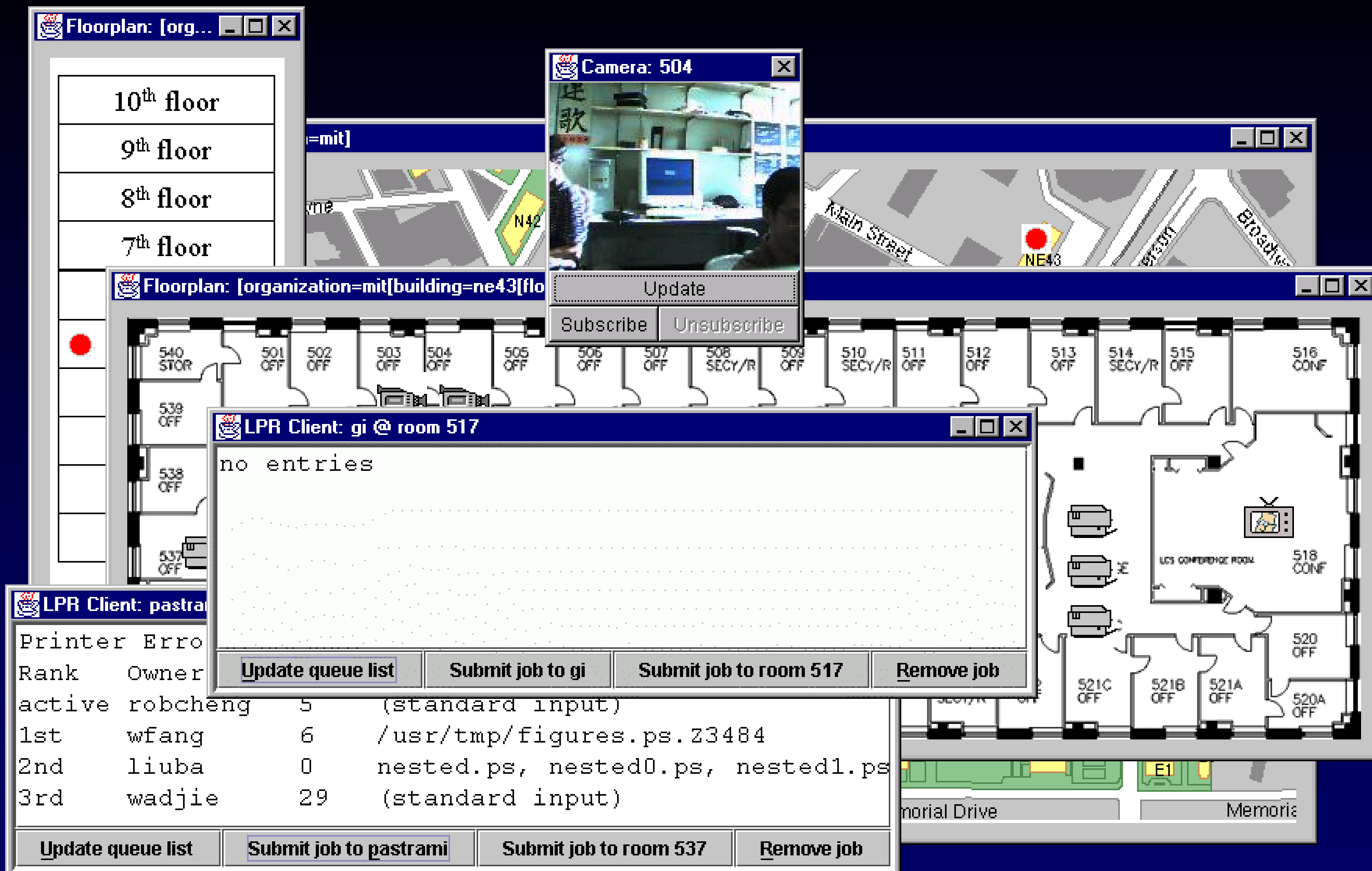
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Update queue list
Submit job to pastrami
Submit job to room 537
Remove job
morial Drive
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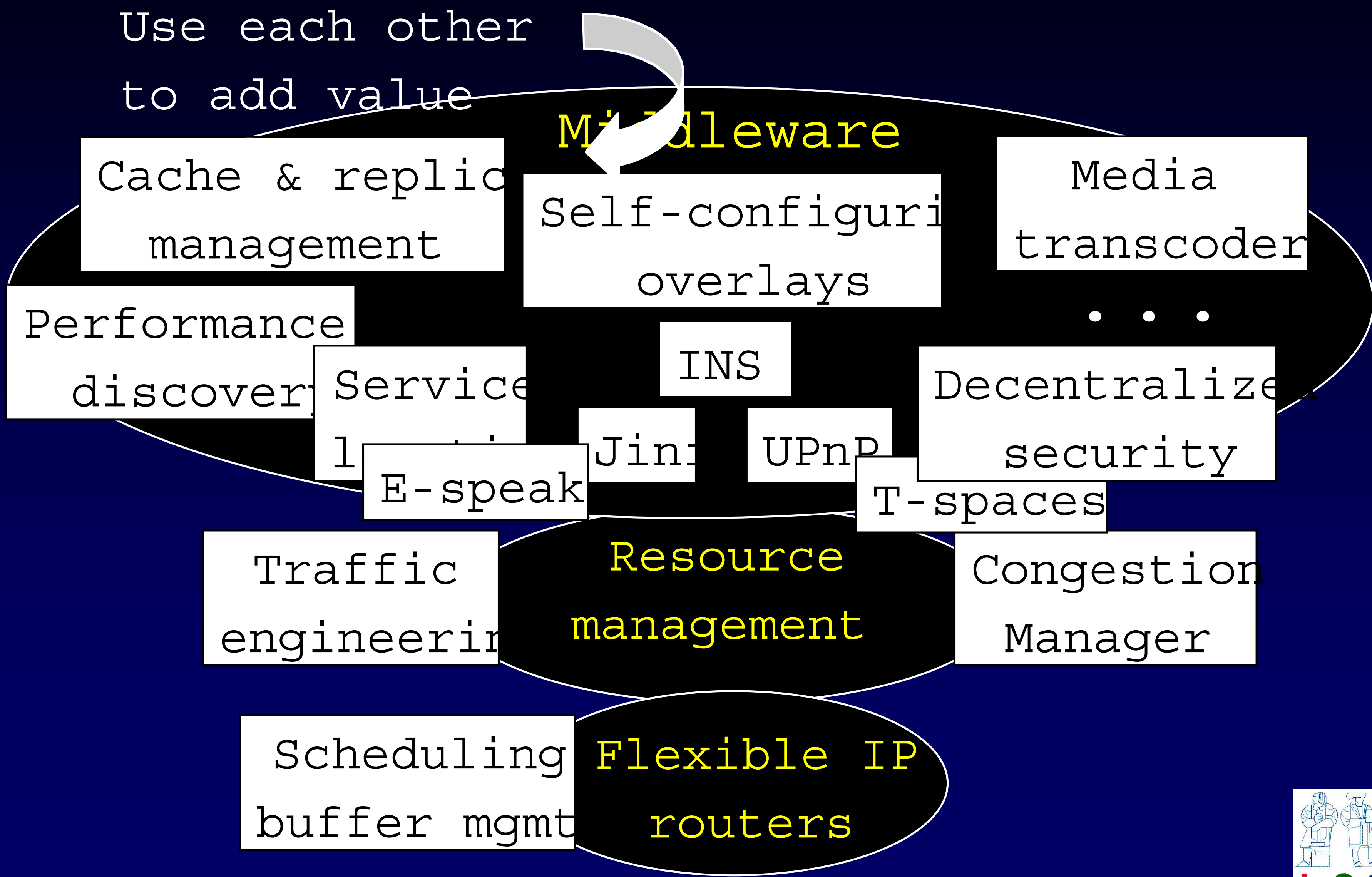
Status & performance

- Java implementation of INS & applications
- PC-based resolver performance
  - 1 resolver: several thousand names @ 100-1000 lookups/s
  - Discovery time linear in hops
- Scalability
  - Virtual space partitions for load-shedding
  - Wide-area design in future
- Deployment
  - Hook in wide-area architecture to DNS
  - Standardize virtual space names (like MIME)
- Paper at SOSP 17

Related work

- Domain Name System
  - Differences in expressiveness and architecture
- Service Location Protocol
  - More centralized, less spontaneous
- Jini
  - INS can be used for self-organization & fault-tolerant discovery
- Universal Plug-and-Play & SSDP
  - XML-based descriptions; INS fits well
- Intentional names in other contexts
  - Semantic file systems, adaptive web caching, DistributedDirector

Future Internet Architectur



Conclusion

- Achieving self-organizing networks requires a flexibl naming system for resource discovery
  - INS works in dynamic, heterogeneous networks
  - Expressiveness: names convey intent
  - Responsiveness: late binding
  - Robustness: soft-state names
  - Configuration: Resolvers self-configure
- Application-level overlay networks are a good way to build flexible, self-organizing network appli