Networks and Operating Systems for Smart Spaces

Emin Gun Sirer
Darko Stefanovic
Rossen Dimitrov
Sivakumar Venkatesan
Sandeep Neema
Huseyin Simitci

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Problem Statement

- Smart space
  - "Room" with embedded computers which create an environment for virtual collaboration
  - A space is an internal network of computers, sensors and actuators
  - Spaces are mobile
  - Spaces change over time
    - Boardroom, car, airplane, aicraft carrier, C3 room, space suit, helmet

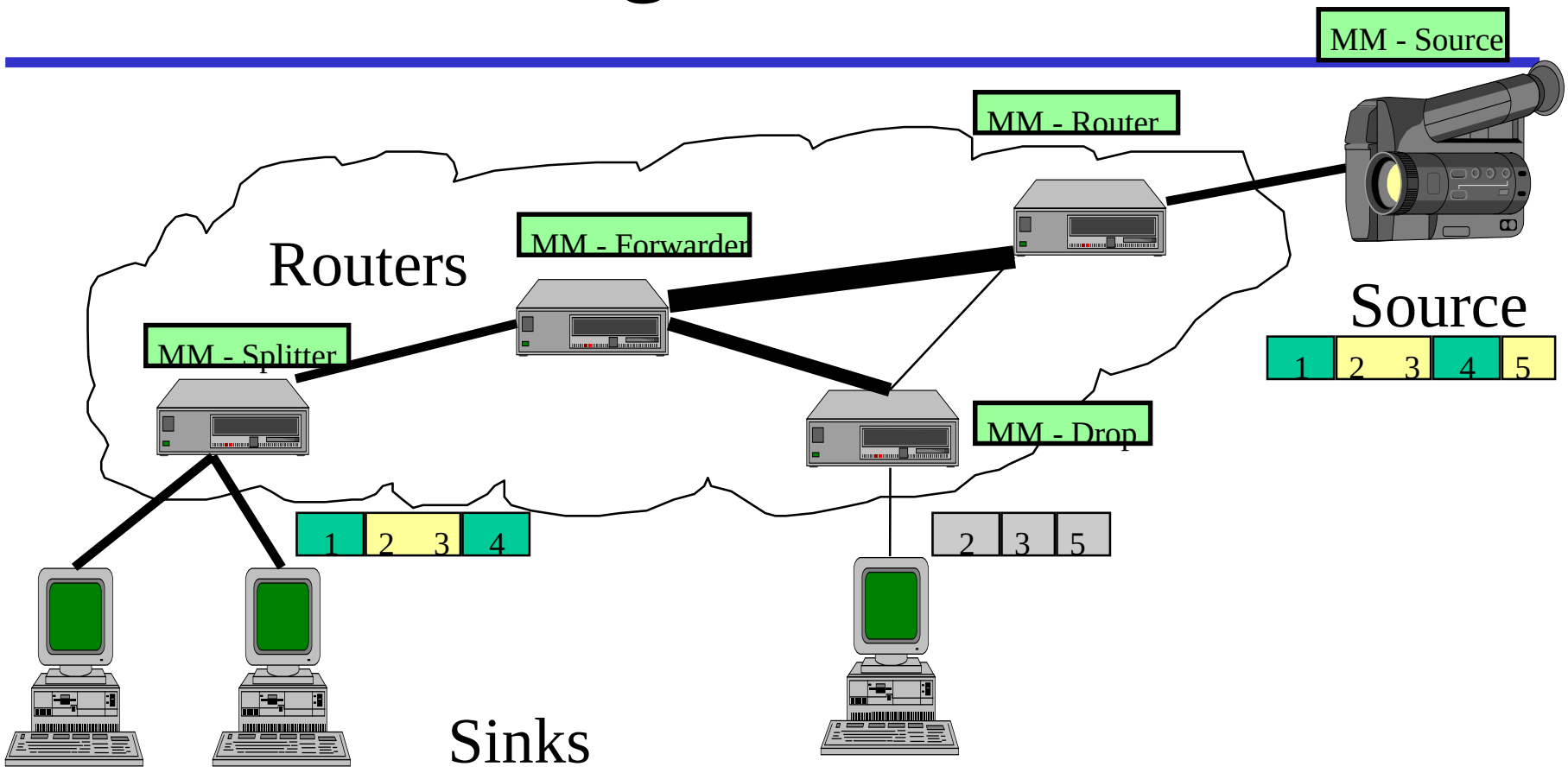
Motivating Question

- What functionality would we need from smart spaces, if the workshop was held with participants at remote sites ?
  - Support multiple video/audio streams
  - Name information sources easily and uniformly
  - Support textual I/O sources (database, web, newsfeed)
  - Create and publish info (push)
  - Create and make information available on demand (pull)
  - Authenticate sources and recipients, provide confidentiality, enforce securit constraints on participants and on sensitive information
  - Self-monitor performance, change paths,sources, connections if necessary
  - Prioritize and filter information, collate, combine and abstract info
  - Allow connections to remote compute servers
  - Support disconnected service, detect failure, tolerate if possible
  - Support mobile agents
  - Support ownership & name changes transparently

Network/OS Functionality

- Transport & Routing
- Naming
  - Uniformity, universality, context, ownership transfer
- Real-time requirements & Quality of service
- Security
  - Authentication, access control, privacy, confidentiality, auditing
- Persistent state and administration
- Information presentation
  - Prioritization, filtering, collation, abstraction
- Adaptability
  - Self-monitoring, fault tolerance, disconnection
- Mobile agents

What's wrong with the Internet?



- Fundamentally: it's end to end, and there is no way to modify internal network behavior

Engineering Trends

- Will the problems be solved by engineering efforts of the IETF ?
  - IPv6
    - Took more than half a decade to develop
    - Will take way into the next century to deploy
    - Does not address most of the problems
      - » Large namespaces are very nice to have, but 128 bits of physical addressing does not solve the logical naming problems. Optional headers are also nice, but doesn't specify how to use them to provide the functions we need
- The problems require fundamental research

Research Trends

- Do active networks solve all the problems ?
  - Enable internal nodes of the network to execute application-specific functions
  - The network can make better informed decisions
  - Applications can provide more functionality
- Enabling technology, but does not solve problems in and of itself

Active Networks

- Issues that need to be addressed in the presence of an active network infrastructure
  - Design of safe interfaces for active code (may draw on extensible system design, e.g. SPIN, Java, Exo, Vino, etc.)
  - Security concerns, perimeter protection
  - Establishment of protocols for code distribution
  - Per-connection or per-packet ?
  - Long-term state
  - Fault isolation
  - Performance

Overview

- In the next few slides, we identify interesting research issues in areas of functionality that are relevant to smart spaces

Security

- uthentication
  - ACurrently, there is no mechanism for establishing and verifying identities
  - Need a global infrastructure for identity/principal and key management (eg SDSI/SPKI)
  - Integrated with a naming scheme
- Privacy & Confidentiality
  - Existing standard techniques need to be applied and deployed
  - Need protocol for encrypting control messages within the network (e.g. headers, control packets), not just the data

Security Infrastructure

- The trusted computing base should be well-defined and quantifiable, preferably small
- Clear interface boundaries
- Need enforcement of system-wide security constraints, especially at perimeters
- Need central management of security state
- Need to share & analyze security policies, need to investigate security policy specification languages which facilitate automated analysis
- Network nodes should have security parameters associated with them
- Numerous tie-ins to Kimera work

Naming

- Current DNS/URL scheme for naming is chaotic and does not scale well
- Requirements from a good naming scheme
  - Universality
  - Uniformity
  - In-context interpretation
  - Extensibility
  - Logical structure
  - Scalability
  - URNs are an alternative, but do not address all requirements

QoS/RT Requirements

- RSVP
  - has a limited set of parameters to describe dynamically changing resource requirements
    - » If an application's needs can be described within the parameters, everything is great
    - » If not, the application is out of luck
- Possible alternative #1 - RSVP++
  - A protocol for reserving time-varying resource requirements and expressing requirements in a flexible way
- Alternative #2 - Application-specific reservations
  - Use active networks to deploy app-specific

Adaptability

- Driving observation: Very difficult to develop adaptive applications
- Need libraries for aiding adaptive application development
  - Need to abstract low-level signals into high-level upcalls
  - Examples: group management, dynamic resolution management for multimedia streams, etc.

Information Filtering

- Filtering is a very common operation
  - May be performed better at different places in the network, maybe at the source, destination, or within
- Support for shipping computation
  - Support for mobile agents would benefit
  - Must be transparent
  - Must support a uniform programming model
  - Must support access to persistent state that outlasts connection lifetimes

How to get there

- Very hard to deploy protocols in the real world
- Use tunneling on the existing Internet
  - Has been done already in the MBONE
  - Utilize existing infrastructure, support additional functionality
  - Only needs a protocol for distributing protocols around the internet

Conclusions

- Boundaries between applications, operating systems and networks are shifting
  - Java, SPIN, PCC, SFI et al.
- Need infrastructure for creating, defining and minimizing boundaries
  - Short, well-defined boundaries are easy to secure and manage