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Agents

- An agent is an autonomous program.
  - It executes code and can communicate with other agents.
- All the components in a pervasive computing application (whatever that is) usually called agents
  - An agent may be a “proxy” for a device
  - Devices, like camera or keyboards, are controlled by some proxy agent
- Agents may appear or disappear at any time
  - There is some issue in how to start them
  - There can be problems when they crash
    - there may be replicates

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A collection of agents

- Parallel or distributed programming
  - a bunch of communicating agents working to solve a problem
  - faster
    - two heads better than one
  - geographically distributed
    - everyone can't live together

Agent communication

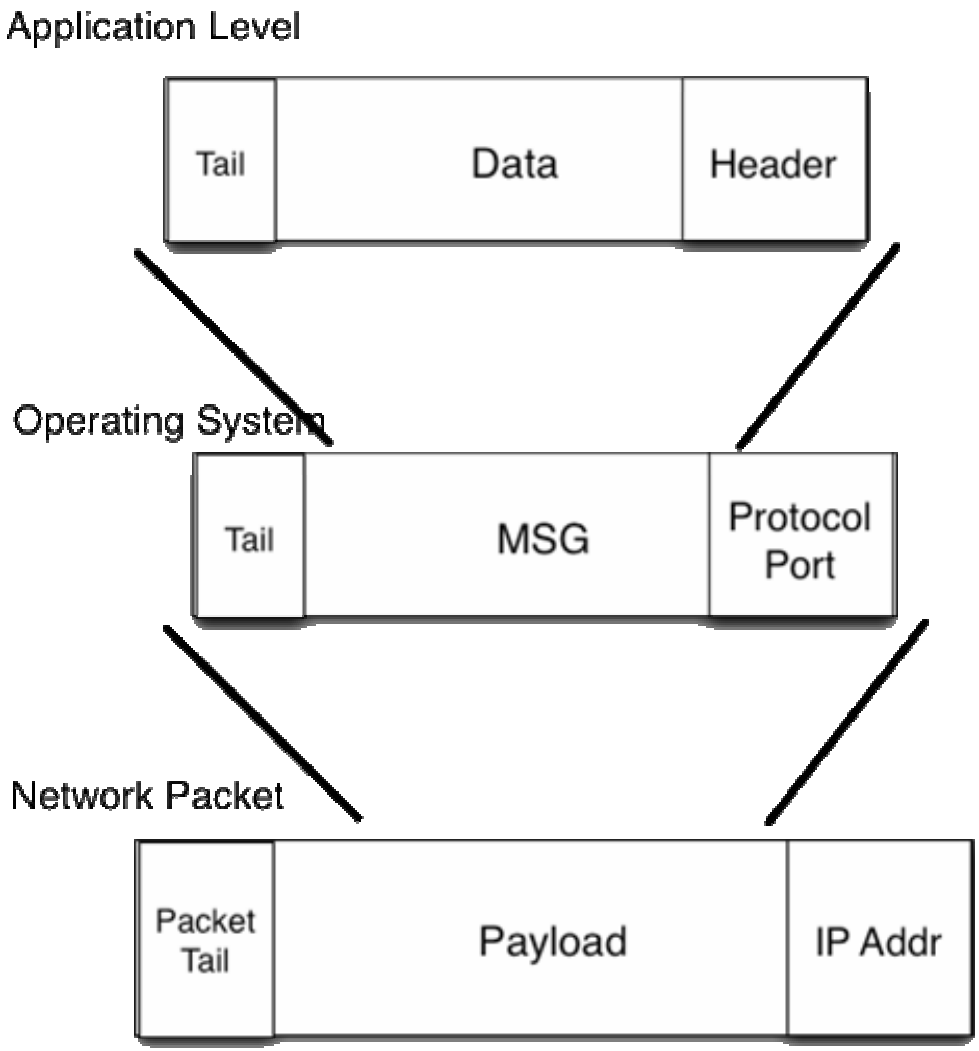
- Two main choices:
  - (which was best used to be “religious battle”)
- Shared memory (SM)
  - agents load and store values
    - start with a set of numbers
    - remove two numbers, insert their sum
    - done when only one value remains
  - issues: synchronization, locks, etc.
- Message-passing (MP)

Agent communication

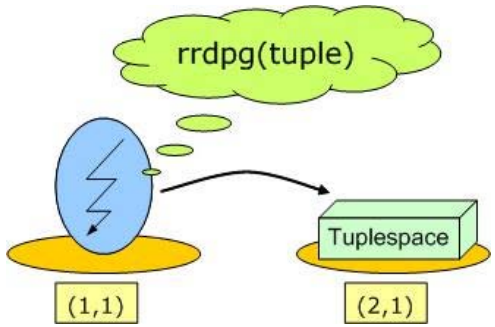
- Message-passing
  - two parts: destination, data
  - Agent Bob: Send(Alice, “Do you want to go out?”)
  - Agent Alice: Recv(from,msg)
    - from = Bob; msg = “do you want to go out?”
    - send(Bob, “No”)
- Issues:
  - Sender must know destination, recv need not
  - blocking or non-blocking
  - low performance, lots of copying of data
- Note: MP can implement SM and vica-versa
  - MP on clusters, SM on multiprocessors

Message Passing via Sockets

- Sockets are general Application can specify
  - port
  - protocol
  - other attributes
- Message-Passing
  - library does all the specification
  - may reformat data

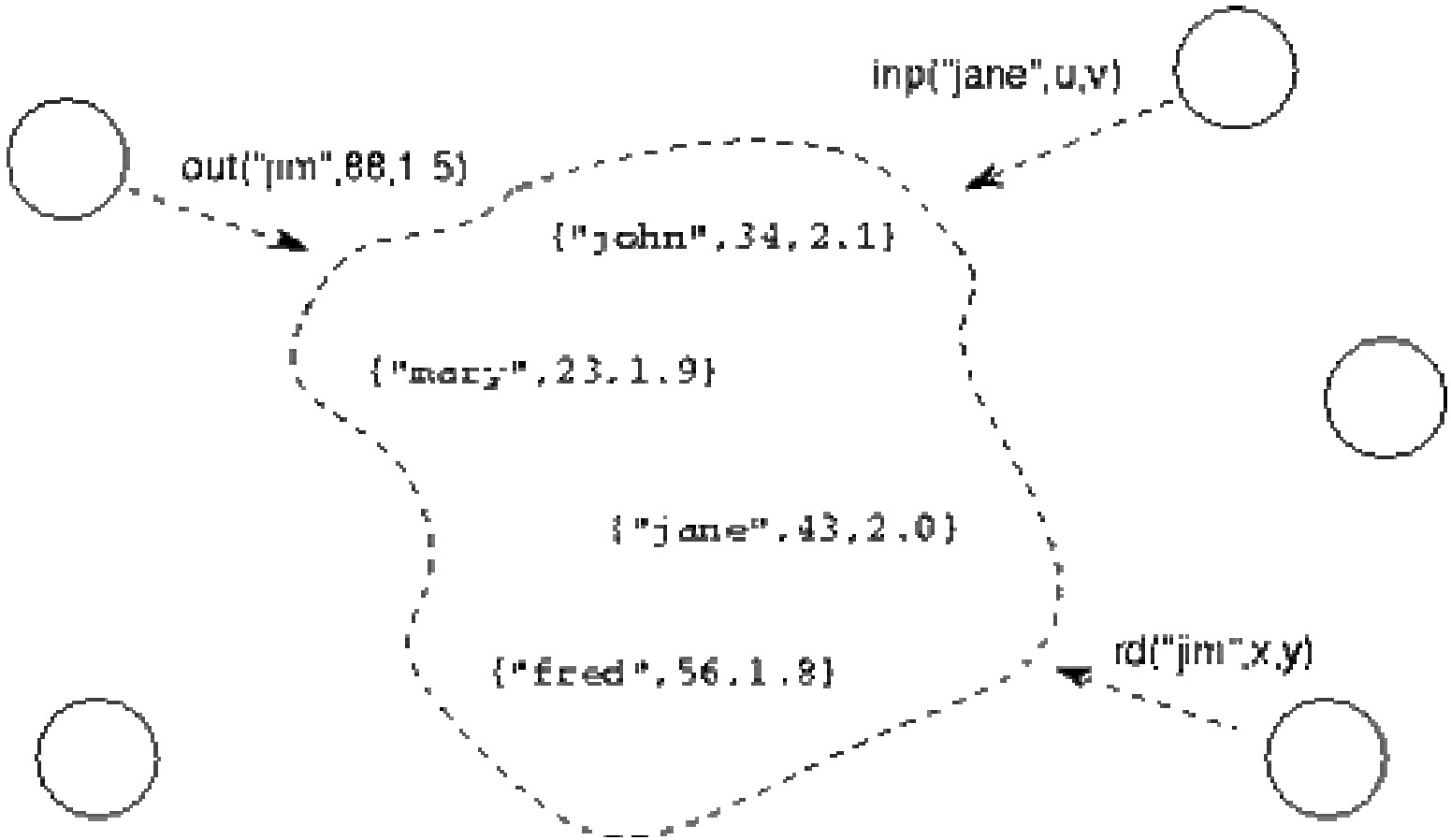


Tuple-space



- A third communication mechanism!
  - formed basis of Linda programming language
  - tuple: ordered collection of typed elements
- Basic Operations
  - **out**: inserts a tuple, whose fields are either
    - **actual**: a static value
    - **formal**: a program variable
  - **in**: extracts tuple, argument is template to match
    - actuals match fields of equal type and value
    - formals match fields of same type
  - **rd**: same as in, but does not remove matched tuple

Tuple-space example



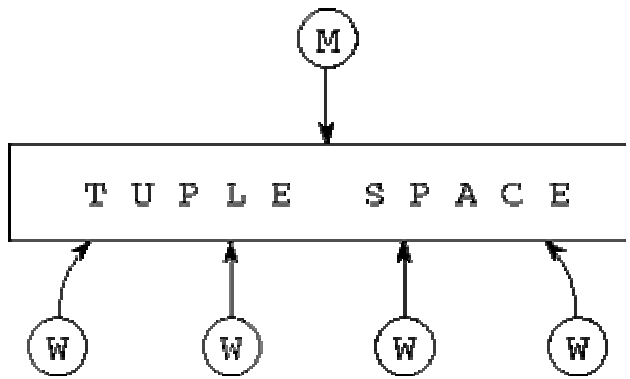
Linda programming example

```
procedure manager
begin
  count = 0
  until end-of-file do
    read datum from file
    OUT("datum",datum)
    count = count+1
  enddo
  best = 0.0
  for i = 1 to count
    IN("score",value)
    if value > best then best = value
  endfor
  for i = 1 to numworkers
    OUT("datum","stop")
  endfor
end
```

```
procedure worker
begin
  IN("datum",datum)
  until datum = "stop" do
    value = compare(datum,target)
    OUT("score",value)
    IN("datum",datum)
  enddo
end
```

What is the big deal?

- Virtual shared memory
  - tuples with [address,value]
  - stores are inserts, loads are non-destructive reads
- Virtual message passing
  - tuples with [dest, data]
  - recv are destructive reads
- Even more, when matching on multiple fields
- Allows many types of implementations



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Agent Interaction Choices

- Direct communication model
  - Jini
  - FIPA
- Indirect, Shared Data-space models
  - EventHeap (centalized)
  - MARS (fully distributed)
- Event-based publish/subscribe models
  - Siena
  - Jini Distributed Events
  - Selective subscription

Stanford's Event Heap

- Based on Tuple Space paradigm
  - tuple: arbitrary mix of typed fields
  - mechanism for passing data & events
- Extensions make it useful for agents
  - many projects exist based on different extensions

Event Heap Extensions

- Extended Delivery Semantics:
  - Per-source ordering, always see events in order they are generated by the source
  - Total order: if tuple space is centralized, get this even if multiple sources
- Persistent Queries:
  - non-destructive read of those matching
  - also matches tuples inserted in future
- Event Notification:
  - like PQ, get notified of future matches
  - at most once semantics

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Need more than simple event heap

Suggested additions

- Need “distributed, replicated or federated local instances
  - (from paper by Storz, Friday, & Davies)
- Multiple event heap instances -- but not easy of implement
  - View: processes that share a view have consistent ordering
  - Session identifiers
    - non-destructive operation on per-session identifier basis
    - can share, copy, or destroy id’s for different semantics

More general issues

- Lots and lots of middleware systems
  - no winner (may never happen)
- What gets communicated?
  - services, events, XML records
- The shared space is often a: BROKER
  - The broker stores the tuples and does the matching

Big Issues

- Naming
  - This is a big, big deal.
  - e.g. how do you name a camera:
    - model brand, IP, DNS name, location, virtual space
    - via attributes (color, 740x1024), ownership?
    - Is there only one name for the agent?
- Matching
  - A big deal
    - Which attributes explicit, which implicit
    - Where to do the lookup?

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Issues

- Addition information provided by broker
  - for services: how to interface them
  - filtering events
  - higher level events implemented at broker
    - based on multiple basic events
- Adaptivity
  - When to discard services, events
    - keep alive, heartbeats
  - Invoke new instance of service automatically
  - Fault tolerance

Issues

- Standards
  - XML, SOAP, WSDL
  - Proprietary Interfaces
- Middleware may be new Operating System
  - Whoever controls it will dominate
  - Not clear if there is or will be a winner
- Integration with web-services
  - Lightweight devices are different
  - May want stateful communication

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