

# Publish-Subscribe Enabled Multisensor Data Fusion

The Federation of Critical Infrastructure Information

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# Ta Prohm, Angkor



Mid 12<sup>th</sup> - Early 13<sup>th</sup> Century Bayon Period

# Goals

- ◆ Dynamic integration of heterogeneous data fusion computing and information services
- ◆ Timely information dissemination
- ◆ Support for loosely-coupled, distributed service oriented applications
- ◆ Scalable deployment suitable for federal critical infrastructure protection

# Acknowledgements

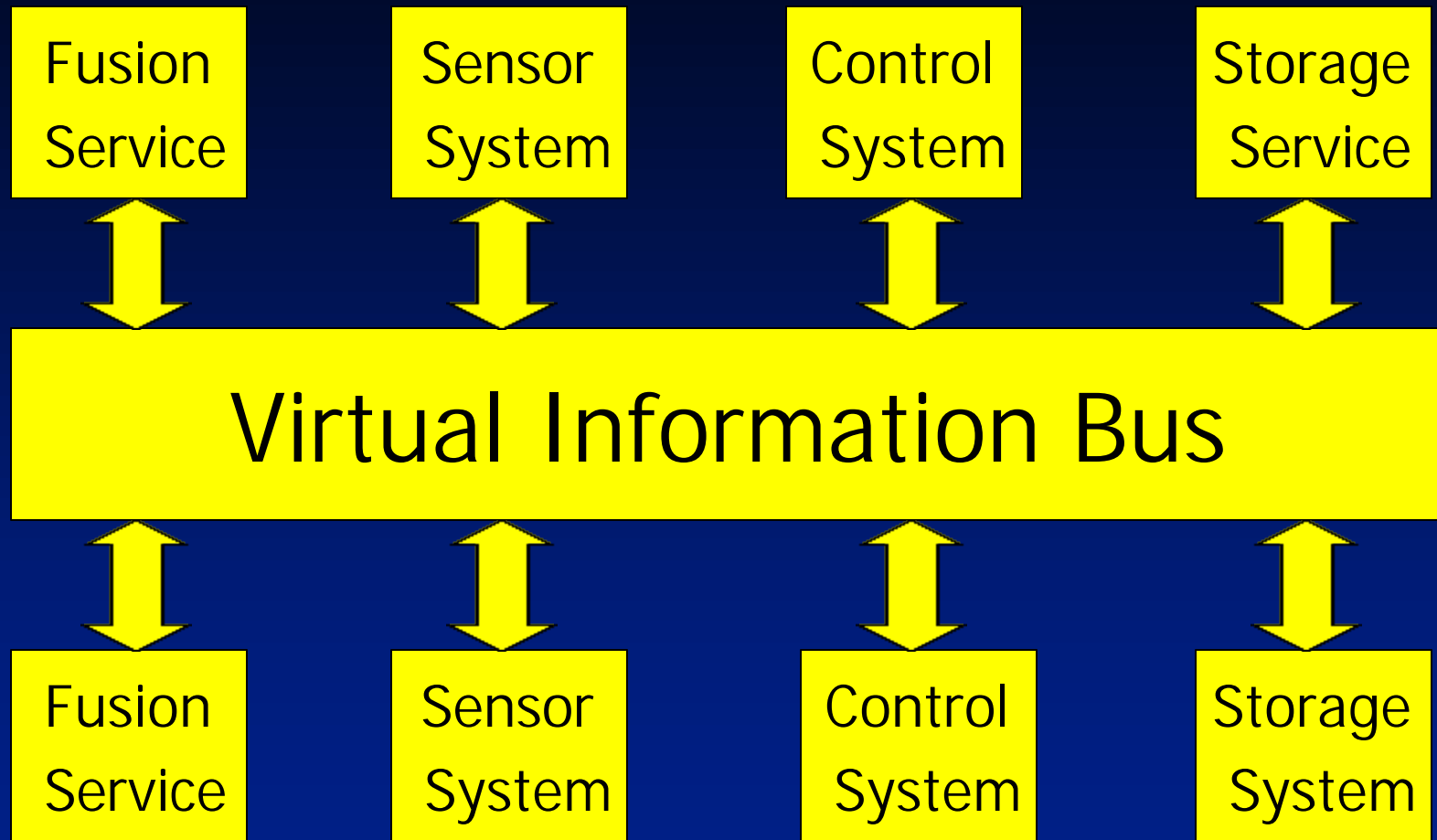
- ◆ United States Air Force, Office of the CIO
- ◆ United States Air Force, Space Command, J6
- ◆ Mitre Corporation, Joint Battle Infosphere
- ◆ University of Colorado at Boulder (Siena)
- ◆ Private Industry (Tibco, Microsoft, IBM)

# Approach

- ◆ Content-based networking
- ◆ New kind of network service
- ◆ Emergent, content-driven information flow
- ◆ Publish/subscribe network service model
- ◆ Highly distributed, robust architecture
- ◆ Suitable for a distributed multisensor data fusion service model

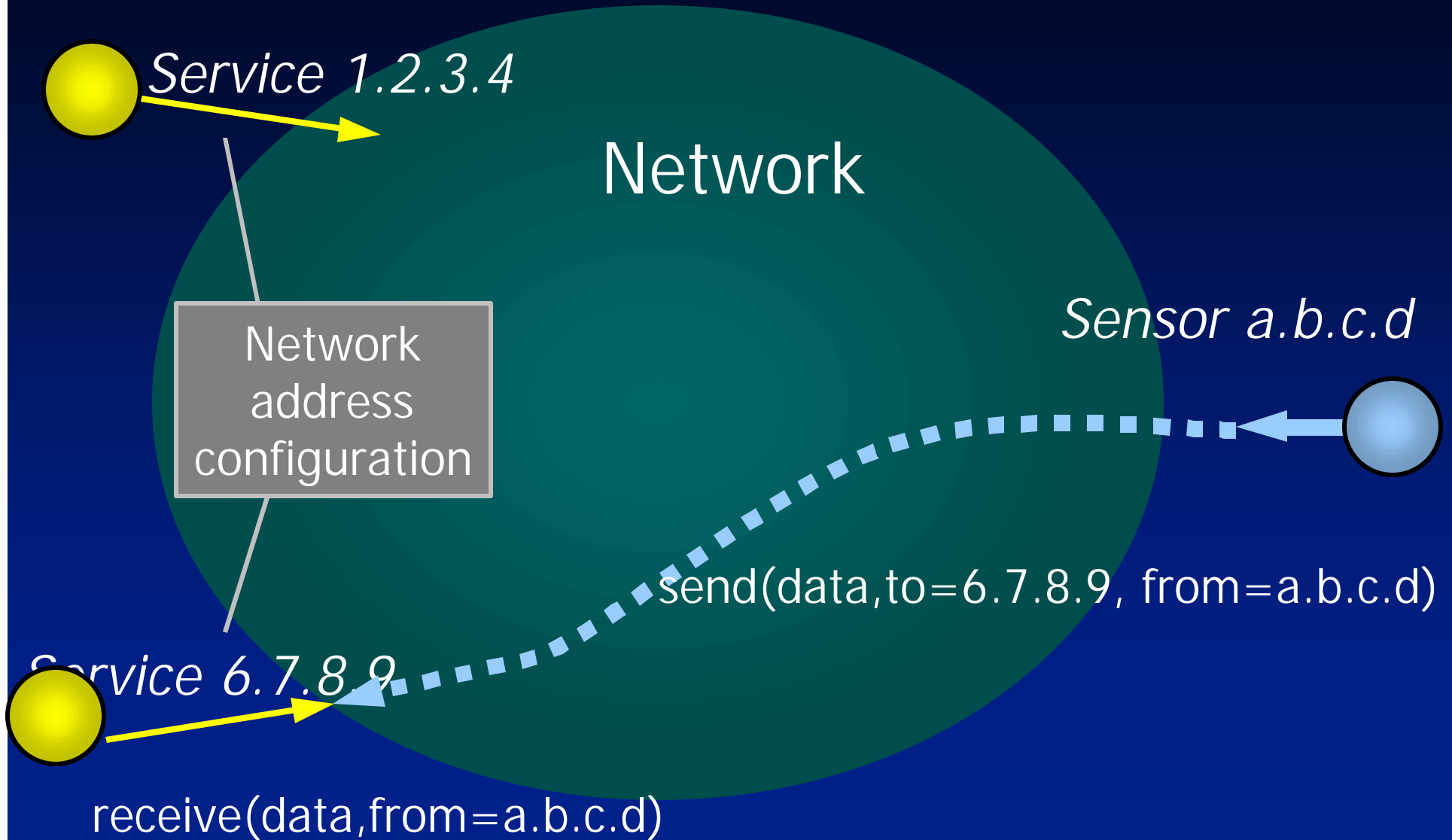
- ◆ Motivation: distributed, scaleable, service-oriented multisensor data fusion architecture
- ◆ Review of traditional networking approaches
- ◆ Content-based networking
  - service model
  - architecture
  - security
  - prototype

# High Level Architecture

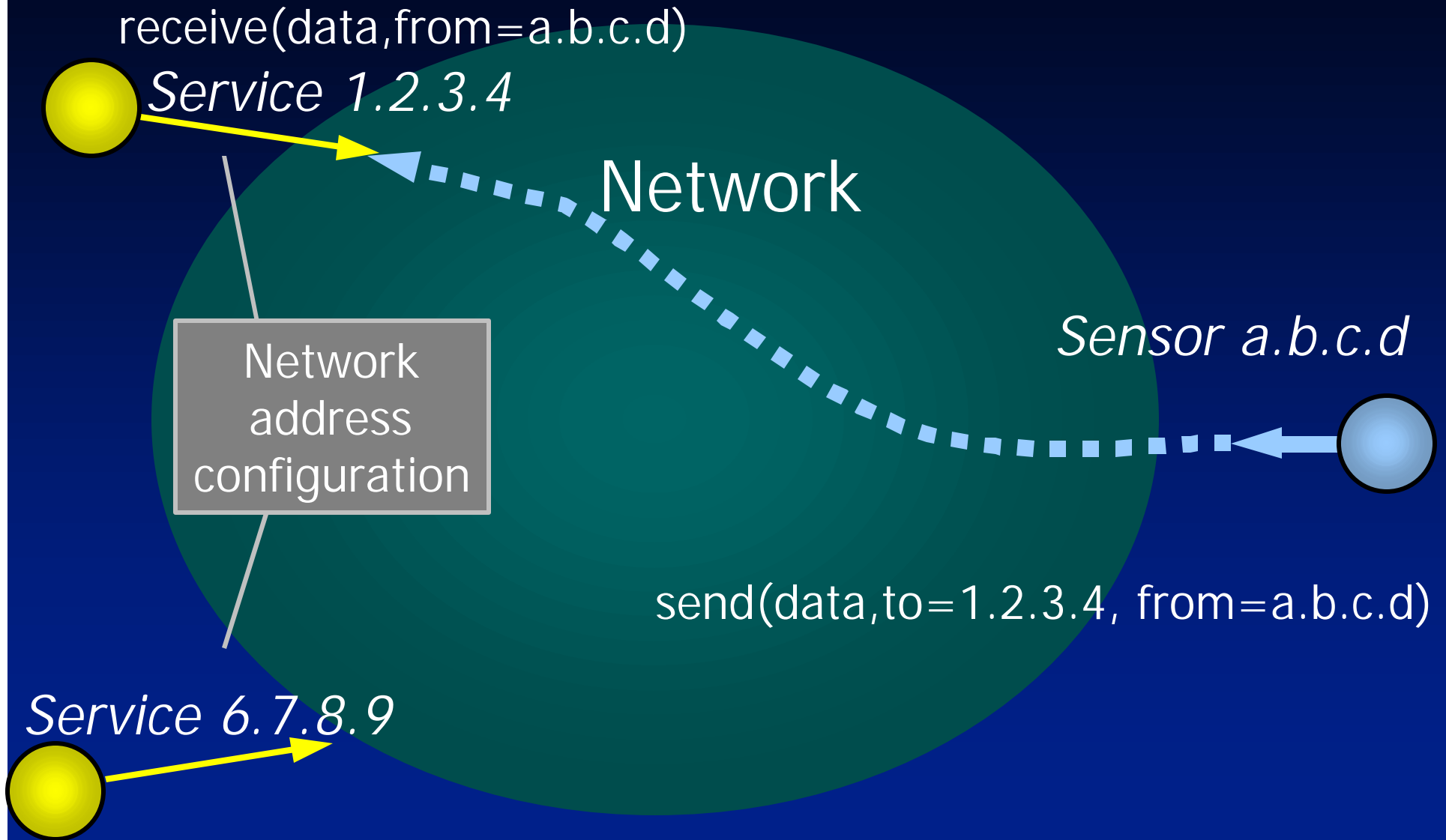


Scaleable, Service-Oriented Fusion

# Traditional Network Service



# Traditional Network Service



# Traditional Network Service

- ◆ Every node is given an address
- ◆ Sender creates a message
- ◆ Sender attaches a destination address
- ◆ Network delivers the message to the node with the attached address
  
- ◆ Information dissemination requires...
  - configuration of addresses
  - knowledge of destination addresses (by senders)
  - availability of destination service

# Traditional Network Service

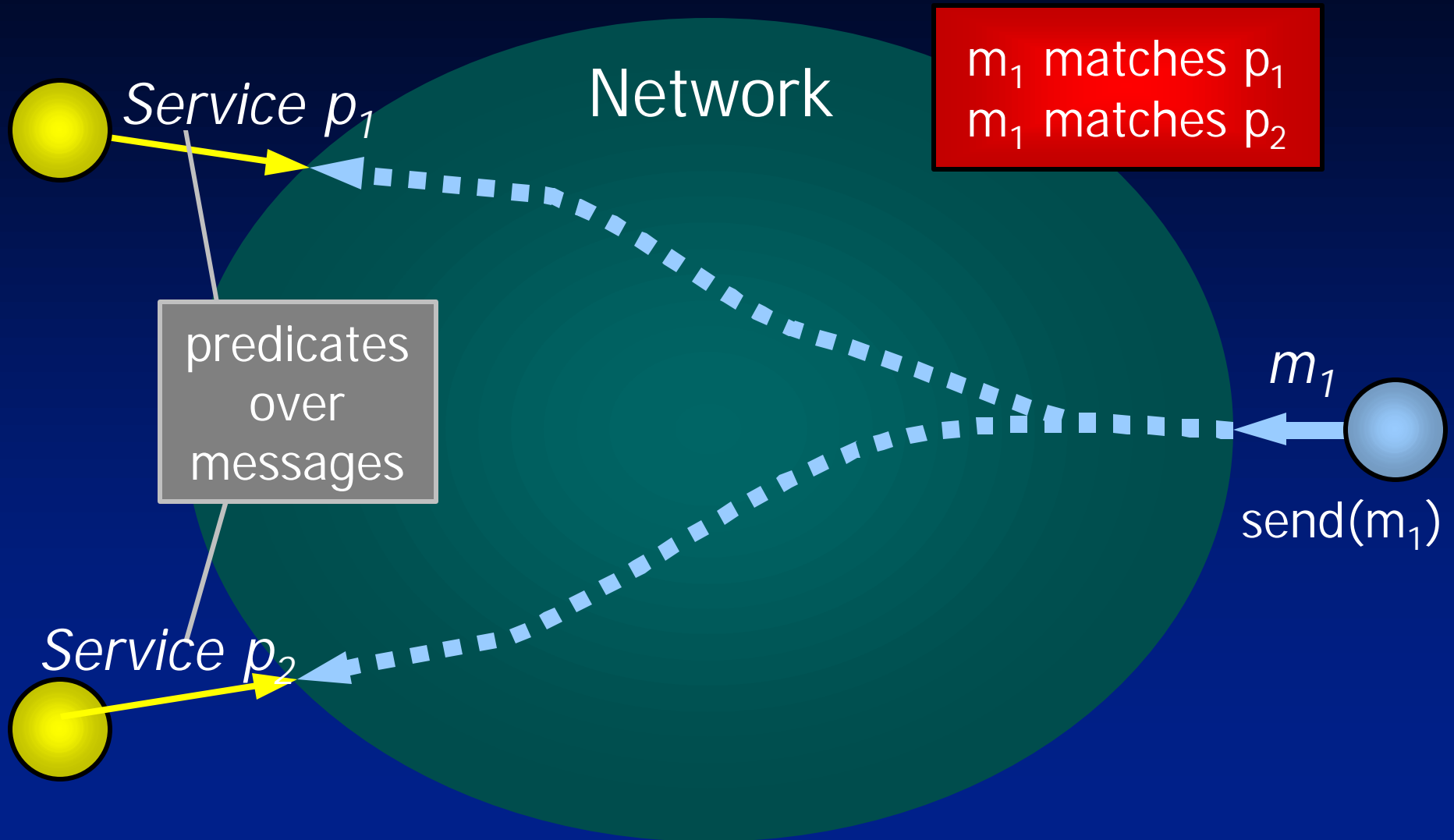
## ◆ Current approaches to dissemination

- ① naming/directory service
- ② search engines
- ③ broadcast/multicast

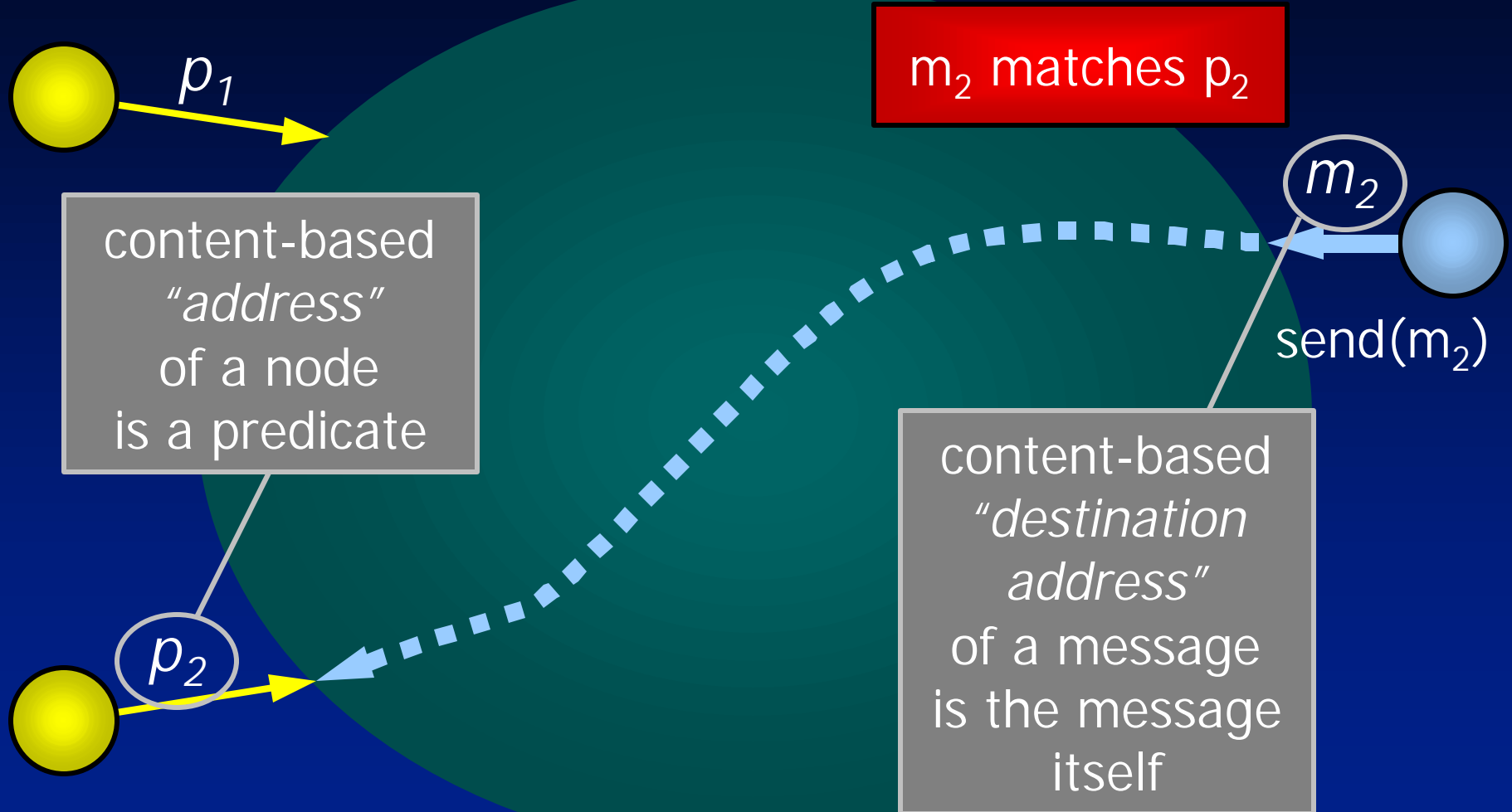
## ◆ Shortcomings

- centralized architectures (1, 2)
- additional indirection (1, 2)
- coarse-grained selection (3)

# Content-Based Network Service



# Content-Based Network Service



# Service Model

- ◆ Message: information unit
  - set of named attributes
  - attributes have types
  - types are basic and common (SQL-like)
- ◆ Predicate: selects messages of interest
  - disjunction of conjunctions of *constraints*
  - operators are basic and common (SQL-like)
- ◆ Pattern: correlates messages of interest
  - expression over predicates using correlation operators (e.g., sequence, alternative, ...)

# Message

- ◆ A *message* is a set of *attributes*

attribute = (type,name,value)

<i>string</i>	class = inventory
<i>date</i>	date = 2002/04/08
<i>string</i>	depot = X2F47G
<i>string</i>	part = h23-449-j72001-02
<i>string</i>	group = panel-3
<i>string</i>	category = avionics
<i>int</i>	in-stock = 5
<i>string</i>	provider = UC-222265

# Message

- ◆ A *message* is a set of *attributes*

attribute = (type,name,value)

<i>string</i>	sensor-type	=	GPS-ground
<i>date</i>	time	=	2002/04/08 15:27:57 MST
<i>string</i>	observation	=	movement/position
<i>string</i>	subject	=	tank
<i>int</i>	heading	=	135
<i>float</i>	velocity	=	11.5
<i>float</i>	longitude	=	-105.26
<i>float</i>	latitude	=	40.0
<i>float</i>	precision	=	0.85

# Predicate

- ◆ A *predicate* selects messages

(*string* category = "avionics"  
**and** *string* part = *any*  
**and** *int* in-stock < 2)

**or**

(*string* provider = "UC-222265")

**or**

(*string* sensor-type = "GPS-ground"  
**and** *string* subject = "tank"  
**and** *float* velocity > 20)

# Pattern

- ◆ A *pattern* correlates messages of interest

```
(string alarm="failed login"  
    and  
    int attempts>2)
```

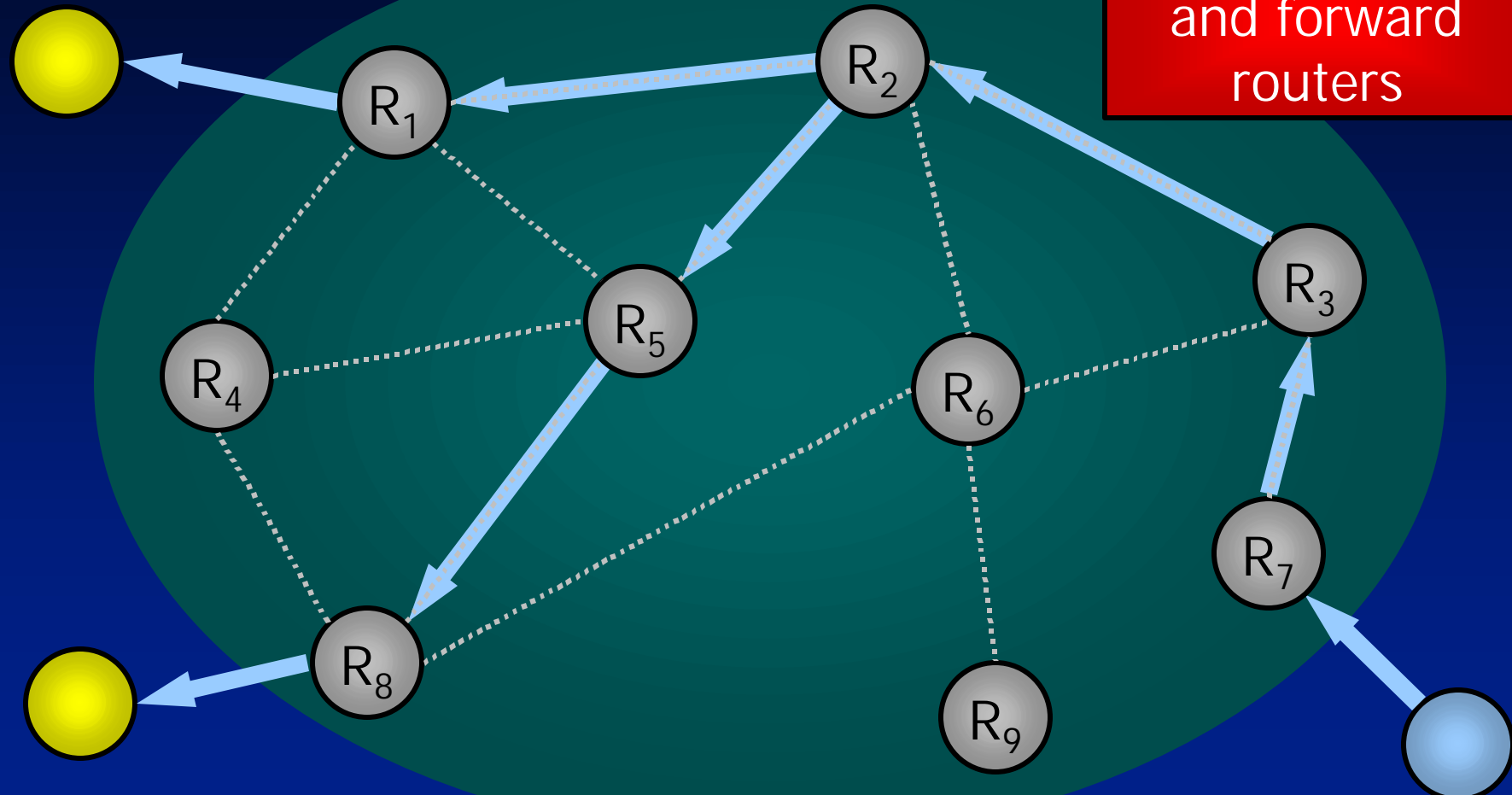
**followed by**

```
(string file=any  
    and  
    string operation = "file change")
```

# Network Architecture

Interested Party

Network of store and forward routers



Fusion Service

Sensor / Event

# Content-Based Network Service

- ◆ Every node declares a selection predicate
- ◆ Sender creates a message
- ◆ Sender inserts the message into the network
- ◆ Network delivers the message to all nodes whose predicate matches the message
  
- ◆ Multiple senders and receivers
- ◆ Addressing implicit in predicates and content

# Advantages

- ◆ Naturally supports various styles of many-to-many distributed communication
  - publish/subscribe and query/response
  - shared data space
- ◆ No mutual knowledge required of senders and receivers
- ◆ More control on the receiver side
- ◆ Immediate service availability not required

# Advantages

- ◆ Inherently scalable and robust
  - amenable to optimization
  - configurable redundancy
- ◆ Ideal service model for many applications
  - middleware
    - communication, integration, service discovery, ...
  - information dissemination
  - sensor networks
  - service oriented workflow
  - electronic commerce
  - event notification

# Security

- ◆ Service-level security
  - SSL senders/receivers (confidentiality, integrity)
  - resource allocation (availability)
  
- ◆ Application-level security
  - signed messages (authenticity)
  - signature-verification operator (authenticity)
  - predicate obfuscation (confidentiality)

# Matrix of Related Technologies

		<i>architecture</i>		
		<i>centralized</i>	<i>hierarchical</i>	<i>peer-to-peer</i>
<i>subscription language</i>	<i>channel</i>	IBM MQS, CORBA ES, Java ES	CORBA ES (IONA)	IP multicast, iBus, IRC
	<i>subject</i>	ToolTalk	NNTP, JEDI	TIB-Rv, SmartSockets, BusinessWare
	<i>content</i>	CORBA NS, JMS, Elvin	Keryx	Gryphon
	<i>content + patterns</i>	Yeast, GEM, active dbases	Siena	Siena

# University of Colorado: Siena

- ◆ Fully functional publish/subscribe service
  - first release: 1998
  - available for anonymous download
    - <http://www.cs.colorado.edu/serl/siena/>
- ◆ Sampling of known users
  - Objsys, Tecknowledge, Lockheed Martin
  - CMU, Columbia, Dartmouth, Oregon
- ◆ DoD programs
  - DARPA: DASADA, OASIS
  - ARO: CIP/SW
  - AFRL: JBI

# Research Issues

- ◆ Advanced content-based routing
  - support highly dynamic predicate space
  - develop advanced optimizations
  - provide reliable routing information propagation
- ◆ Advanced content-based forwarding
  - enhance optimizations for basic types/operators
  - integrate deeply with advanced routing
- ◆ Advanced service model
  - preserve message order
  - improve reliability
  - support predicate and message persistence

# Research Issues

- ◆ Wireless networks
  - mobility and connectivity
- ◆ QoS
  - service guarantees and accounting
- ◆ Security
  - trust and autonomous administrative domains
- ◆ Ontologies
  - establishing common vocabularies
- ◆ Benchmarking
  - vehicles for evaluating service implementations

# Selected Publications

- ◆ T. Bass, "**Intrusion Detection Systems & Multisensor Data Fusion**", *Communications of the ACM*, pp. 99-105, Vol. 43, No. 4, April 2000
- ◆ A. Carzaniga, D.S. Rosenblum, and A.L. Wolf, "**Achieving Expressiveness and Scalability in an Internet-Scale Event Notification Service**", *Nineteenth ACM Symposium on Principles of Distributed Computing (PODC2000)*, July 2000.
- ◆ A. Carzaniga, D.S. Rosenblum, and A.L. Wolf, "**Design and Evaluation of a Wide-Area Event Notification Service**", *ACM Transactions on Computer Systems*, 19(3):332-383, August 2001.
- ◆ A. Carzaniga and A.L. Wolf, "**Content-based Networking: A New Communication Infrastructure**", *NSF Workshop on an Infrastructure for Mobile and Wireless Systems*, October 2001.
- ◆ A. Carzaniga, J. Deng, and A.L. Wolf, "**Fast Forwarding for Content-Based Networking**". *Technical Report CU-CS-922-01*, Department of Computer Science, University of Colorado, November 2001 (submitted for publication).
- ◆ T. Bass, "**The Federation of Critical Infrastructure Information via Publish-Subscribe Enabled Multisensor Data Fusion**", *International Conference on Information Fusion: Fusion 2002*, July 2002.



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