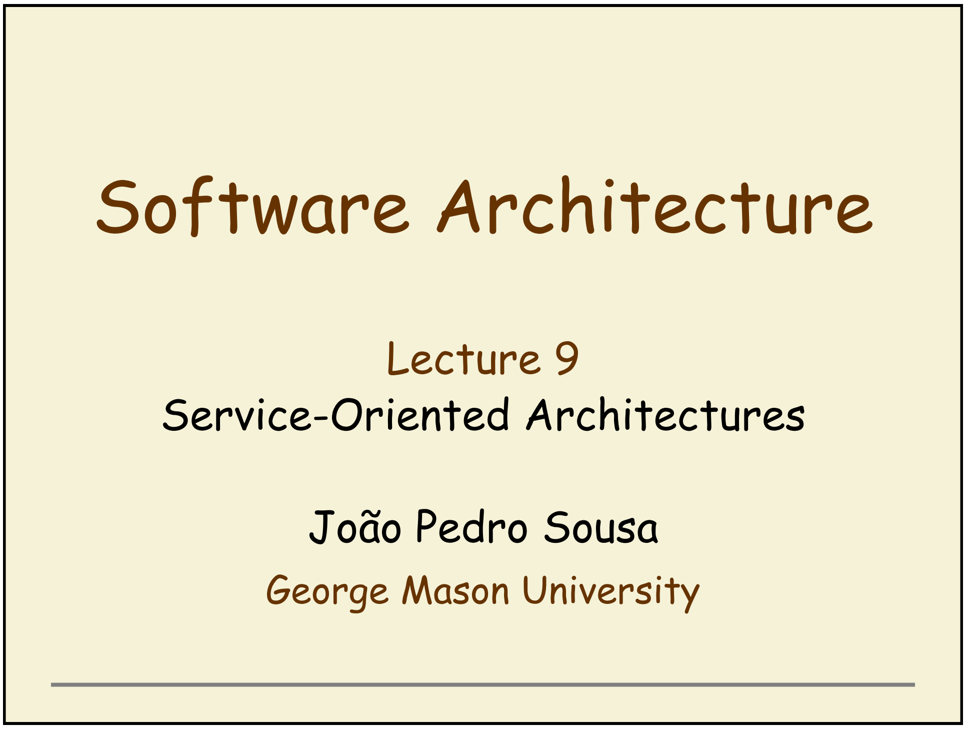


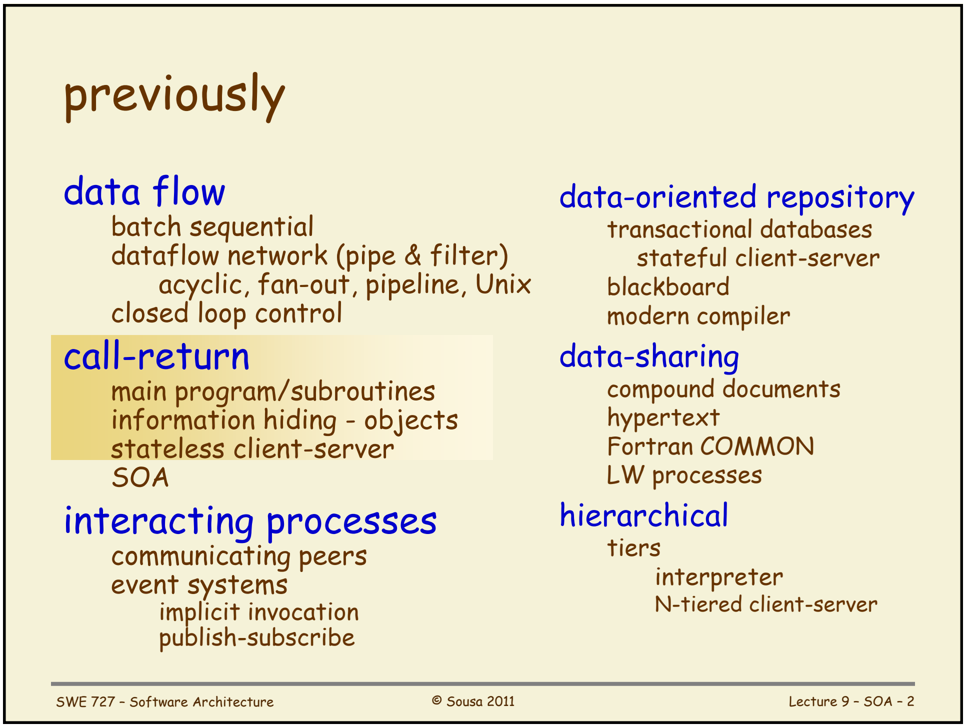
Software Architecture

Lecture 9

Service-Oriented Architectures

João Pedro Sousa

George Mason University



previously

data flow
- batch sequential
- dataflow network (pipe & filter)
  - acyclic, fan-out, pipeline, Unix
- closed loop control

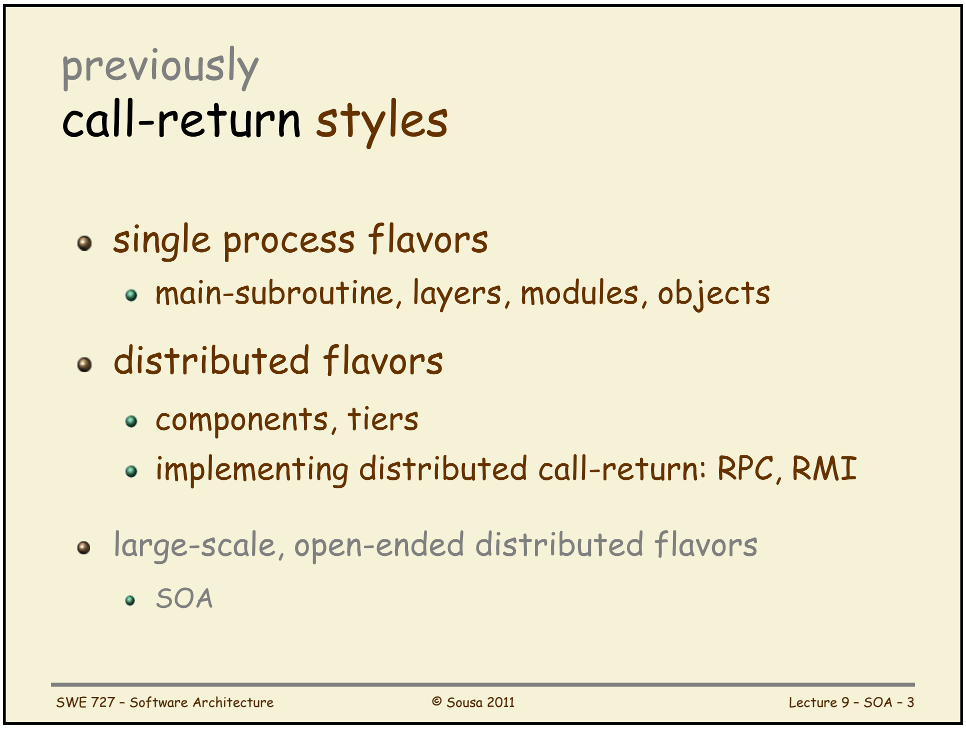
call-return
- main program/subroutines
- information hiding - objects
- stateless client-server
- SOA

interacting processes
- communicating peers
- event systems
  - implicit invocation
  - publish-subscribe

data-oriented repository
- transactional databases
  - stateful client-server
- blackboard
- modern compiler

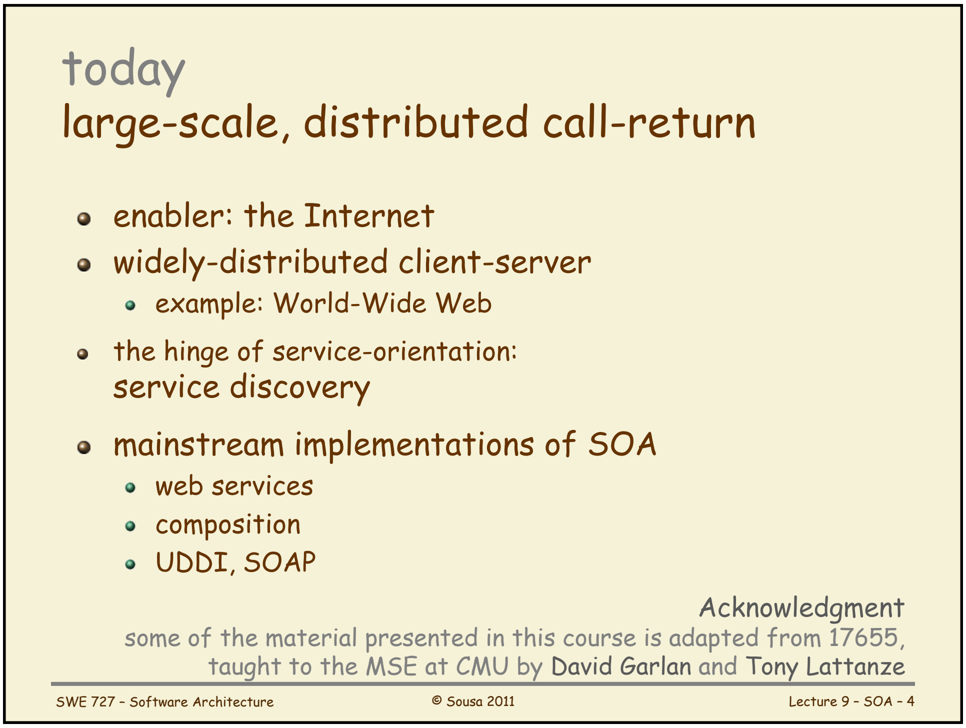
data-sharing
- compound documents
- hypertext
- Fortran COMMON
- LW processes

hierarchical
- tiers
  - interpreter
  - N-tiered client-server



previously
call-return styles

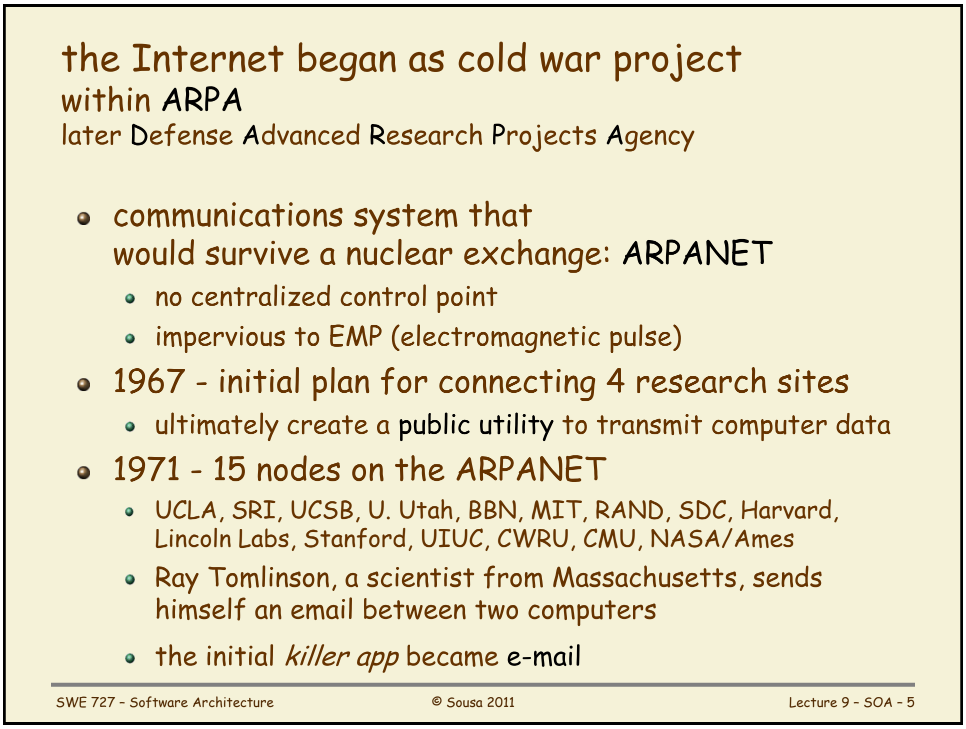
- single process flavors
  - main-subroutine, layers, modules, objects
- distributed flavors
  - components, tiers
  - implementing distributed call-return: RPC, RMI
- large-scale, open-ended distributed flavors
  - SOA



today
large-scale, distributed call-return

- enabler: the Internet
- widely-distributed client-server
  - example: World-Wide Web
- the hinge of service-orientation:
  service discovery
- mainstream implementations of SOA
  - web services
  - composition
  - UDDI, SOAP

Acknowledgment
some of the material presented in this course is adapted from 17655,
taught to the MSE at CMU by David Garlan and Tony Lattanze

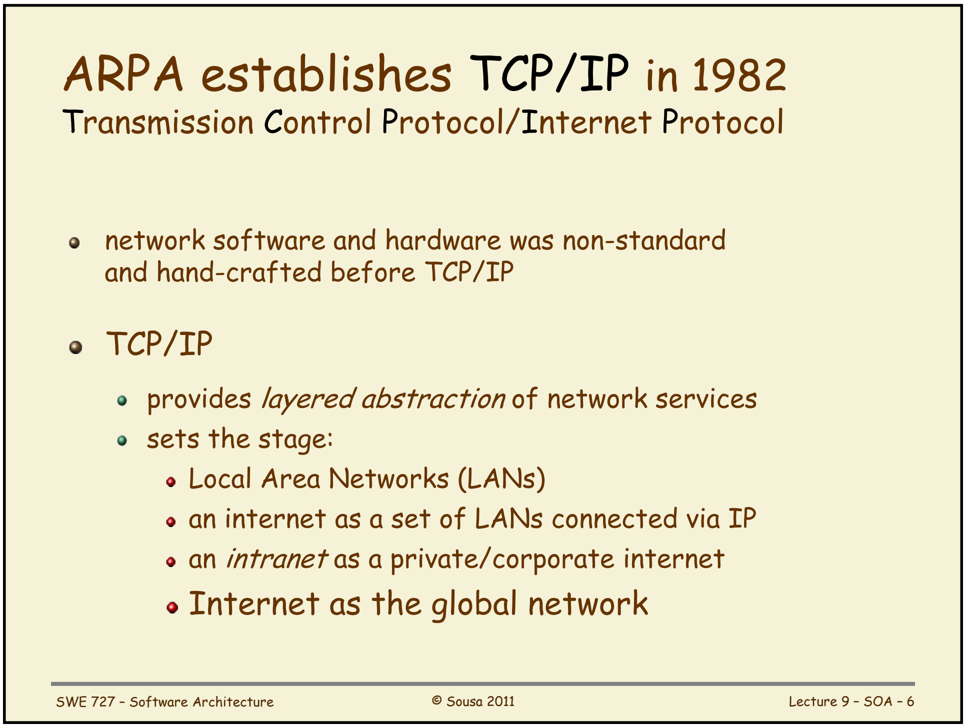


the Internet began as cold war project

within ARPA

later Defense Advanced Research Projects Agency

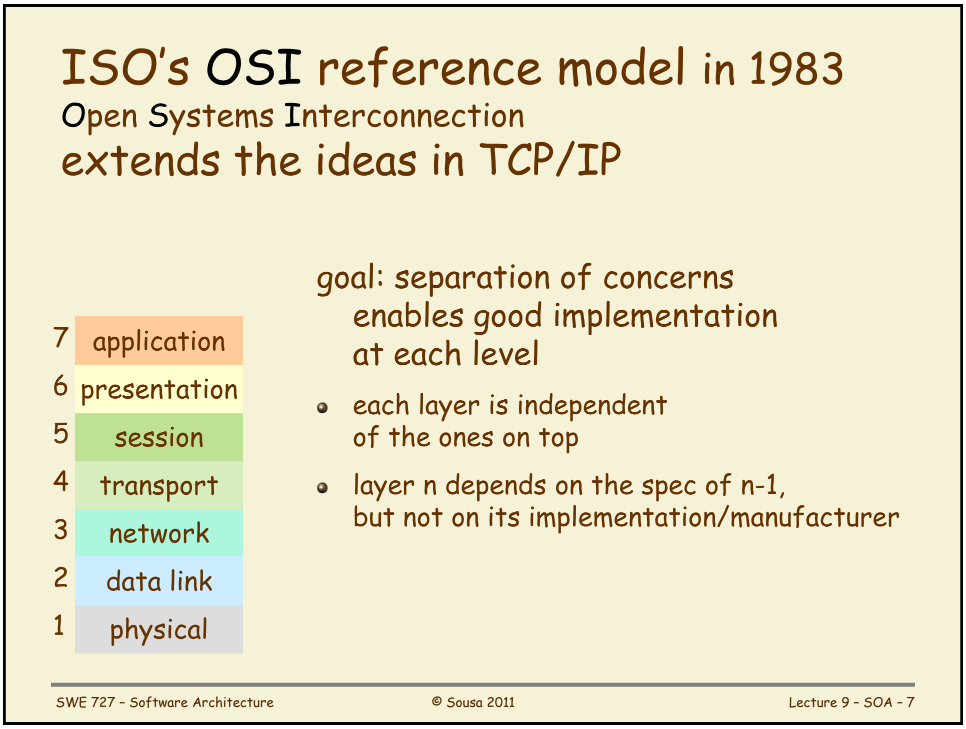
- communications system that would survive a nuclear exchange: ARPANET
  - no centralized control point
  - impervious to EMP (electromagnetic pulse)
- 1967 - initial plan for connecting 4 research sites
  - ultimately create a public utility to transmit computer data
- 1971 - 15 nodes on the ARPANET
  - UCLA, SRI, UCSB, U. Utah, BBN, MIT, RAND, SDC, Harvard, Lincoln Labs, Stanford, UIUC, CWRU, CMU, NASA/Ames
  - Ray Tomlinson, a scientist from Massachusetts, sends himself an email between two computers
  - the initial *killer app* became e-mail



ARPA establishes TCP/IP in 1982

Transmission Control Protocol/Internet Protocol

- network software and hardware was non-standard and hand-crafted before TCP/IP
- TCP/IP
  - provides *layered abstraction* of network services
  - sets the stage:
    - Local Area Networks (LANs)
    - an internet as a set of LANs connected via IP
    - an *intranet* as a private/corporate internet
    - Internet as the global network



ISO's OSI reference model in 1983

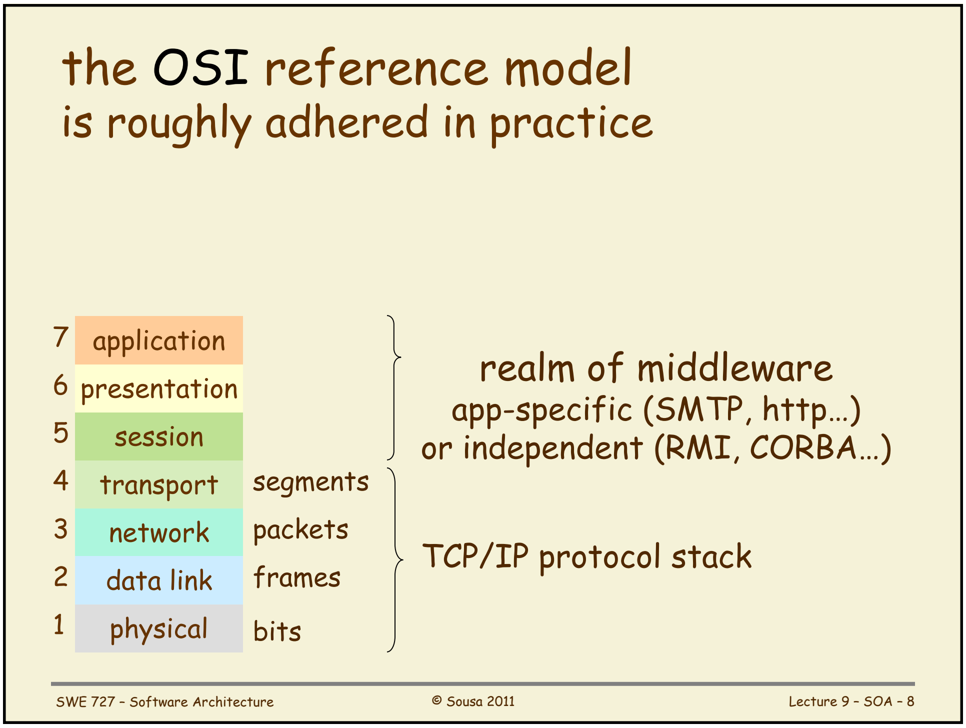
Open Systems Interconnection

extends the ideas in TCP/IP

7	application
6	presentation
5	session
4	transport
3	network
2	data link
1	physical

goal: separation of concerns
enables good implementation
at each level

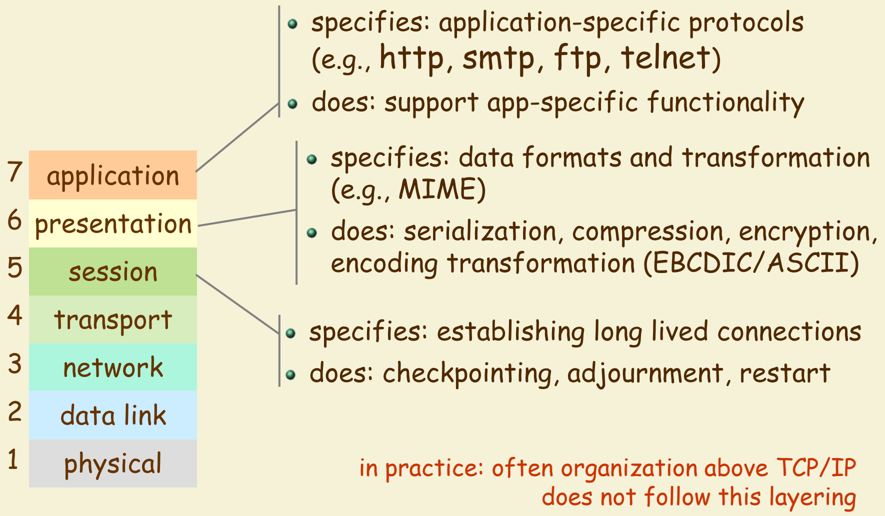
- each layer is independent of the ones on top
- layer n depends on the spec of n-1, but not on its implementation/manufacturer



the OSI reference model is roughly adhered in practice

7	application		realm of middleware app-specific (SMTP, http…) or independent (RMI, CORBA…)
6	presentation		
5	session		
4	transport	segments	TCP/IP protocol stack
3	network	packets	
2	data link	frames	
1	physical	bits	

the upper layers of the OSI



- specifies: application-specific protocols (e.g., http, smtp, ftp, telnet)
- does: support app-specific functionality

- specifies: data formats and transformation (e.g., MIME)
- does: serialization, compression, encryption, encoding transformation (EBCDIC/ASCII)

- specifies: establishing long lived connections
- does: checkpointing, adjournment, restart

in practice: often organization above TCP/IP does not follow this layering

Internet expanded fast

- 1984 - hosts on the Internet tops 1,000
  - *DNS* introduced
    Domain Name System

more in a bit

- 1987 - Number of hosts tops 10,000
- 1988 - worm burrows through the net
  affecting 6,000 of 60,000 hosts on the Internet
  - CERT formed by DARPA
    Computer Emergency Readiness Team
- 1989 - number of hosts tops 100,000

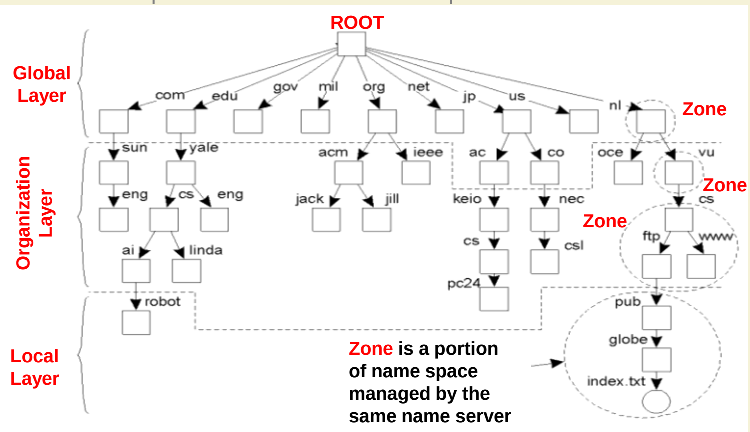
to manage scale: human readable URLs

Universal Resource Locators

example ftp://ftp.cs.vu.nl/pub/globe/index.txt

access protocol — host name — local name

resources are servers and files



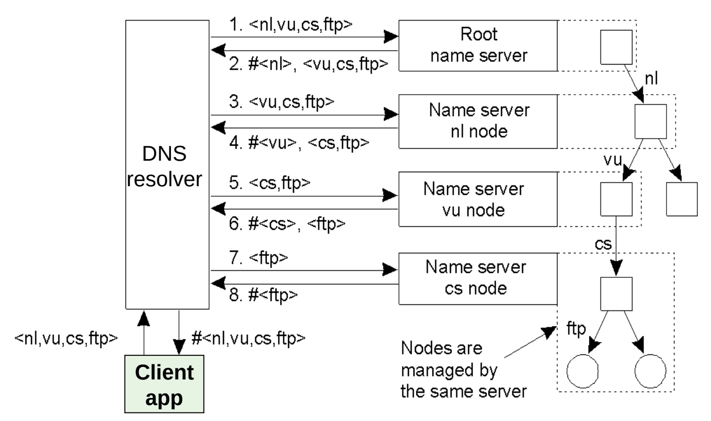
Zone is a portion of name space managed by the same name server

DNS servers resolve URLs to IP addresses

example: resolve *ftp://ftp.cs.vu.nl/pub/globe/index.txt*

in practice: a resolver on your PC, another on your ISP...

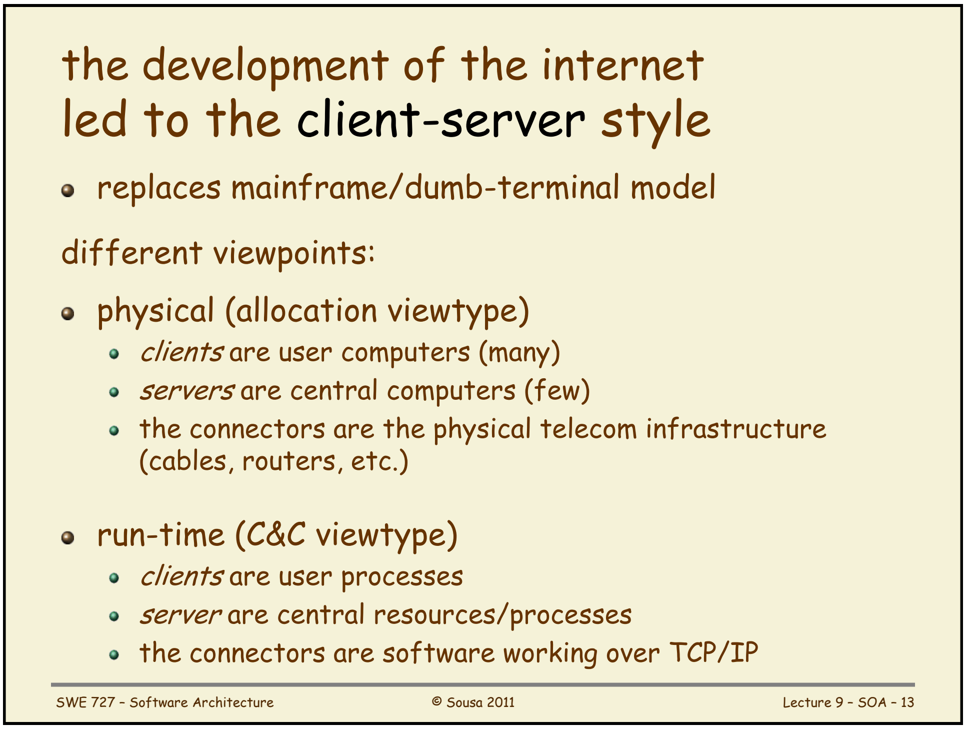
each with cashing



1. <nl,vu,cs,ftp>
2. #<nl>, <vu,cs,ftp>
3. <vu,cs,ftp>
4. #<vu>, <cs,ftp>
5. <cs,ftp>
6. #<cs>, <ftp>
7. <ftp>
8. #<ftp>

Nodes are managed by the same server

#<...> stands for 32-bit IP address of server <...>

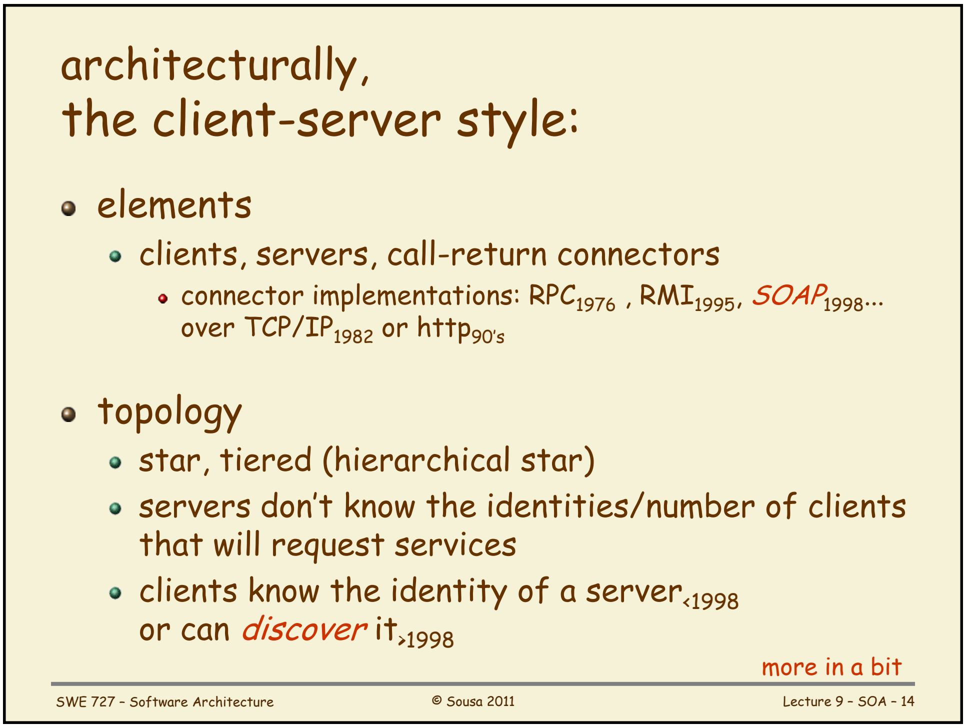


the development of the internet led to the client-server style

- replaces mainframe/dumb-terminal model

different viewpoints:

- physical (allocation viewtype)
  - *clients* are user computers (many)
  - *servers* are central computers (few)
  - the connectors are the physical telecom infrastructure (cables, routers, etc.)
- run-time (C&C viewtype)
  - *clients* are user processes
  - *server* are central resources/processes
  - the connectors are software working over TCP/IP

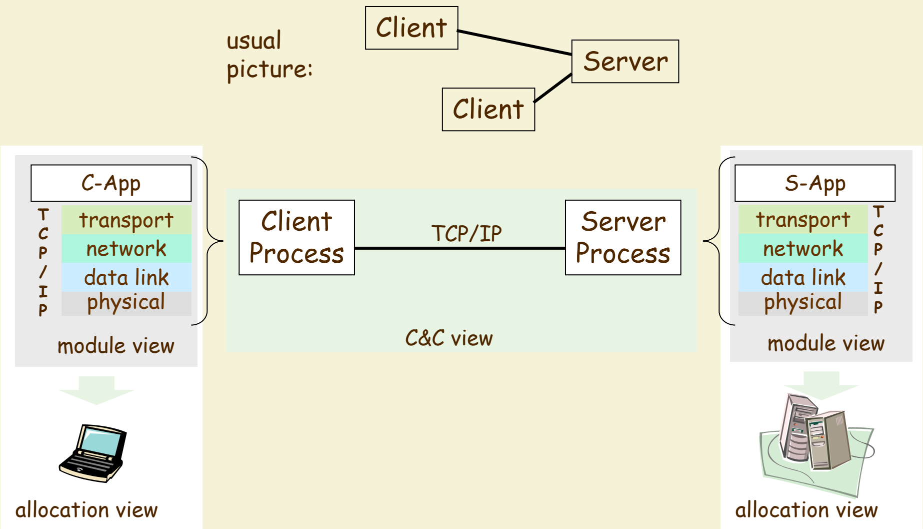


architecturally, the client-server style:

- elements
  - clients, servers, call-return connectors
    - connector implementations: RPC$_{1976}$, RMI$_{1995}$, *SOAP*$_{1998}$... over TCP/IP$_{1982}$ or http$_{90's}$
- topology
  - star, tiered (hierarchical star)
  - servers don't know the identities/number of clients that will request services
  - clients know the identity of a server$_{<1998}$ or can *discover* it$_{>1998}$

more in a bit

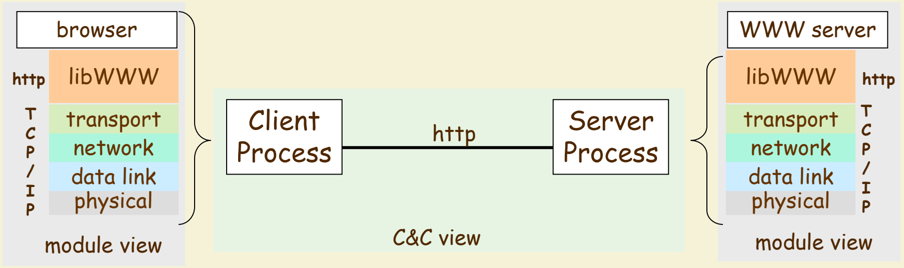
relation among views
client-server



client-server example
World-Wide Web

- hypertext idea first published in 1965 by Ted Nelson as part of the *Xanadu* project
- Tim Berners-Lee, a software engineer at CERN, saw the potential of this idea for the Internet in 1989
- initially rejected, Tim re-circulated his proposal and writes first WYSIWYG browser in 1990
  - libWWW supports new protocol http, on top of TCP/IP
    hypertext transfer protocol
  - new format for documents: HTML
    HyperText Markup Language
  - the next *killer app* became web browsing (aka surfing)

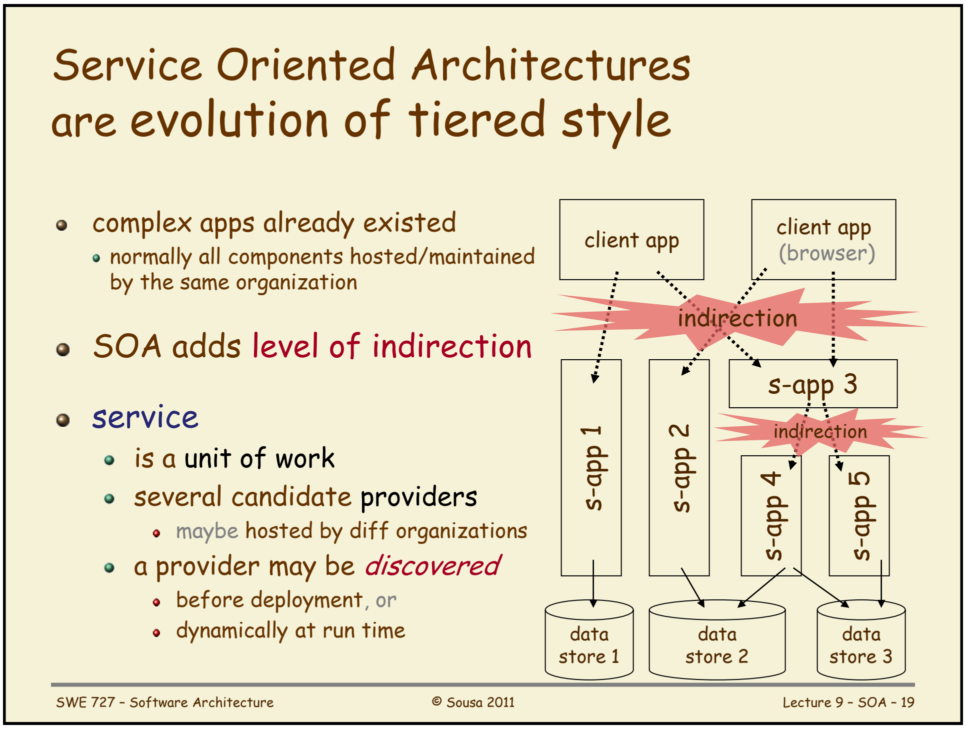
client-server example World-Wide Web



- thin clients, called browsers
  - invoke DNS to resolve URLs
  - request documents to WWW servers over http
  - interpret HTML documents
- servers
  - host data in many formats (in addition to HTML)
  - serve http requests

role of Internet continued to expand to business applications

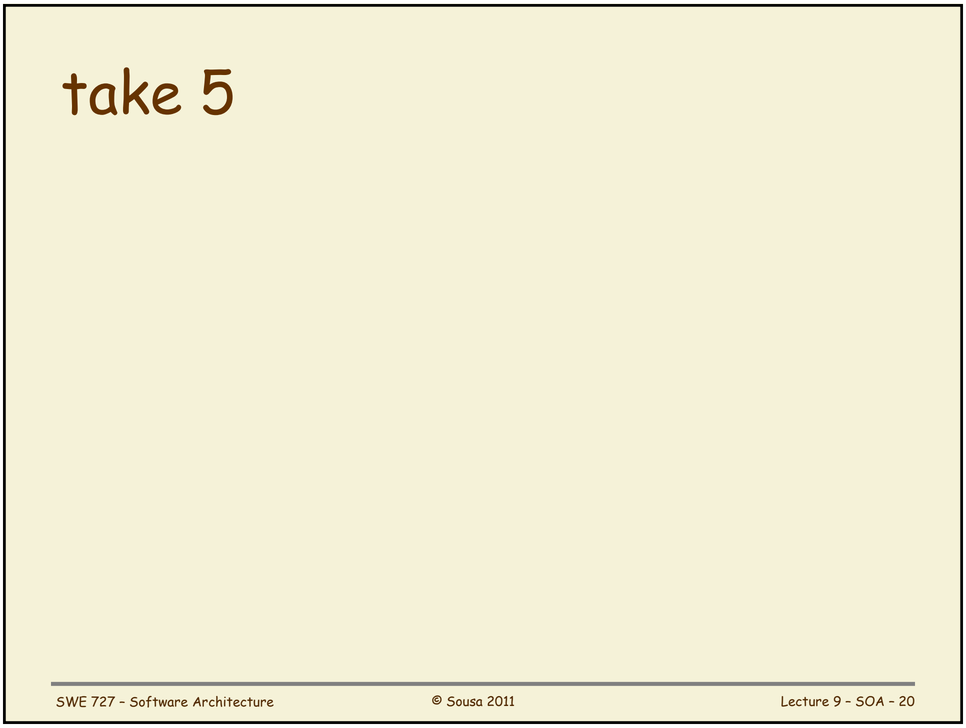
- client-server applications have been around since the early days of the internet
  - early 80's: proprietary app protocols over TCP/IP
  - late 80's: candidate standards emerge, e.g. CORBA, DCOM... with some success, sometimes in specialized domains
- in the late 90's push for business over the Internet
  - requirements considerably different from
    - original vision of ARPANET => led to TCP/IP
    - vision at CERN/Berners-Lee => led to http
- vision SOA: Internet-wide protocol for e-business
  - the next *killer app* is e-services
  - will web services fill the role of supporting technology?



Service Oriented Architectures are evolution of tiered style

- complex apps already existed
  - normally all components hosted/maintained by the same organization
- SOA adds level of indirection
- service
  - is a unit of work
  - several candidate providers
    - maybe hosted by diff organizations
  - a provider may be *discovered*
    - before deployment, or
    - dynamically at run time

client app
client app (browser)
indirection
s-app 1
s-app 2
s-app 3
indirection
s-app 4
s-app 5
data store 1
data store 2
data store 3



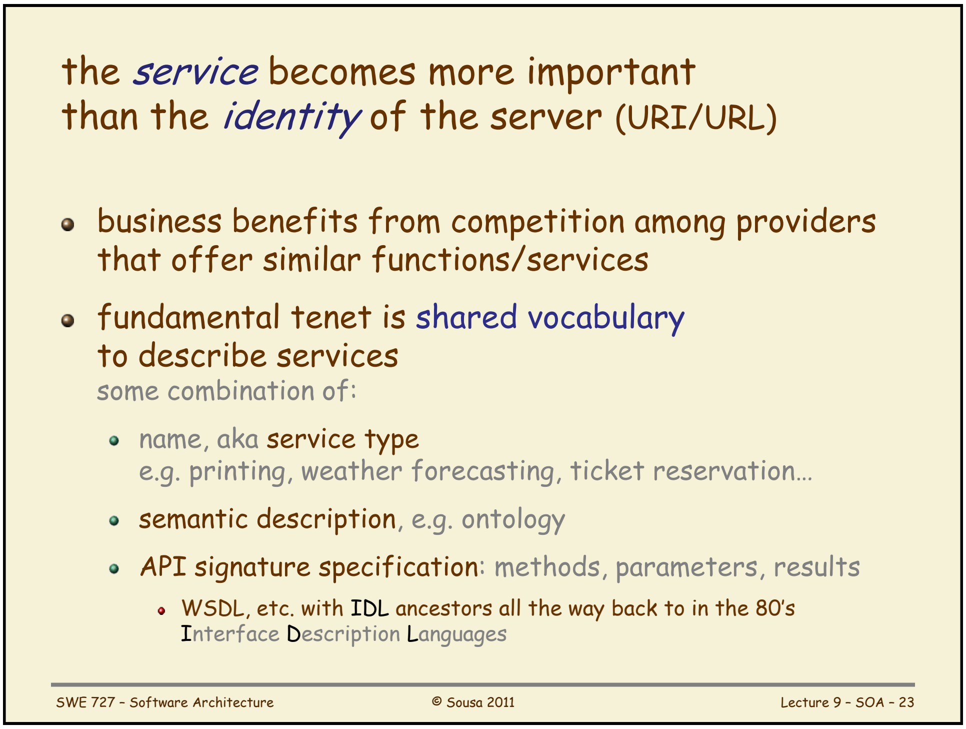
take 5

outline

- enabler: the Internet
- widely-distributed client-server
  - example: World-Wide Web
- the hinge of service-orientation:
  service discovery
- current implementation of SOA
  - web services
  - composition
  - UDDI, SOAP

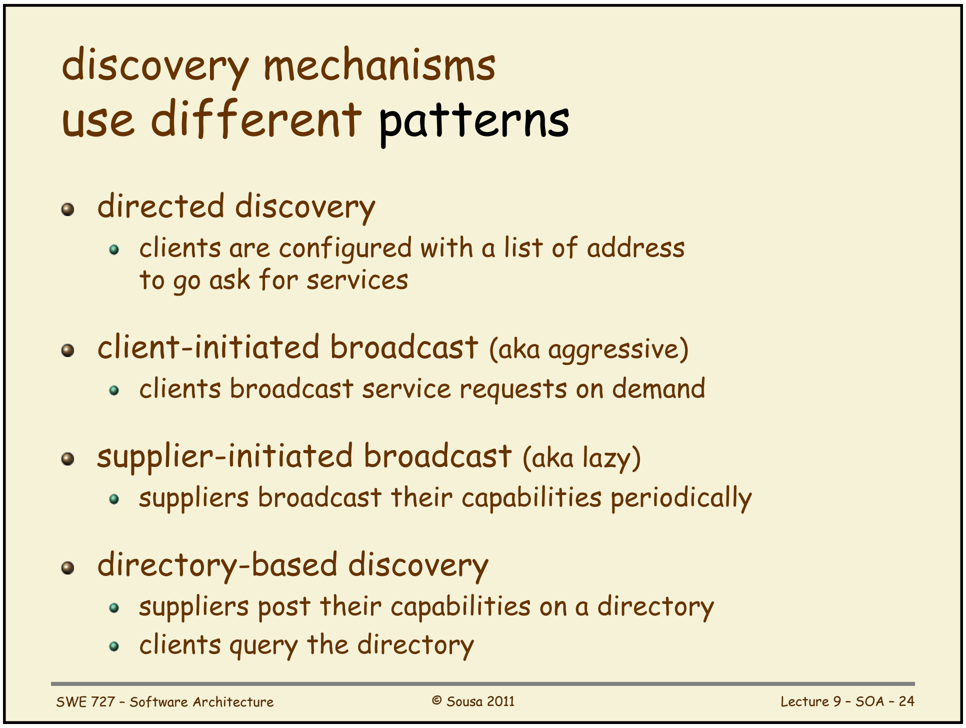
concept of *service discovery* develops in ubiquitous computing circa 1998

- an application may need to find
  some component with certain capabilities
- discovery is guided by the capabilities,
  not the identity of servers, aka service providers
  examples:
  - find a duplex printer < 100 ft away and with < 2 minute wait
  - find a weather forecast website with wind details for x ZIP code
  - find a speech recognizer with > 95% accuracy



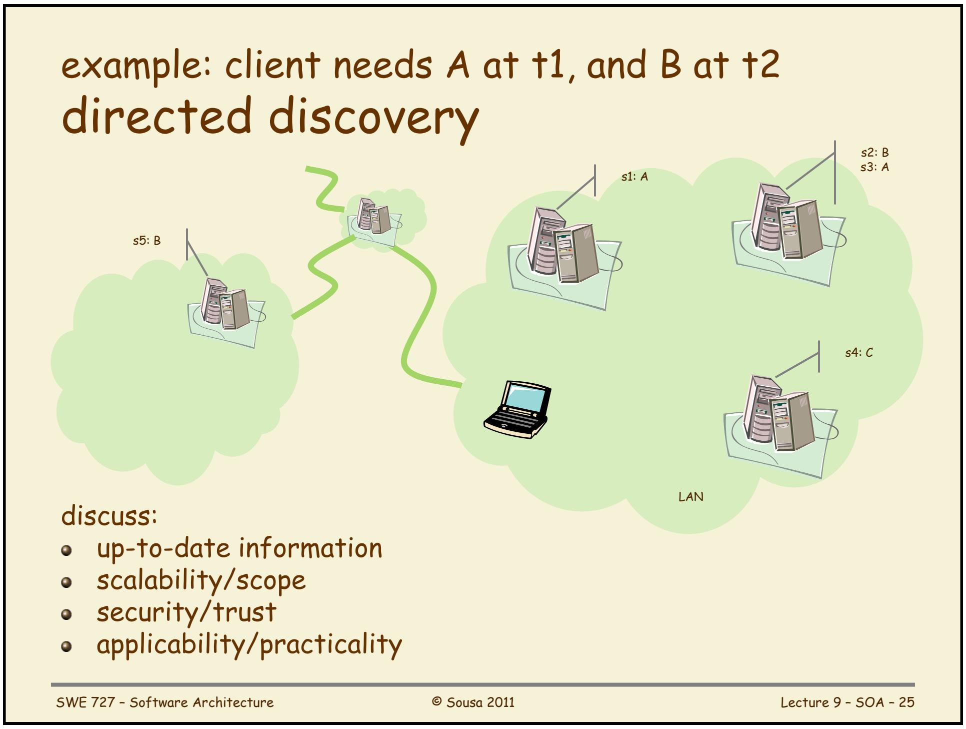
the *service* becomes more important than the *identity* of the server (URI/URL)

- business benefits from competition among providers that offer similar functions/services
- fundamental tenet is shared vocabulary to describe services
  some combination of:
  - name, aka service type
    e.g. printing, weather forecasting, ticket reservation…
  - semantic description, e.g. ontology
  - API signature specification: methods, parameters, results
    - WSDL, etc. with IDL ancestors all the way back to in the 80's
      Interface Description Languages



discovery mechanisms use different patterns

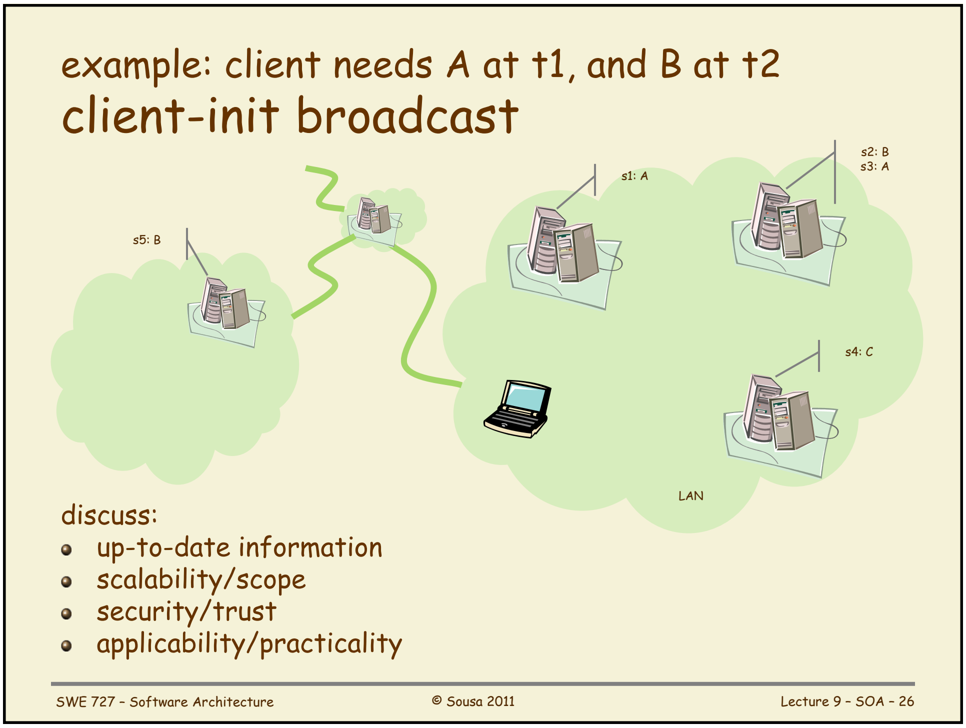
- directed discovery
  - clients are configured with a list of address to go ask for services
- client-initiated broadcast (aka aggressive)
  - clients broadcast service requests on demand
- supplier-initiated broadcast (aka lazy)
  - suppliers broadcast their capabilities periodically
- directory-based discovery
  - suppliers post their capabilities on a directory
  - clients query the directory



example: client needs A at t1, and B at t2
directed discovery

discuss:

- up-to-date information
- scalability/scope
- security/trust
- applicability/practicality



example: client needs A at t1, and B at t2
client-init broadcast

discuss:

- up-to-date information
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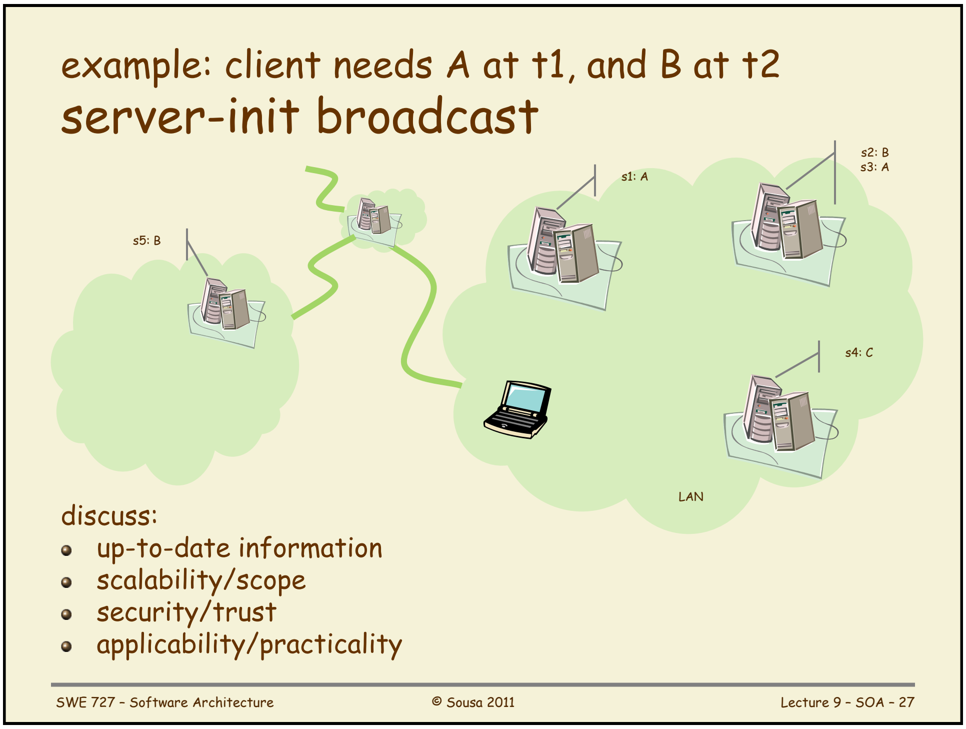
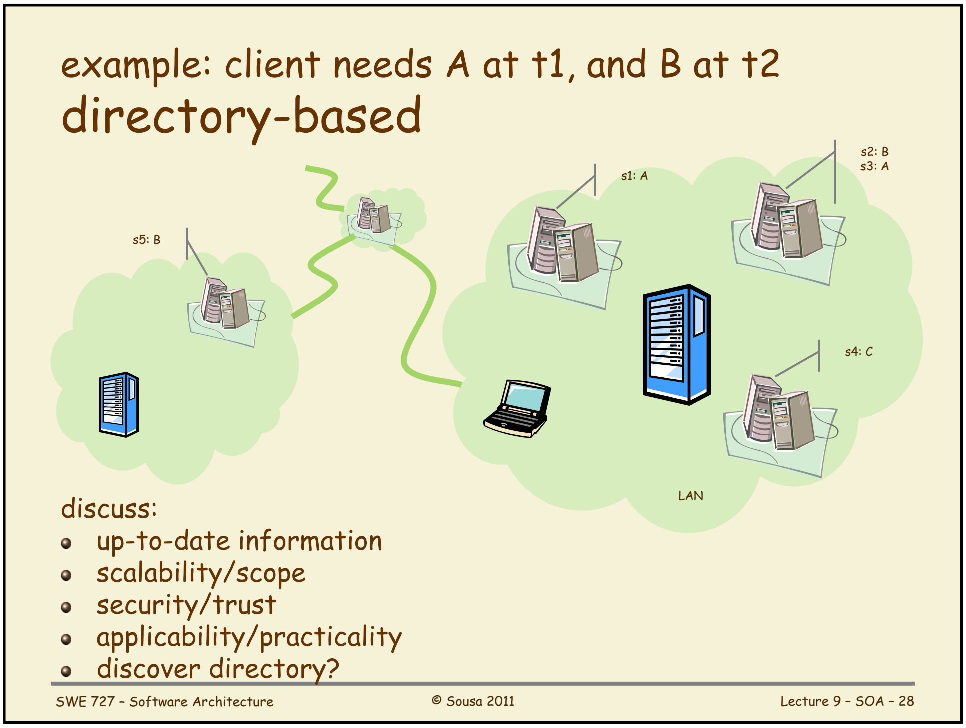


example: client needs A at t1, and B at t2

server-init broadcast

discuss:

- up-to-date information
- scalability/scope
- security/trust
- applicability/practicality

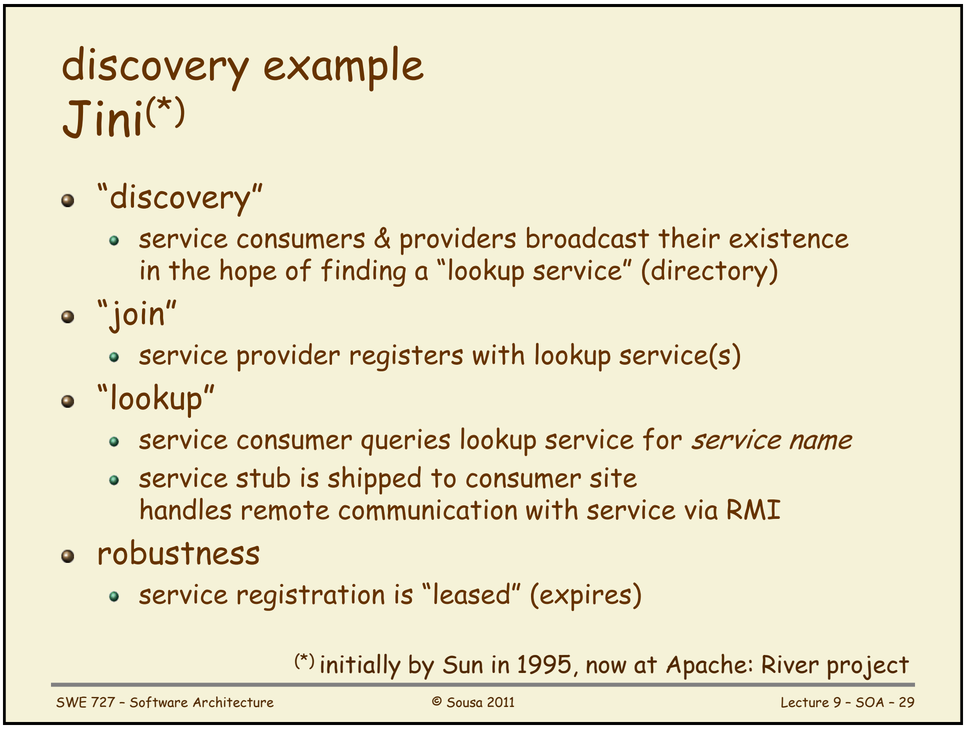


example: client needs A at t1, and B at t2

directory-based

discuss:

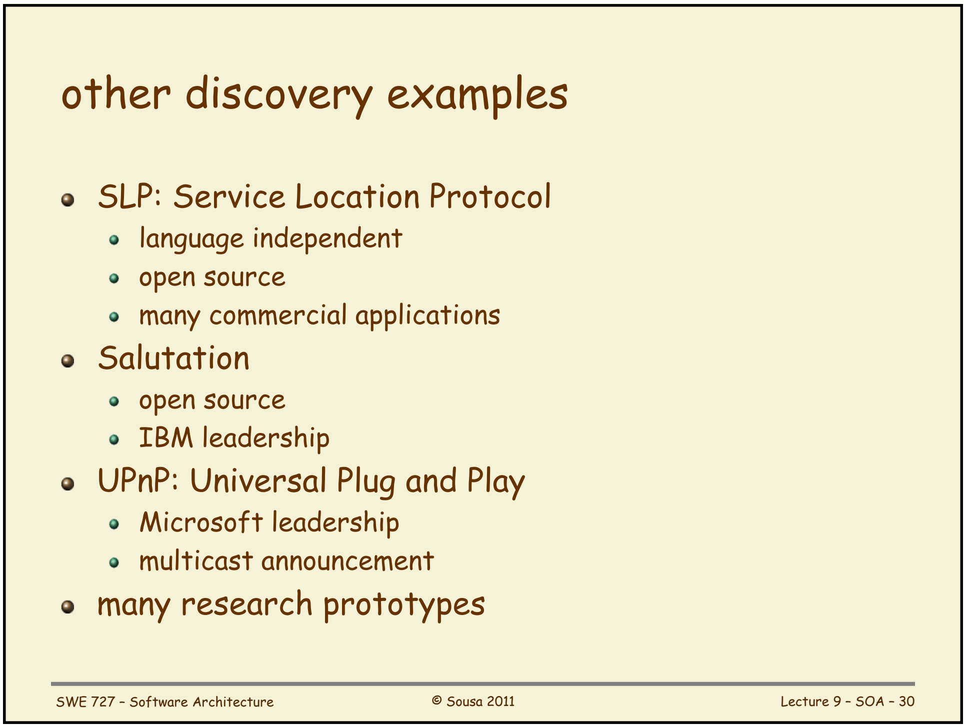
- up-to-date information
- scalability/scope
- security/trust
- applicability/practicality
- discover directory?



discovery example Jini[*]

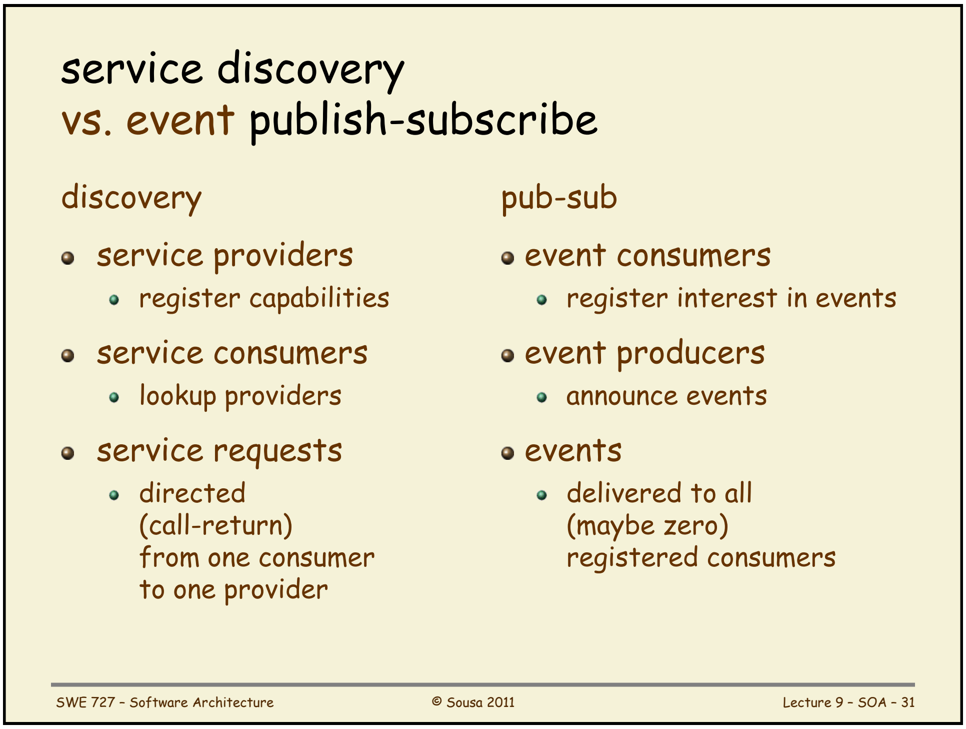
- "discovery"
  - service consumers & providers broadcast their existence in the hope of finding a "lookup service" (directory)
- "join"
  - service provider registers with lookup service(s)
- "lookup"
  - service consumer queries lookup service for *service name*
  - service stub is shipped to consumer site
    handles remote communication with service via RMI
- robustness
  - service registration is "leased" (expires)

[*] initially by Sun in 1995, now at Apache: River project



other discovery examples

- SLP: Service Location Protocol
  - language independent
  - open source
  - many commercial applications
- Salutation
  - open source
  - IBM leadership
- UPnP: Universal Plug and Play
  - Microsoft leadership
  - multicast announcement
- many research prototypes



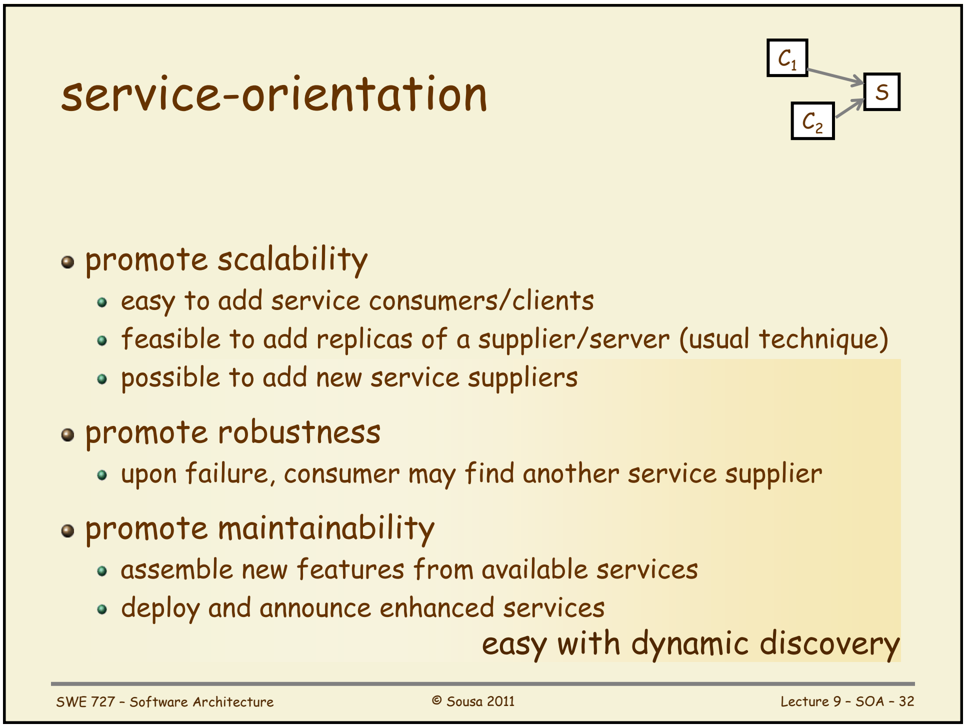
service discovery vs. event publish-subscribe

discovery

- service providers
  - register capabilities
- service consumers
  - lookup providers
- service requests
  - directed (call-return) from one consumer to one provider

pub-sub

- event consumers
  - register interest in events
- event producers
  - announce events
- events
  - delivered to all (maybe zero) registered consumers

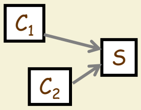


service-orientation

- promote scalability
  - easy to add service consumers/clients
  - feasible to add replicas of a supplier/server (usual technique)
  - possible to add new service suppliers
- promote robustness
  - upon failure, consumer may find another service supplier
- promote maintainability
  - assemble new features from available services
  - deploy and announce enhanced services

easy with dynamic discovery

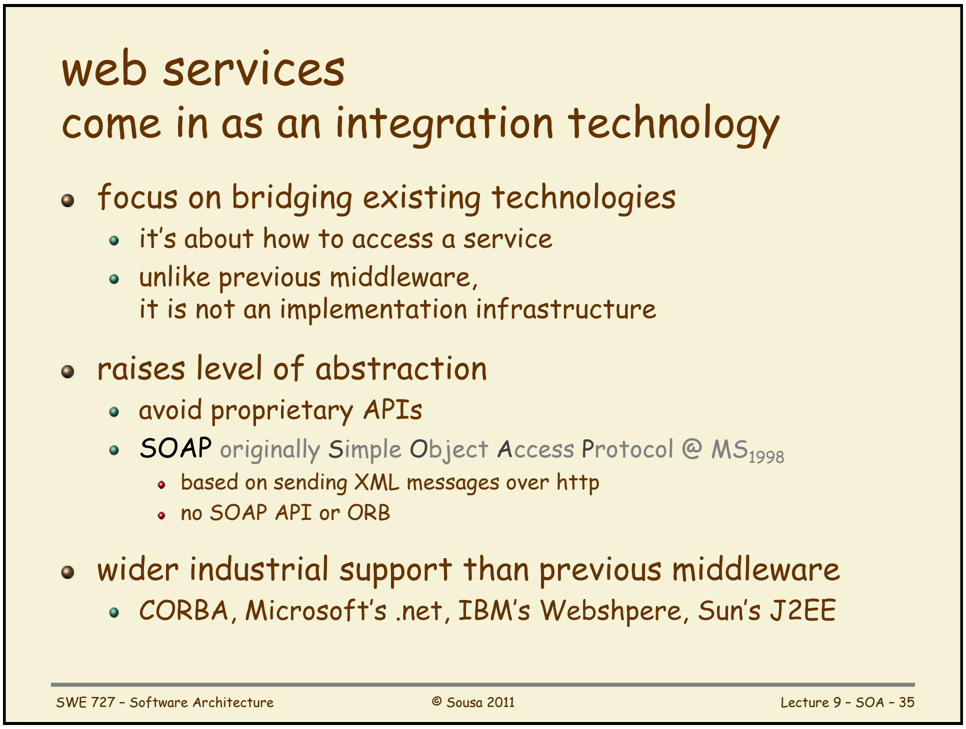
service-orientation



- promote security
  (relative to event systems)
  - each server may set up encryption and access control to authorized clients
- conceptual integrity
  reliability
  & performance may be challenges
  - service consumers depend entirely on service providers

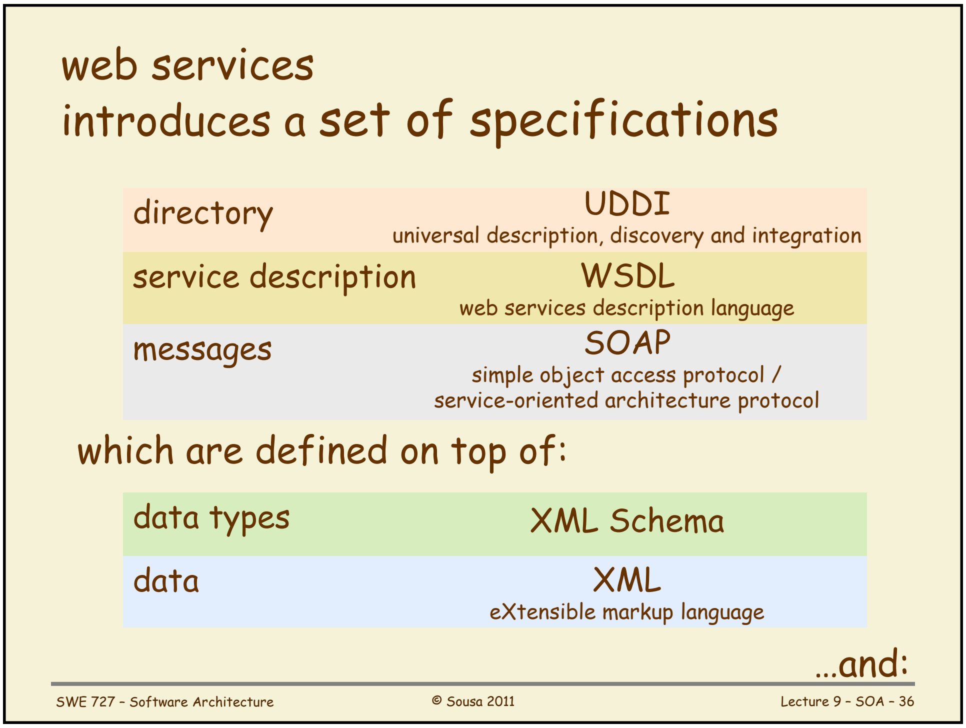
outline

- enabler: the Internet
- widely-distributed client-server
  - example: World-Wide Web
- the hinge of service-orientation:
  service discovery
- current implementation of SOA
  - web services
  - composition
  - UDDI, SOAP



web services
come in as an integration technology

- focus on bridging existing technologies
  - it's about how to access a service
  - unlike previous middleware,
    it is not an implementation infrastructure
- raises level of abstraction
  - avoid proprietary APIs
  - SOAP originally Simple Object Access Protocol @ MS$_{1998}$
    - based on sending XML messages over http
    - no SOAP API or ORB
- wider industrial support than previous middleware
  - CORBA, Microsoft's .net, IBM's Webshpere, Sun's J2EE



web services
introduces a set of specifications

directory	UDDI universal description, discovery and integration
service description	WSDL web services description language
messages	SOAP simple object access protocol / service-oriented architecture protocol

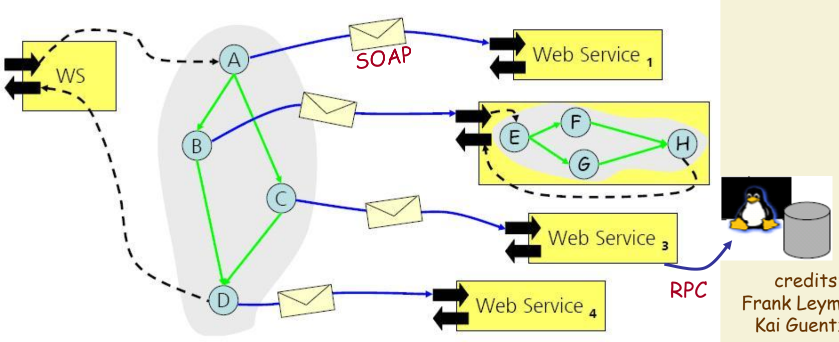
which are defined on top of:

data types	XML Schema
data	XML eXtensible markup language

...and:

multiple proposals for service composition and coordination

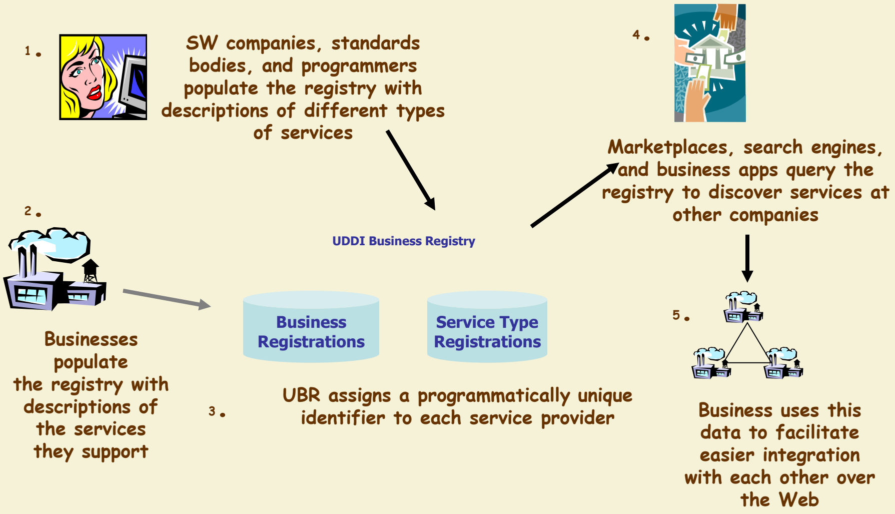
- Business Process Execution Language BPEL
- Web Services Conversation Language WSCL
- Web Services Coordination WS-C
- Web Services Transaction WS-Tx



credits:
Frank Leymann,
Kai Guentzel

WS descriptions may be posted on UBRs

UDDI Business Registry



1. SW companies, standards bodies, and programmers populate the registry with descriptions of different types of services

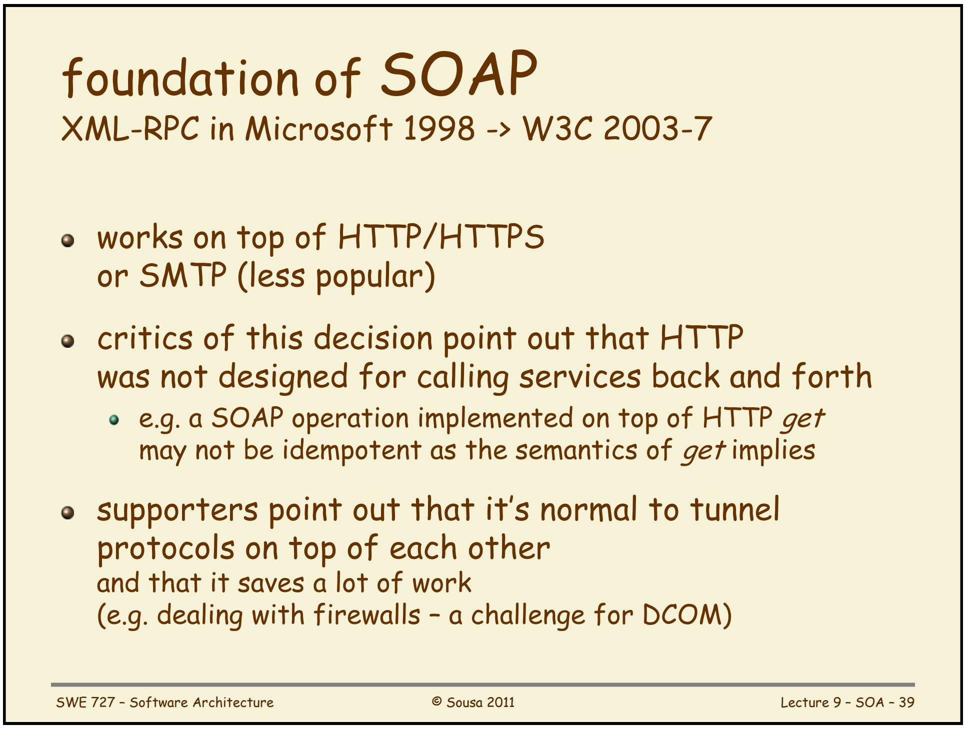
2. Businesses populate the registry with descriptions of the services they support

3. UBR assigns a programmatically unique identifier to each service provider

4. Marketplaces, search engines, and business apps query the registry to discover services at other companies

5. Business uses this data to facilitate easier integration with each other over the Web

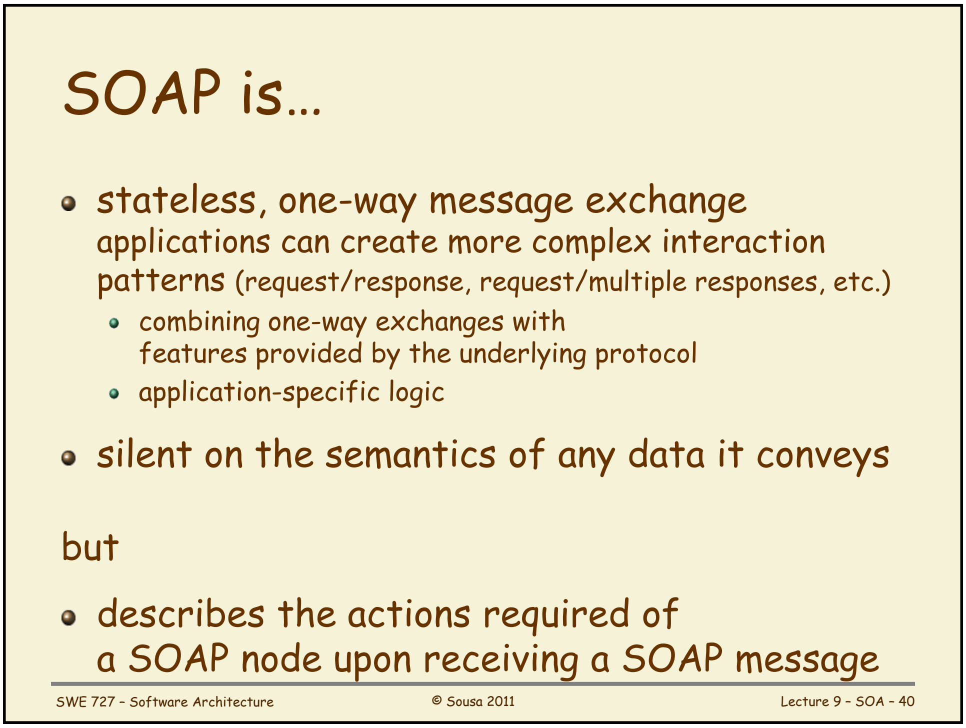
credits: Tevfik Bultan



foundation of SOAP

XML-RPC in Microsoft 1998 -> W3C 2003-7

- works on top of HTTP/HTTPS
  or SMTP (less popular)
- critics of this decision point out that HTTP
  was not designed for calling services back and forth
  - e.g. a SOAP operation implemented on top of HTTP *get*
    may not be idempotent as the semantics of *get* implies
- supporters point out that it's normal to tunnel
  protocols on top of each other
  and that it saves a lot of work
  (e.g. dealing with firewalls – a challenge for DCOM)



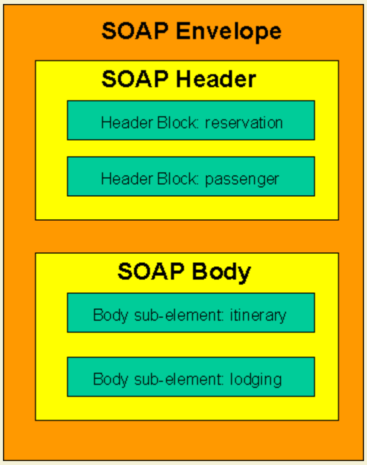
SOAP is…

- stateless, one-way message exchange
  applications can create more complex interaction
  patterns (request/response, request/multiple responses, etc.)
  - combining one-way exchanges with
    features provided by the underlying protocol
  - application-specific logic
- silent on the semantics of any data it conveys

but

- describes the actions required of
  a SOAP node upon receiving a SOAP message

structure of a SOAP message



SOAP Envelope

SOAP Header

Header Block: reservation

Header Block: passenger

SOAP Body

Body sub-element: itinerary

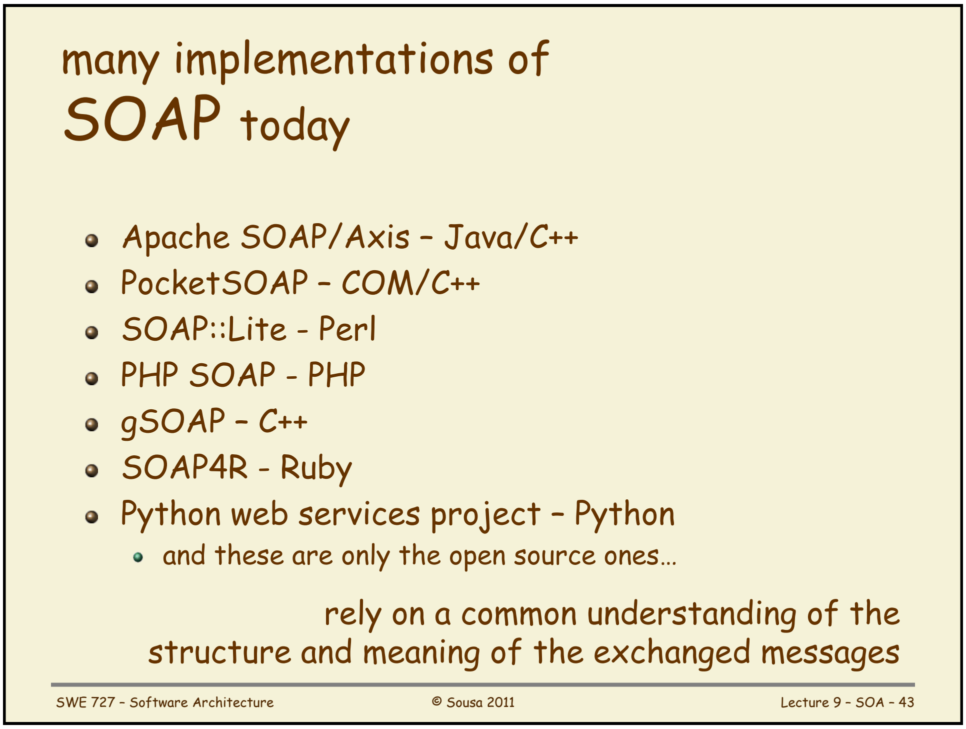
Body sub-element: lodging

example: travel reservation

- optional
  extension mechanism
  e.g., directives on how to process the message
- application payload

```
<env:Envelope xmlns:env="http://www.w3.org/2003/05/soap-envelope">
  <env:Header>
    <t:transaction xmlns:t="http://thirdparty.example.org/transaction"
                   env:encodingStyle="http://example.com/encoding"
                   env:mustUnderstand="true" >5</t:transaction>
  </env:Header>
  <env:Body>
     <m:chargeReservation
            env:encodingStyle="http://www.w3.org/2003/05/soap-encoding"
            xmlns:m="http://travelcompany.example.org/">
       <m:reservation xmlns:m="http://travelcompany.example.org/reservation">
          <m:code>FT35ZBQ</m:code>
       </m:reservation>
       <o:creditCard xmlns:o="http://mycompany.example.com/financial">
          <n:name xmlns:n="http://mycompany.example.com/employees">
             Åke Jógvan Øyvind </n:name>
          <o:number>123456789099999</o:number>
          <o:expiration>2005-02</o:expiration>
       </o:creditCard>
     </m:chargeReservation>
  </env:Body>
</env:Envelope>
```

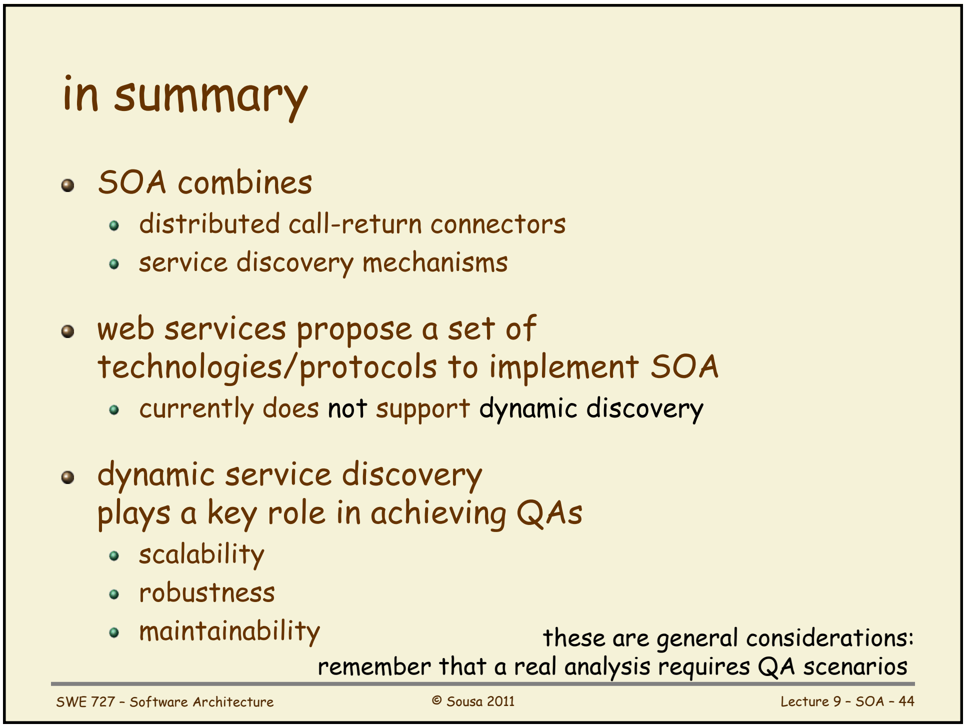
example
call-return communication in SOAP



many implementations of SOAP today

- Apache SOAP/Axis – Java/C++
- PocketSOAP – COM/C++
- SOAP::Lite - Perl
- PHP SOAP - PHP
- gSOAP – C++
- SOAP4R - Ruby
- Python web services project – Python
  - and these are only the open source ones…

rely on a common understanding of the structure and meaning of the exchanged messages



in summary

- SOA combines
  - distributed call-return connectors
  - service discovery mechanisms
- web services propose a set of technologies/protocols to implement SOA
  - currently does not support dynamic discovery
- dynamic service discovery plays a key role in achieving QAs
  - scalability
  - robustness
  - maintainability

these are general considerations:
remember that a real analysis requires QA scenarios