Towards the Web of Things

Dave Raggett, W3C

Contents

- The origins of the Web and how it has evolved
- Challenges posed by the explosion of new kinds of networked devices
- Changing the way we think about the Web
- What's wrong with today's hacks
- More effective approaches based upon separating out different concerns
- Looking further out to the future

Before the Web

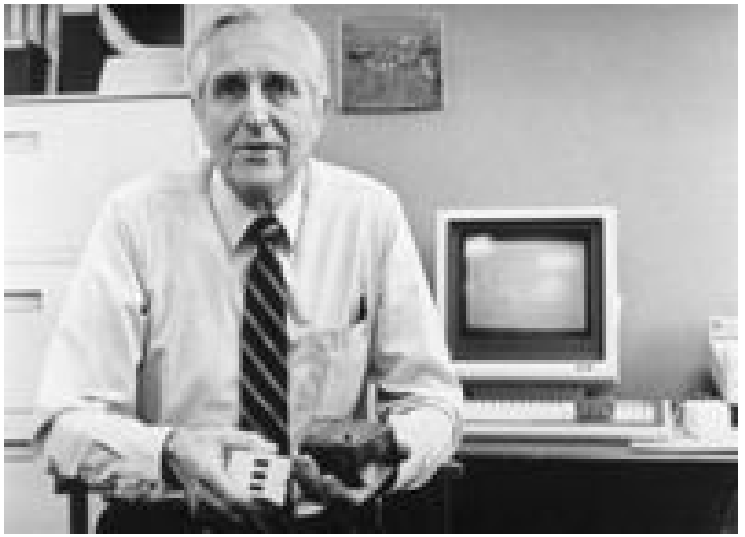
Vannevar Bush

- Scientific advisor to President Roosevelt
- “As We May Think” published July 1945 in The Atlantic Monthly

  A conceptual machine (the Memex) that can store vast quantities of interlinked information

- Same article describes the Cyclops Camera:

  "worn on forehead, it would photograph anything you see and want to record”



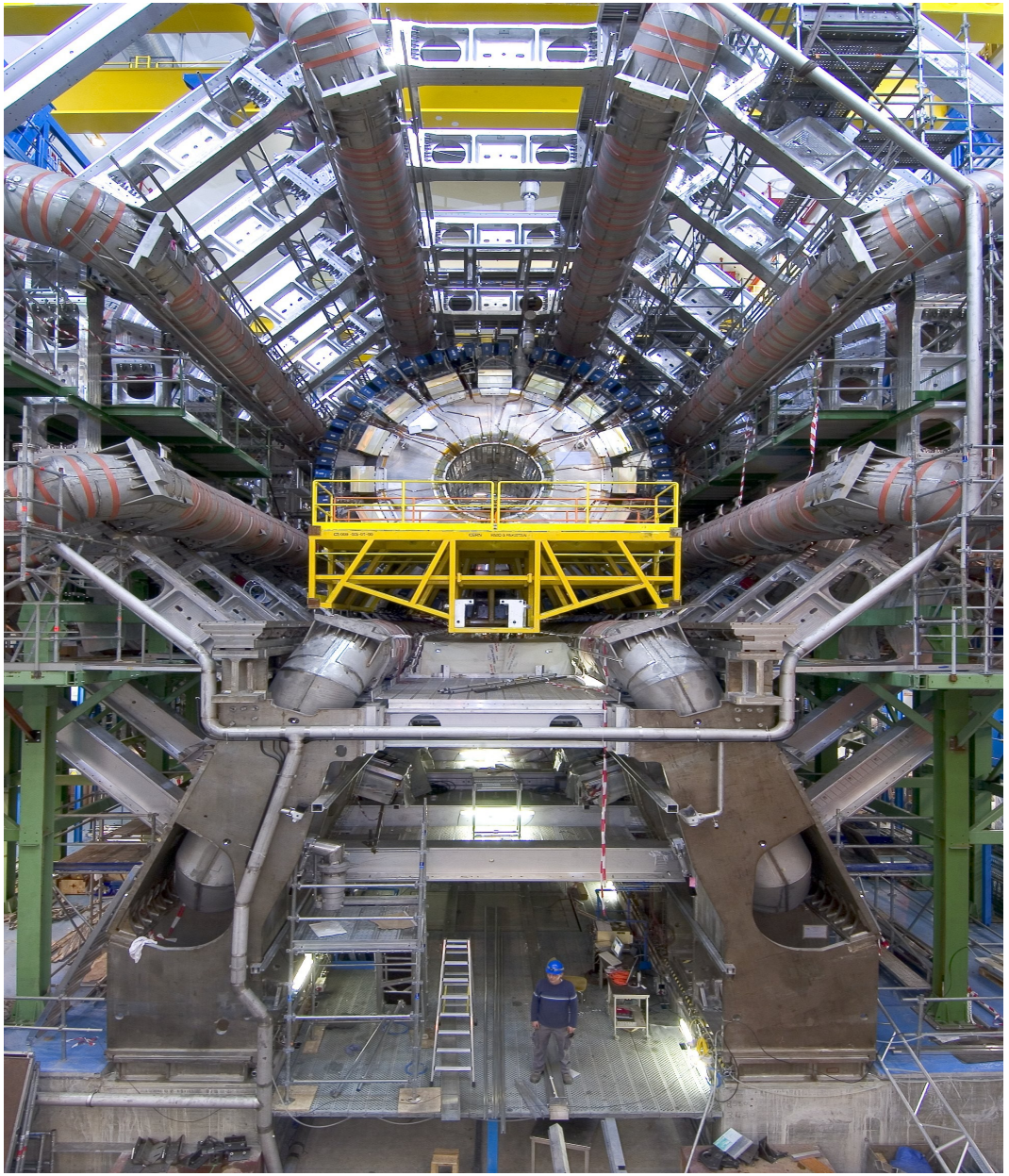
Douglas Engelbart

- mid-1960's Inventor of the computer mouse, he led work on hypertext and graphical user interfaces at SRI International

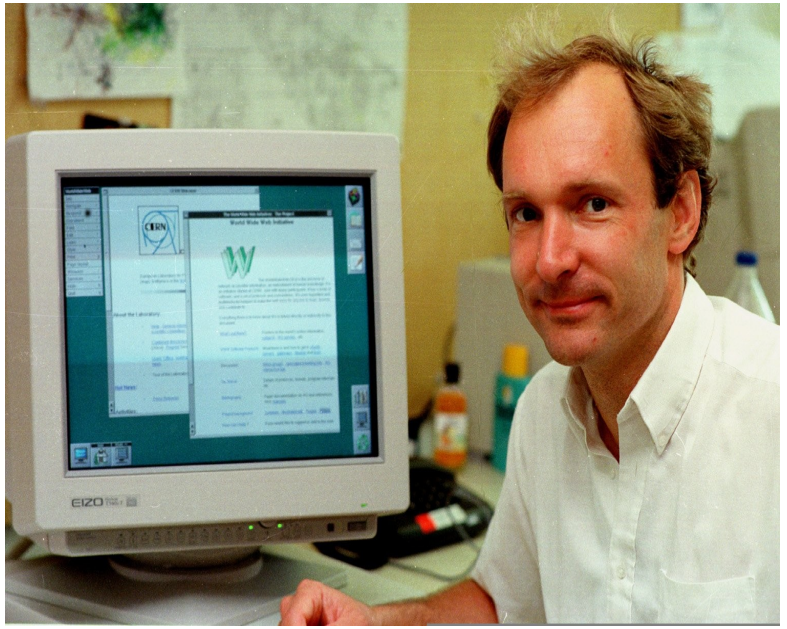
Ted Nelson

- 1965 coins the term “Hypertext”
  - in "A File Structure for the Complex, the Changing, and the Indeterminate". 20th National Conference, New York, Association for Computing Machinery
- Project Xanadu founded in 1960
  - Goal: a networked pay-per-document hypertext database encompassing all written information

CERN – birthplace of the Web



- International research centre for high energy physics located near Geneva
- Large Hadron Collider (LHC) Atlas detector due to start working in mid 2008
- Probing conditions at earliest moments of the Universe



Tim Berners-Lee

Inventor of the World Wide Web

- Friend of a friend at Oxford, we first meet in '92
- 1980 Develops “Enquire” as a simple hypertext system whilst consulting for CERN
- 1989 Project proposal for World Wide Web
- 1994 Founds W3C to lead the Web to its full potential

Enquire

```
> ENQUIRE
Enquire V 1.1

Hello!
Opening file (PSK-PCP)VAC-V1:ENQR...

PSB Vacuum Control System                        (concept)  <   O>
--- ------ ------- ------

 [ 1] described-by: Enquiry System
      An experimental system for which this is a test.

 [ 2] includes: Vacuum History System
      Records and displays slow changes in pressure.

 [ 3] includes: Vacuum equipment modules
      Perform all the hardware interface

 [ 4] includes: Control and status applications programs
      Provide operator interaction from the consoles.

 [ 5] described-by: Controle du System a Vide du Booster 11-2-80
      Operational specification of the software

 [ 6] includes: PSB Pump Surveillance System          PCP 228
      Allows rapid monitoring of pressure changes

[number      ]
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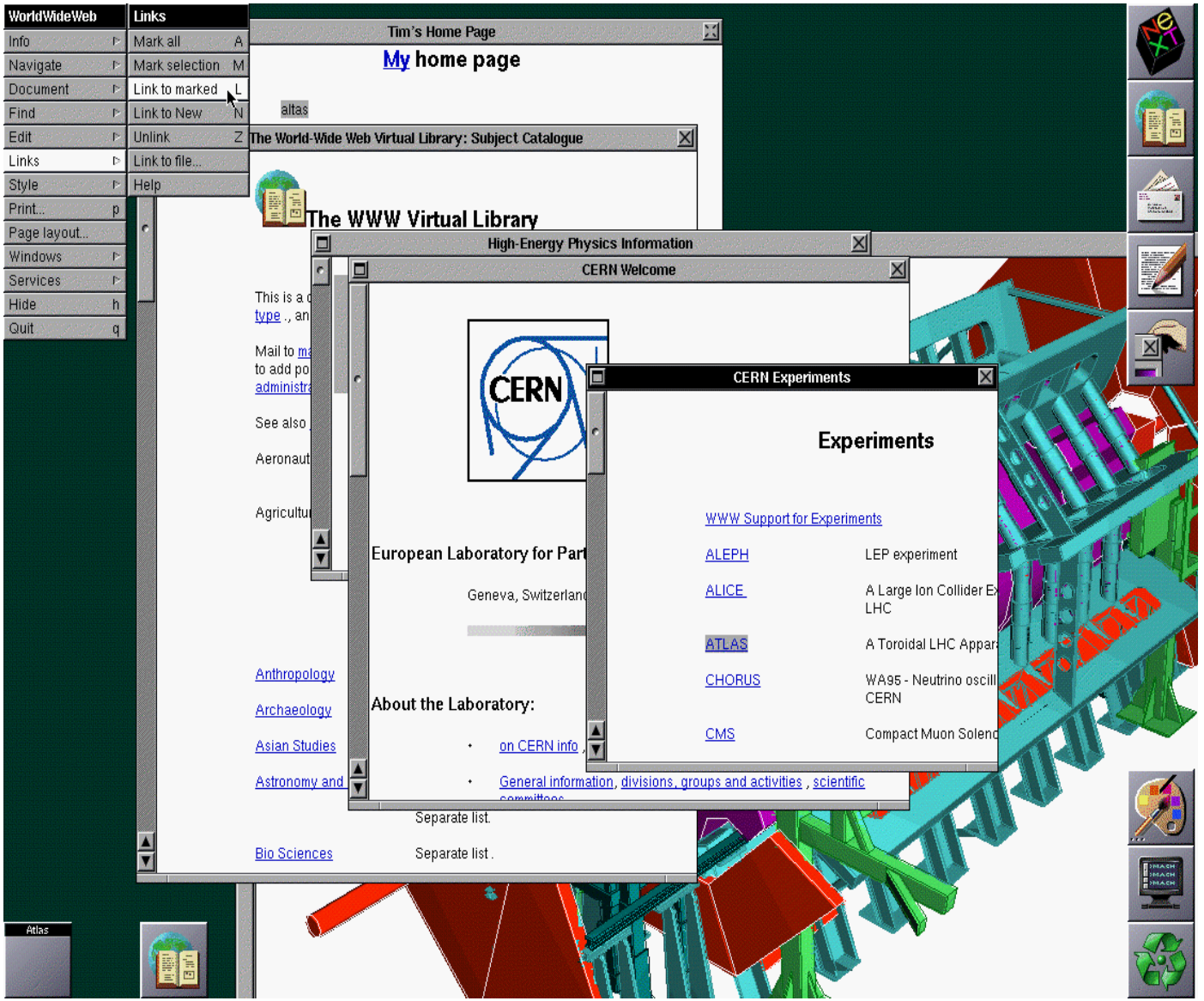
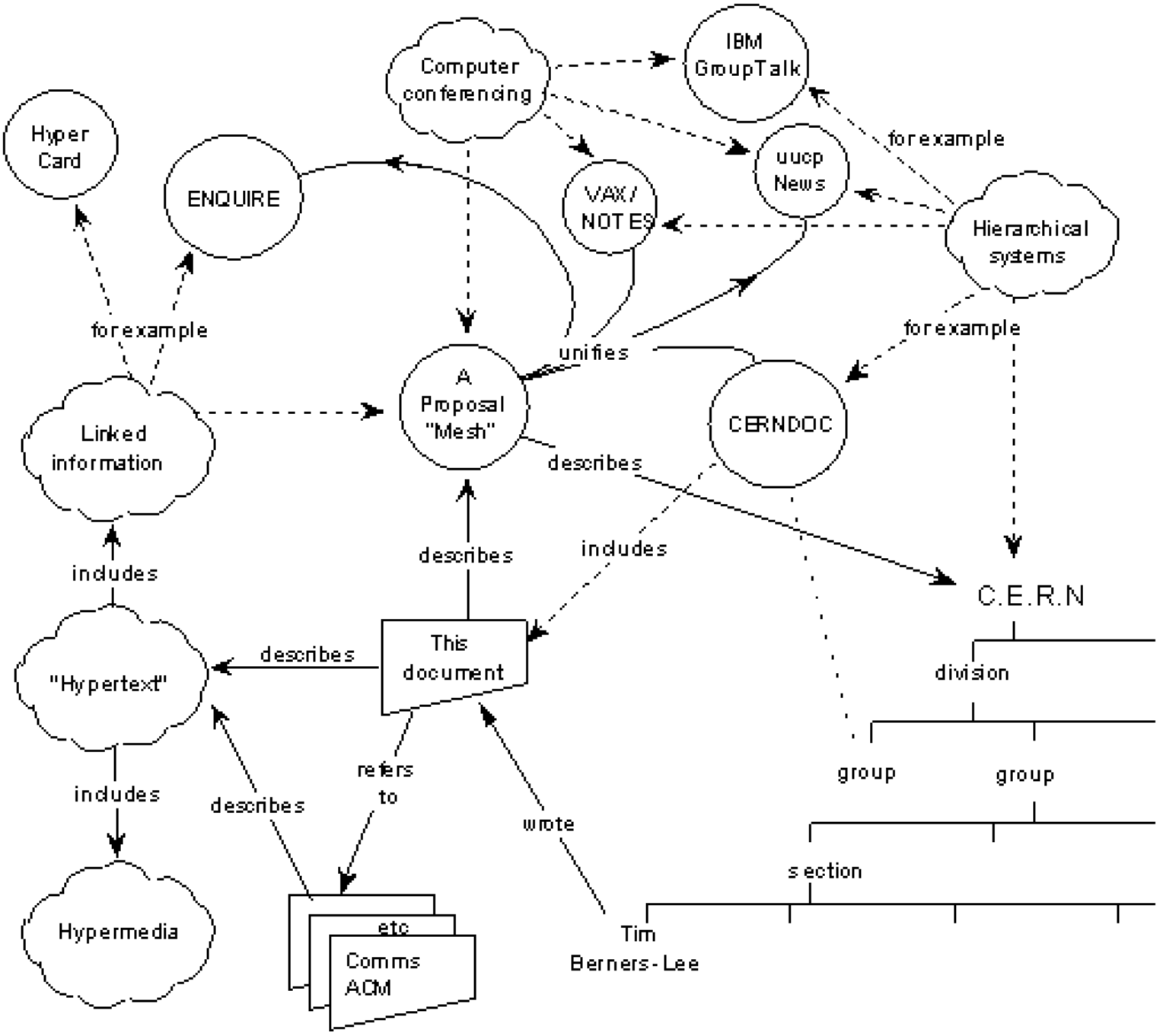
Early Web Browser

Browser/editor on NextStep workstation



1990: WWW Architecture



Only worth a Poster at Hypertext '91

Hypertext'91 Conference decides that the WWW is only worth a Poster!

Initial Simplicity

- Tim deliberately chose to keep the initial version of the Web really simple to encourage widespread adoption
- Simple hypertext markup (html) with link types
  - Chapter 1
  - Simple protocol (http) with global addresses
- Designed to be rendered on wide range of devices
- Images and other media shown in external viewers

Followed by Rapid Evolution

- Exponential growth in Web traffic
- Addition of capabilities to HTML and HTTP
- NCSA Mosaic as first widely used browser
- Netscape as first Internet boom company
- Microsoft turns on a dime
- Browser wars won by Internet Explorer
- Today: Firefox, Opera and Safari
- Mobile browsers and XML standards
- Competition with proprietary formats

World Wide Web Consortium (W3C)

- International consortium founded in 1994 with a mission to lead the Web to its full potential
- Directed by Sir Tim Berners-Lee, inventor of the Web
- Over 400 members from all across the World
- Hosted by Keio University in Japan, ERCIM in Europe and MIT in North America
- Over 60 staff members
- 17 regional partners to promote W3C work

World Wide Web Consortium (W3C)

- W3C has produced over one hundred Recommendations covering HTML, XML, CSS, Web Services, Semantic Web and many more
- Open process and patent policy designed to enable royalty fee implementations of W3C specifications
- 47 Working Groups, 12 Interest Groups, 4 Coordination Groups, 4 Incubator Groups, Technical Architecture Group, Advisory Board, and the Advisory Committee with one representative from each W3C Member

W3C Team
December 2006

How I got involved

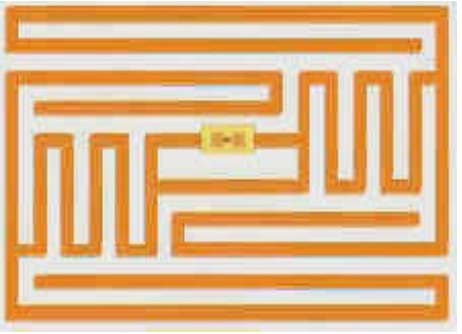
- Studied physics/astrophysics at Oxford
- AI at Edinburgh and Imperial College
- HP Labs, working on knowledge-based systems
- Hypertext-based expert system for generating quotes for HP computer systems
- Started working with TimBL on WWW in 1992
- HTML+, HTML 3.0, HTML3.2, HTML4, XHTML
- HTTP, Math, Forms, Voice, Multimodal and now the Ubiquitous Web

Web of Things

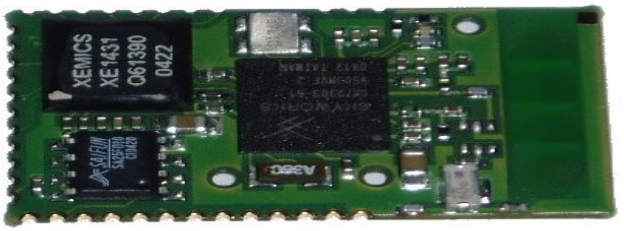
Barcodes as a way to connect physical objects to the Web

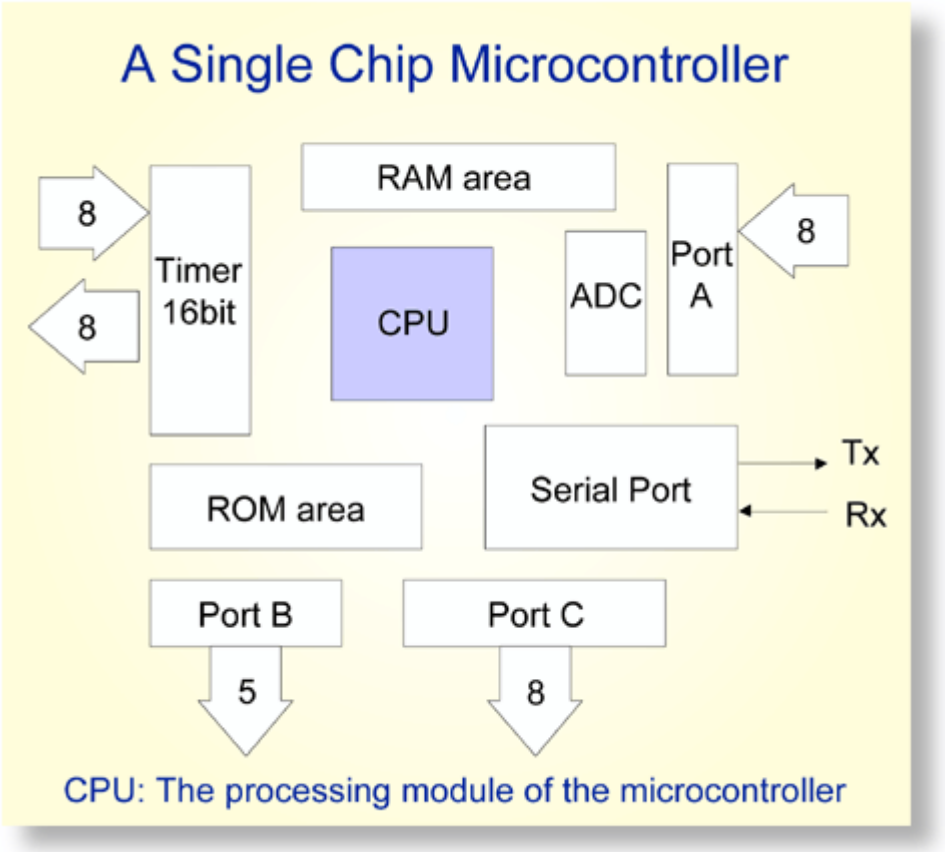
RFID

Electronic versions of barcodes
but with extended capabilities



Microcontrollers





- Computer on a chip
- Fastest growing segment of computer industry
- Average home now contains around 200
- Cars between 35 and 100 for luxury models

Uses of Microcontrollers

- TV sets, TV remote controls, Video recorders printers, cameras, scanners, fax machines
- Ovens, toasters, refrigerators, washing machines, central heating systems
- Mobile phones, PDAs, MP3 players, computer monitors
- Car body electronics, air conditioning, seat control, chassis and safety, infotainment, power train
- The list goes on and on ...

Web of Things

- Rapidly diminishing incremental cost for networking all kinds of devices
- The challenge for how to integrate devices as part of distributed applications
- Changing the way we think of the Web
  - No longer just about viewing websites on desktop browsers with big screens
  - Instead apply Web technologies to ease the task of developing new kinds of applications across a very wide range of devices

What's the Value?

- Improved physical security and peace of mind
- Reduced costs of heating/cooling/lighting homes and offices
- Preventative maintenance in advance of appliances breaking down
- Better choices for home entertainment systems
- Access to information services any time, any where and on any device you choose
- Fulfilling the potential for applications that combine local and remote services

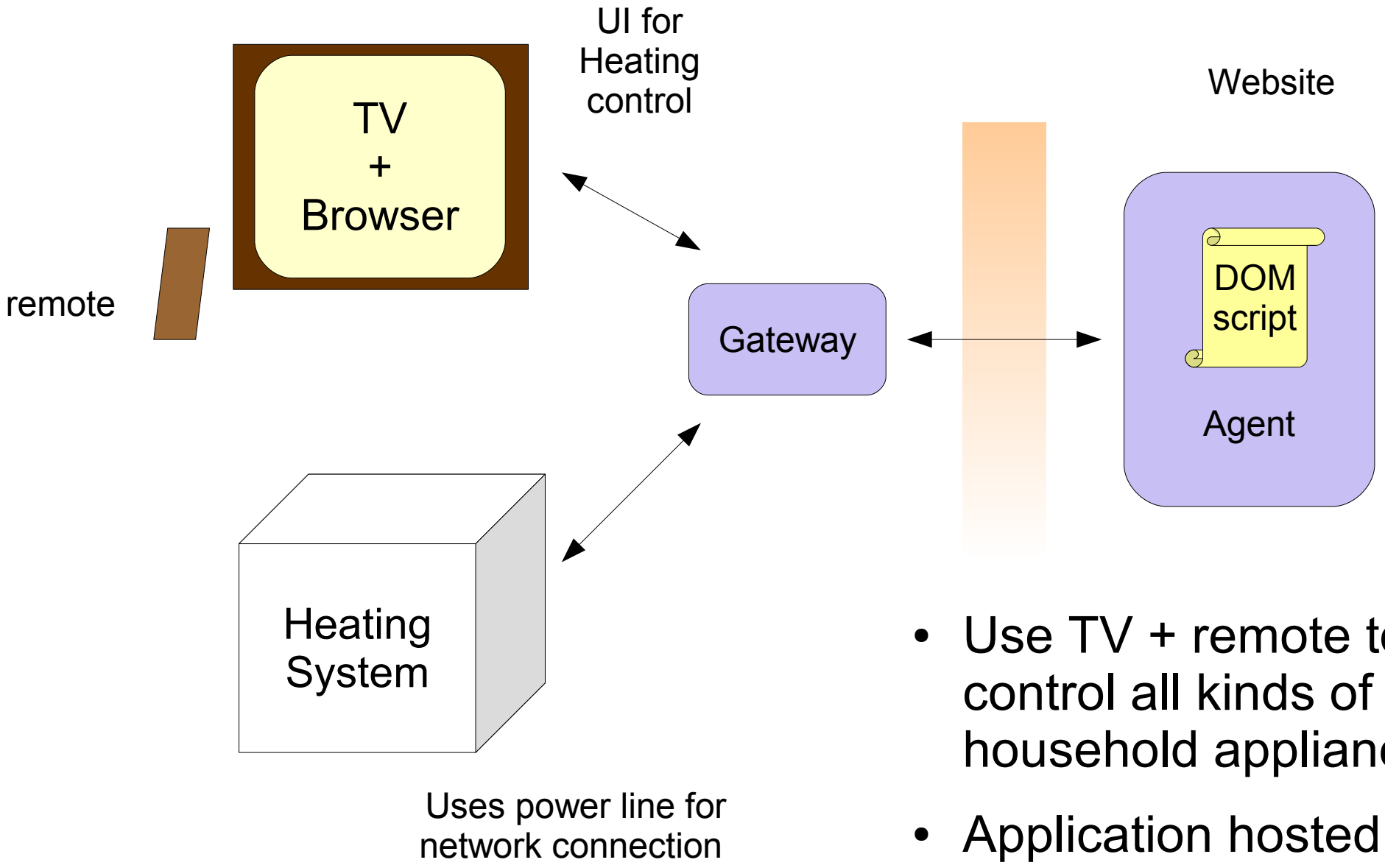
Why Standards?

- Standards are expensive and time consuming to create, why bother?
- Large and small companies may feel they can just develop their own solutions, much easier!
- But standards encourage a bigger market with many more players and more innovation
- That means that everyone wins
- Users are no longer in thrall to single vendors

Aren't current standards sufficient?

- Lots of people are building web applications using HTML with lots of client and server-side scripting
- This is expensive and very specific to desktop browsers with poor user experience on mobile devices
- Ajax is cool, but too low a level of abstraction
- The same is true for Web Services
- Very limited access to local device capabilities
- Inadequate for harnessing ubiquitous devices

Home network example



- Use TV + remote to control all kinds of household appliance
- Application hosted by website

Networking Technologies

- Applications will need to work over a mix of rapidly evolving networking technologies
  - Ethernet over twisted pair or coax
  - DSL over copper phone lines
  - Ethernet over building power wiring
  - WiFi and WiMax
  - Bluetooth
  - ZigBee sensor networks
  - GSM and cellular packet radio
- Further challenge of different addressing schemes, e.g. peer to peer networks

Realizing the Potential

- Initially, just proprietary solutions
  - end user purchases complete solution
  - single vendor and single product generation
- Followed by narrowly focused industry standards
  - e.g. Pictbridge as solution for printing direct from camera when printer and camera from different vendors
- Broader standards follow later, enabling new applications
  - Traditional programming languages like C++ and Java offer low level control but are costly to develop with
  - Web technologies will make applications easier and cheaper to develop, enabling a much bigger ecosystem

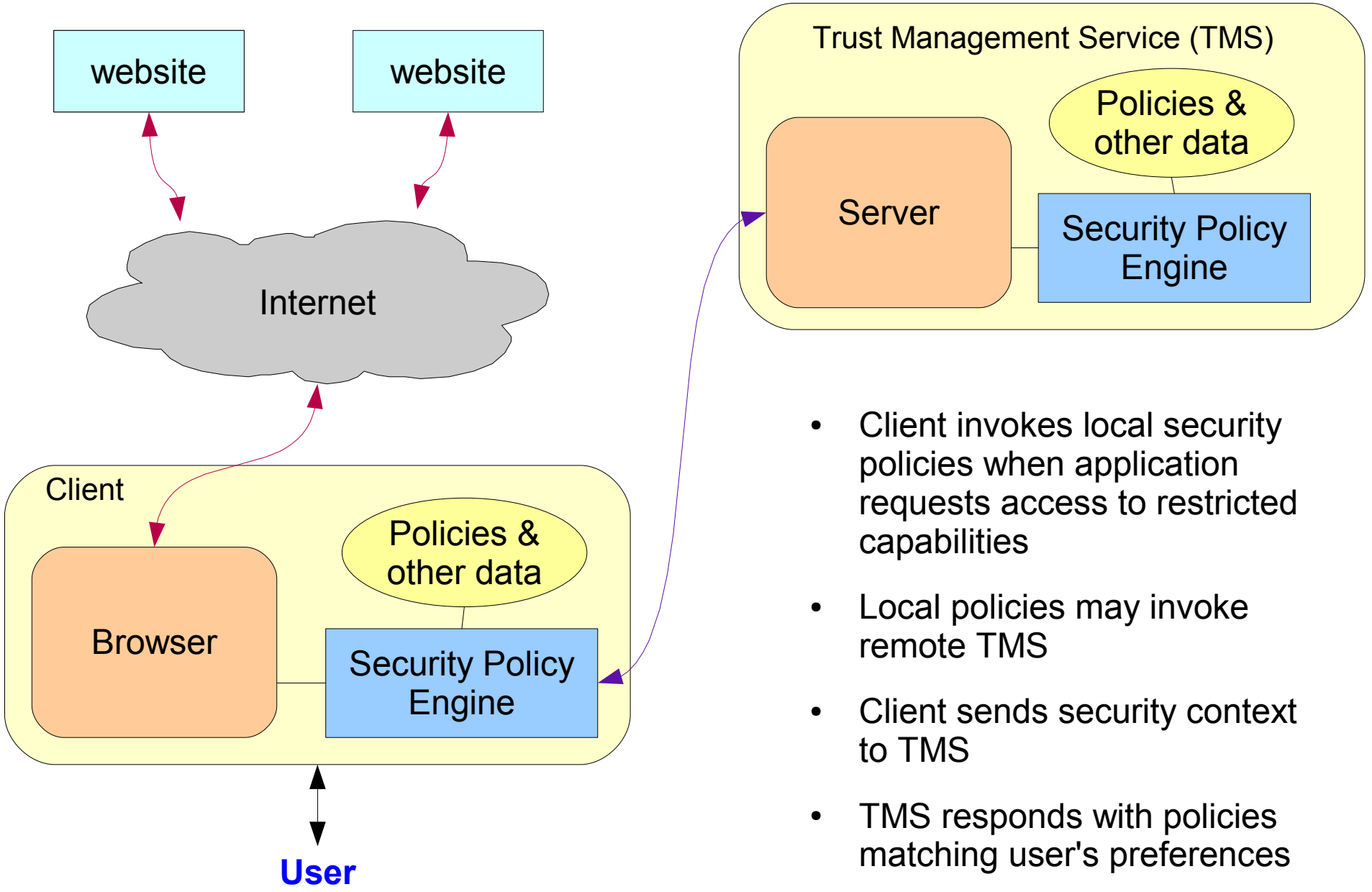
Security and Privacy Concerns

- The Web is a mess when it comes to security
- Different user name/password for each website encourages people to use weak passwords
- Wide open to phishing attacks
- Criminal gangs harnessing compromised PCs to send out spam and to launch attacks
- Privacy abuses are commonplace
- Browser sandbox model and same-site policy are too weak and work-arounds introduce major security/privacy holes

Trust Management Solutions

- Users tend to click through security related dialogues that “get in the way” of the task
- Users are often not really informed about the trustworthiness of a website/application
- We need to find solutions that offer greater security with improved usability
- Improved security through SIM cards and biometric techniques
- New ideas for trust management solutions involving a trusted third party

Trust Management



- Client invokes local security policies when application requests access to restricted capabilities
- Local policies may invoke remote TMS
- Client sends security context to TMS
- TMS responds with policies matching user's preferences

Layered Approaches to UI

- Professional Web applications are developed by teams of people with different roles & skills
- Frequent need for redesign as data models, business requirements and branding changes
- Reduce costs and increase re-use through separation of concerns
- Allows team members to focus on what they each do best
- Outsource tough task of adaptation to particular browsers and devices (analogous to compilers)

Layered UI

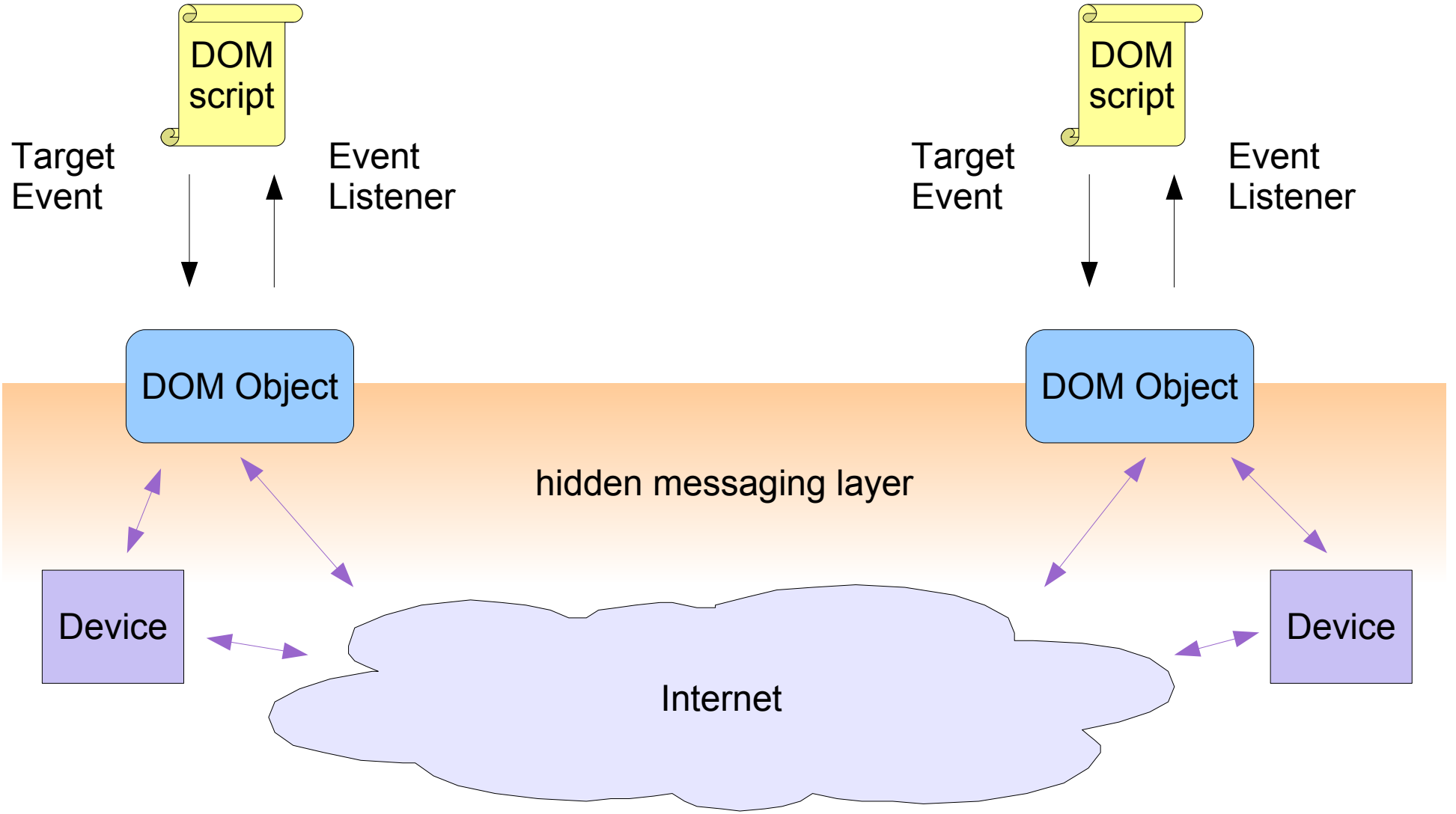
with transformations defined between each layer

1) Application task and data models
2) Dialogues and history
   - event driven state transition models
3) Abstract User Interface
   - modality independent, e.g. select 1 from n
4) Concrete User Interface
   - modality specific, e.g. radio buttons
5) Realization on specific device context
   - may involve markup, scripting and CSS hacks

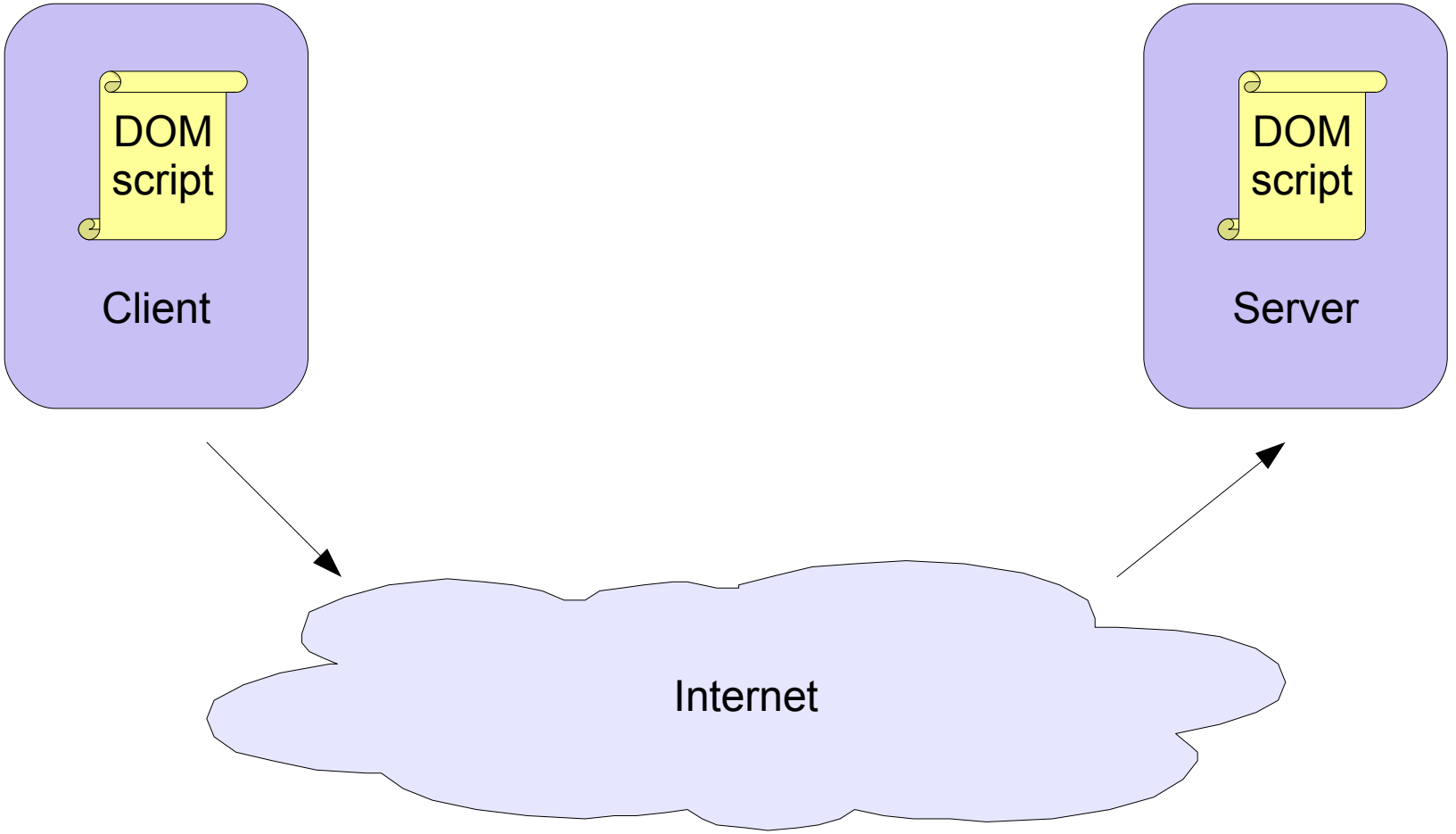
Device Coordination

- How to bind devices and services as part of distributed applications
- Web approach involves
  - Using markup for describing UI and behaviour
  - Using URIs to name devices and services
  - Rich meta-data for describing device capabilities and security policies
  - Expose device/resource as object in local object model
  - Hides addressing/communication details

Proxies for accessing services

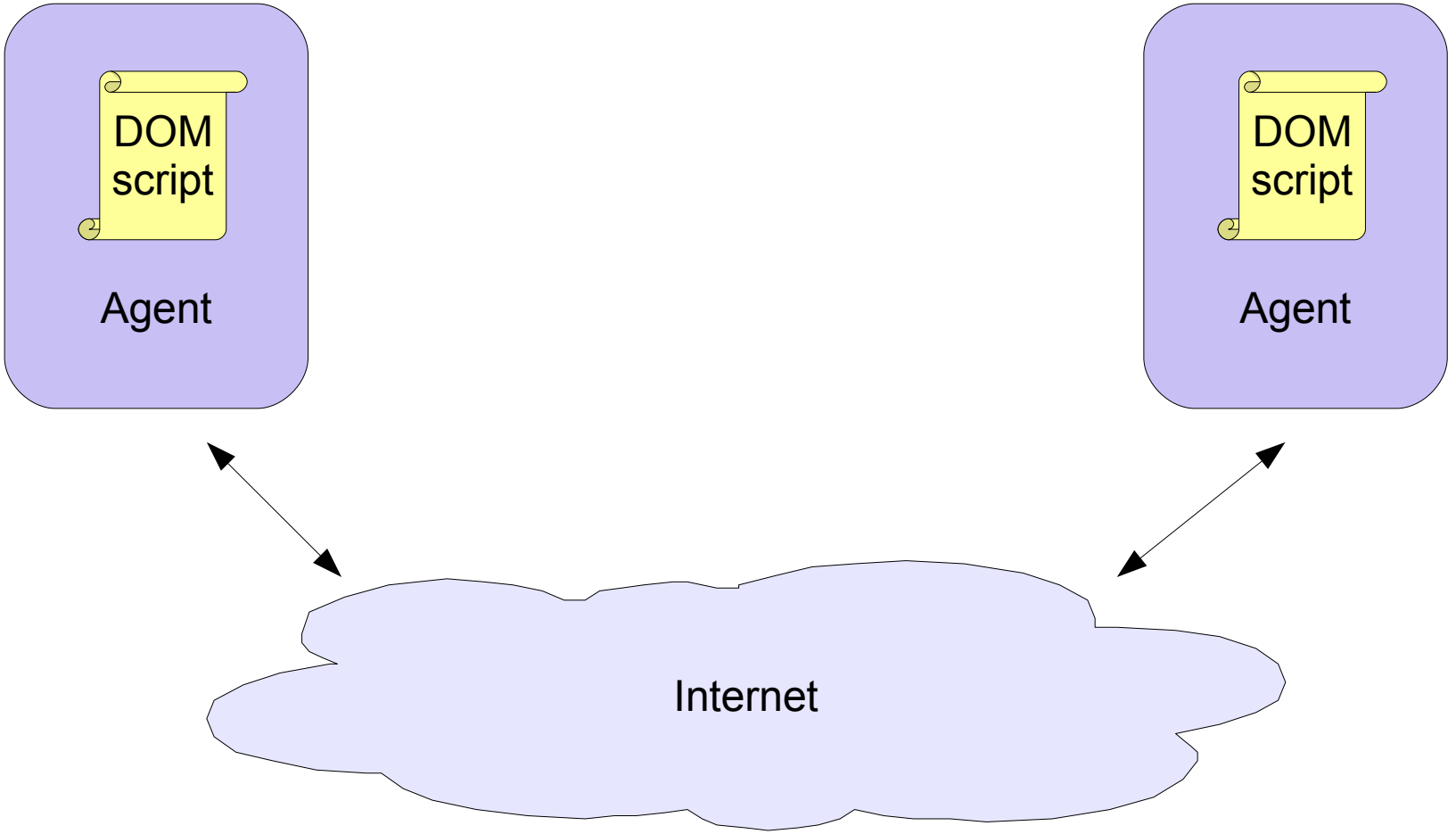


Client or Server?



Client or Server?

Agent combines client and server

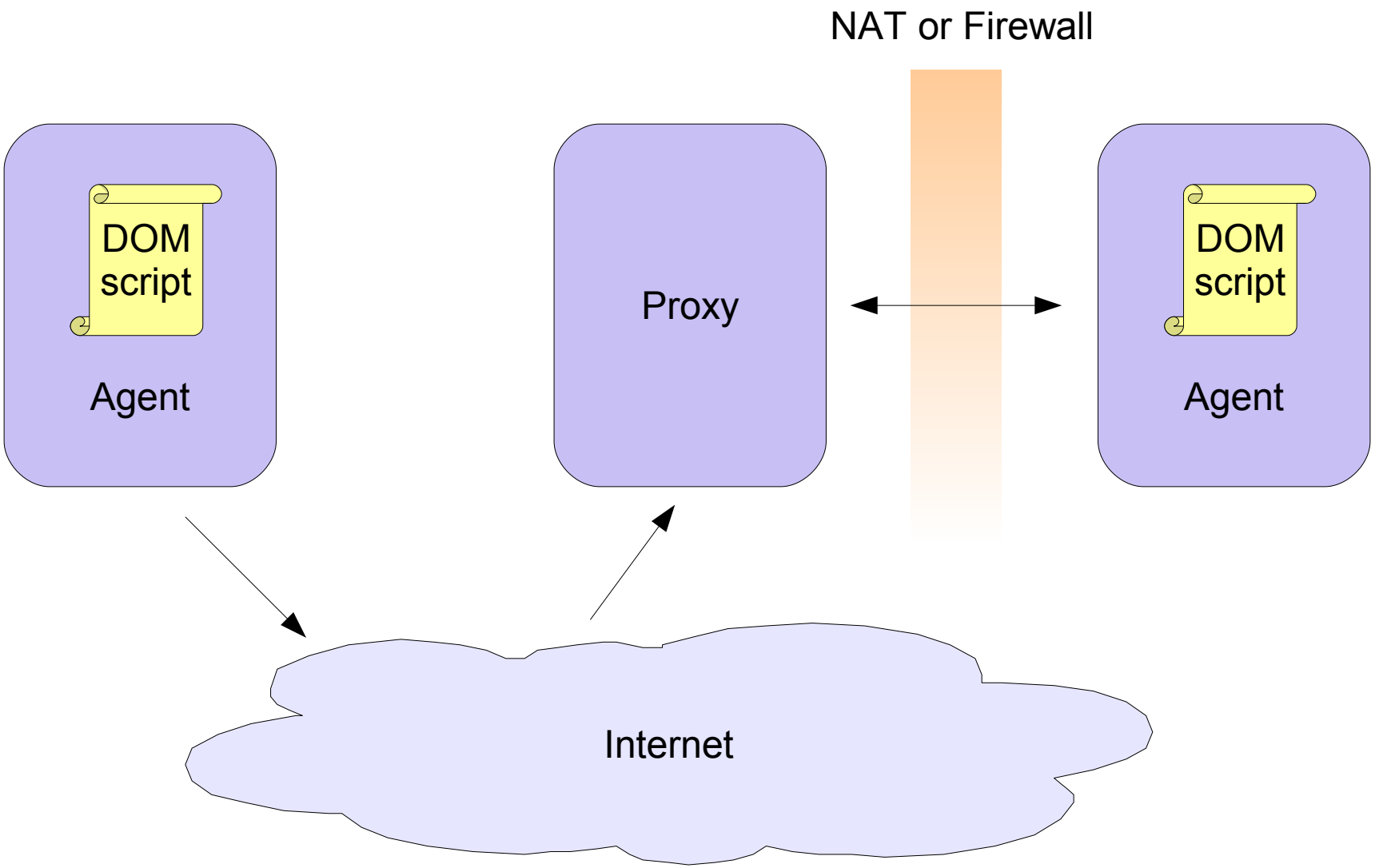


Event Transport

How to deliver events to devices?

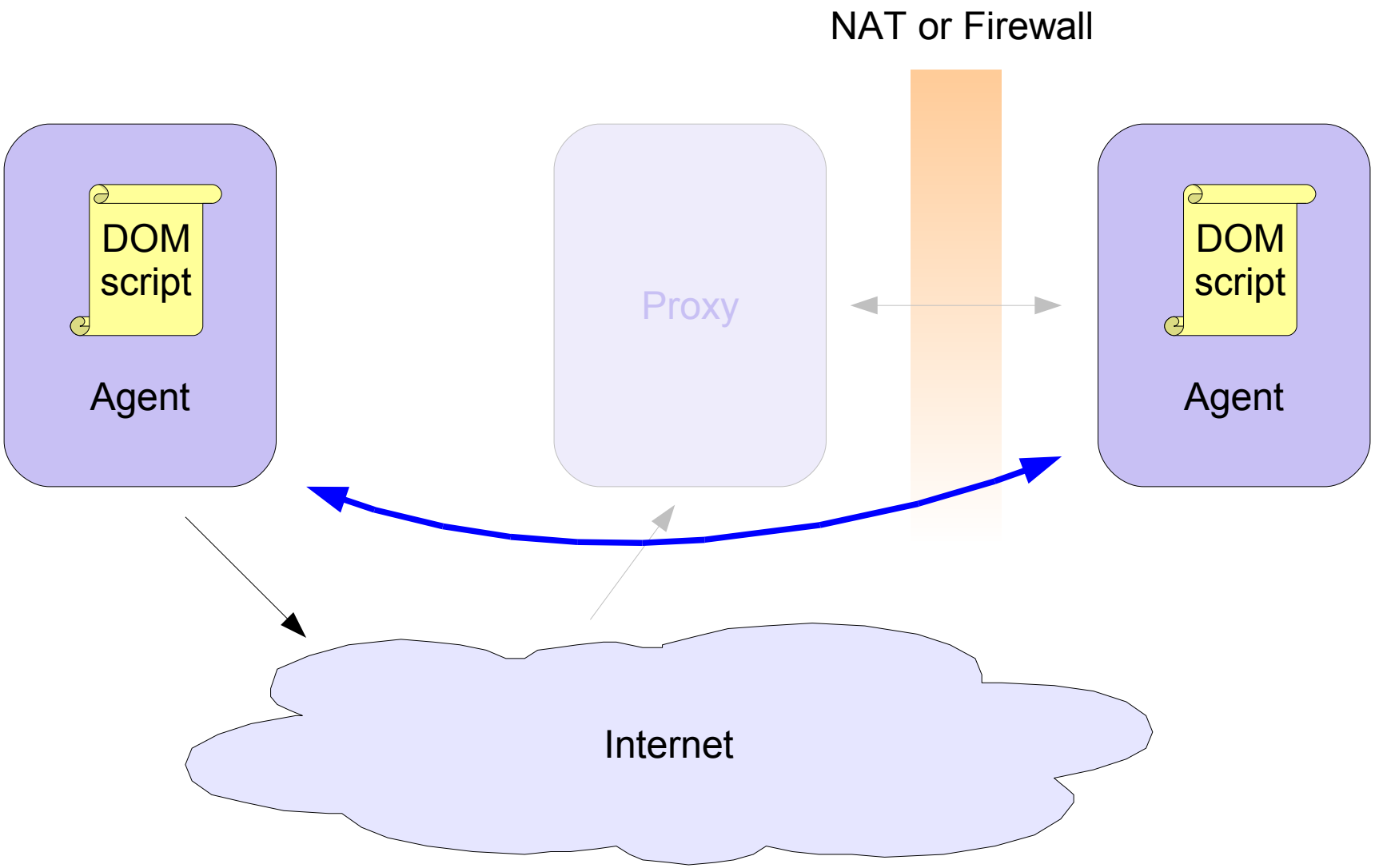
- Firewalls are intended to block undesired traffic
- Evolution of mechanisms to tunnel events through Network Address Translation
  - STUN, STUNT, TURN, etc.
- Bindings to event transport protocols
  - HTTP, SIP, XMPP

Tunnelling through NAT



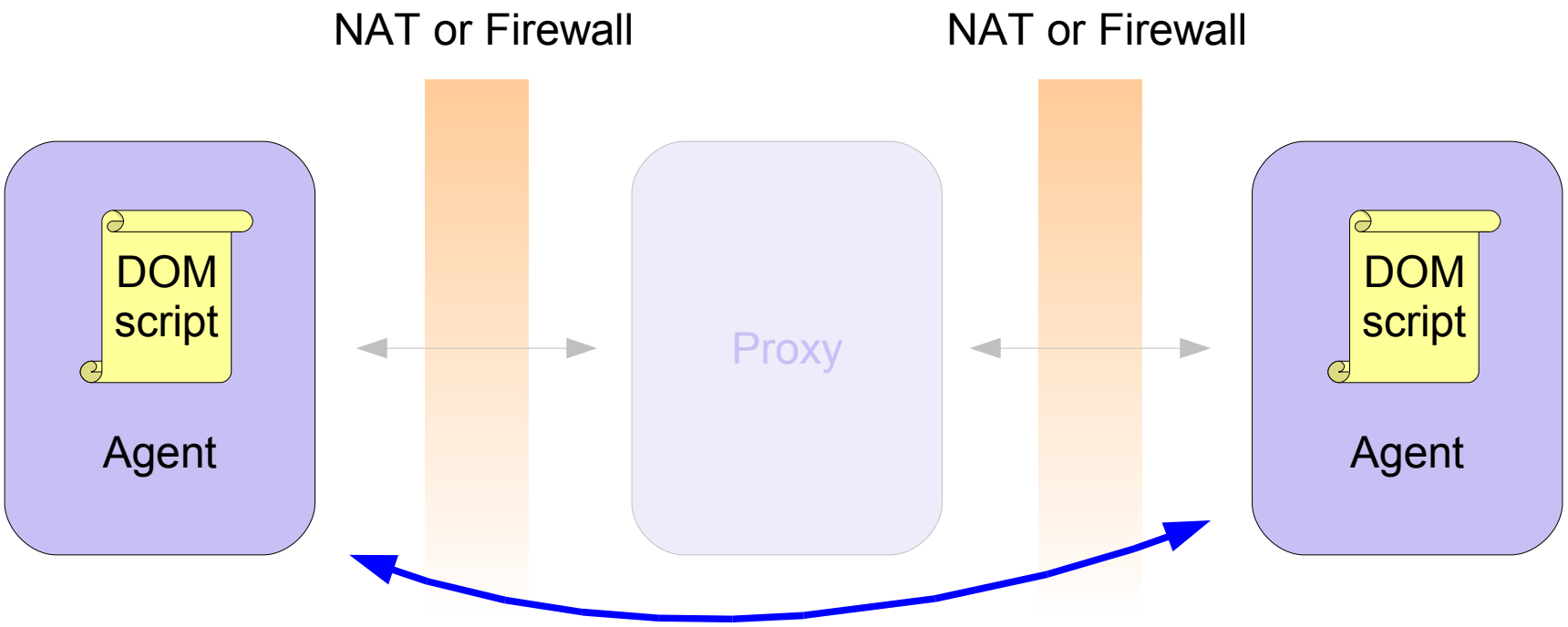
Tunnelling through NAT

Proxy may arrange for direct link through NAT



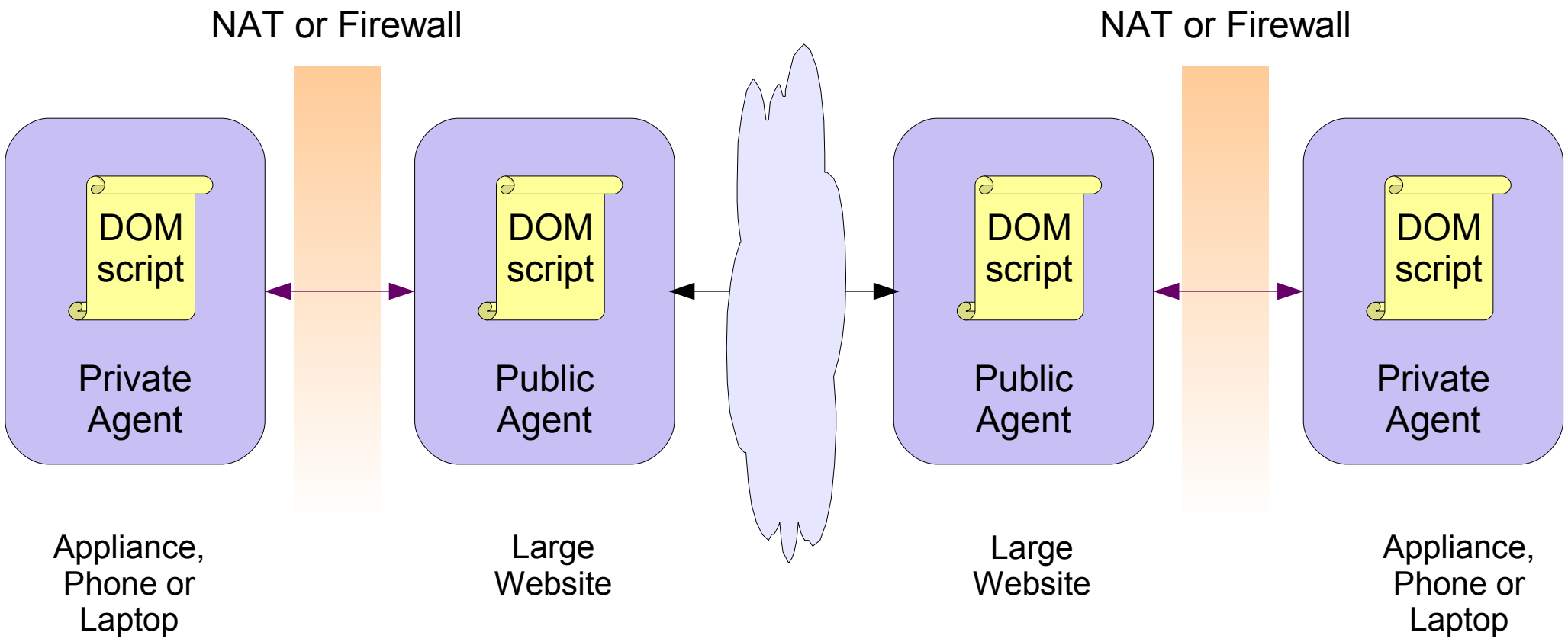
See STUN, TURN and other techniques

Tunnelling through NAT



Connecting devices behind different NATs

Public and Private Agents



- Private agents may be off-line or powered down
- Enabling off-line operation via data synchronization

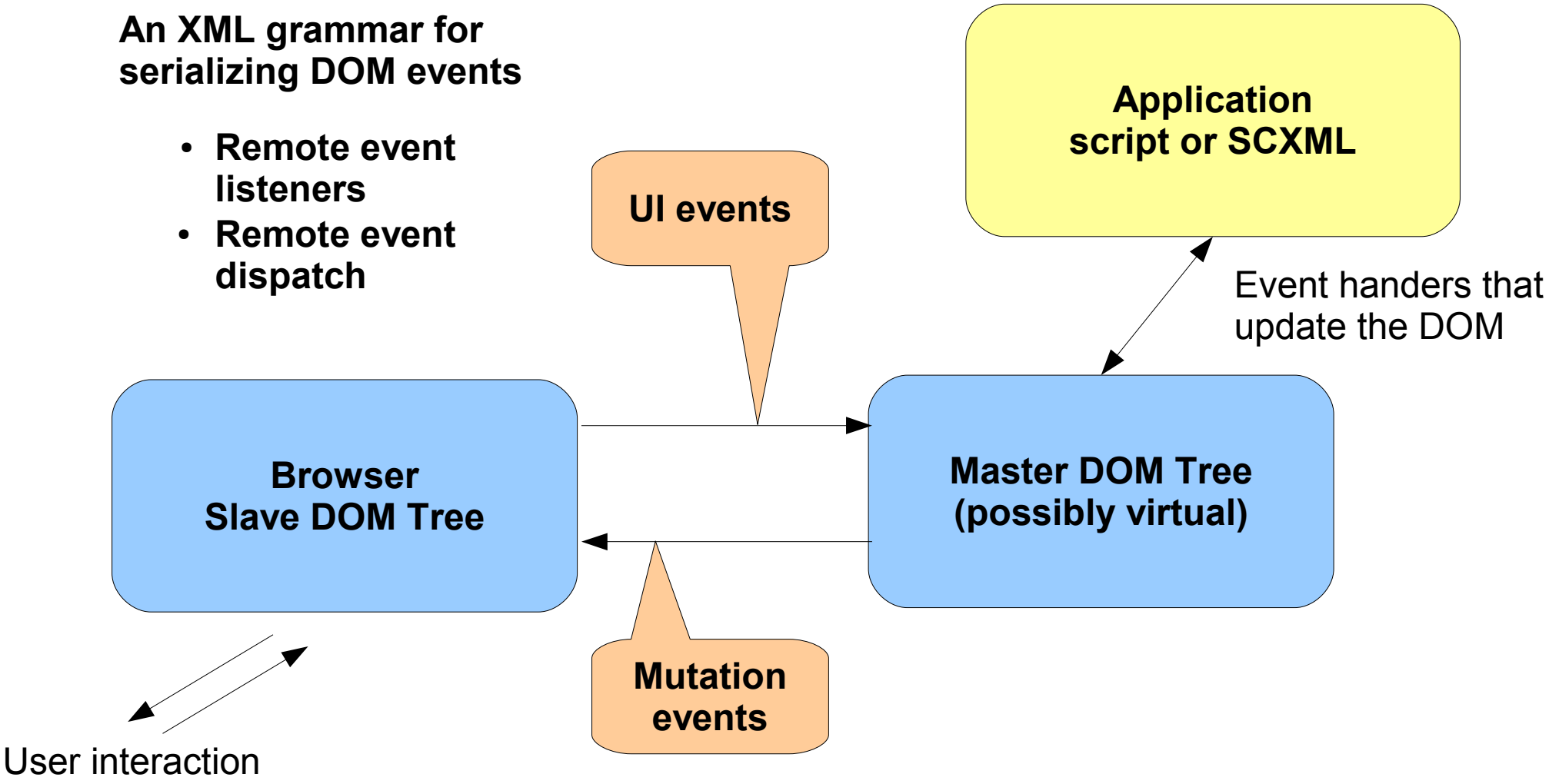
Remote User Interfaces

- Moving beyond Web browsers to new kinds of applications
  - based upon distributed document object models
  - application running on one device is coupled to a user interface on another via an exchange of events
- Layered architecture involving mappings between different levels of abstraction
  - High level events as interpretations of lower level ones
  - Realizing high level tasks as particular UI behaviour

Remote User interfaces

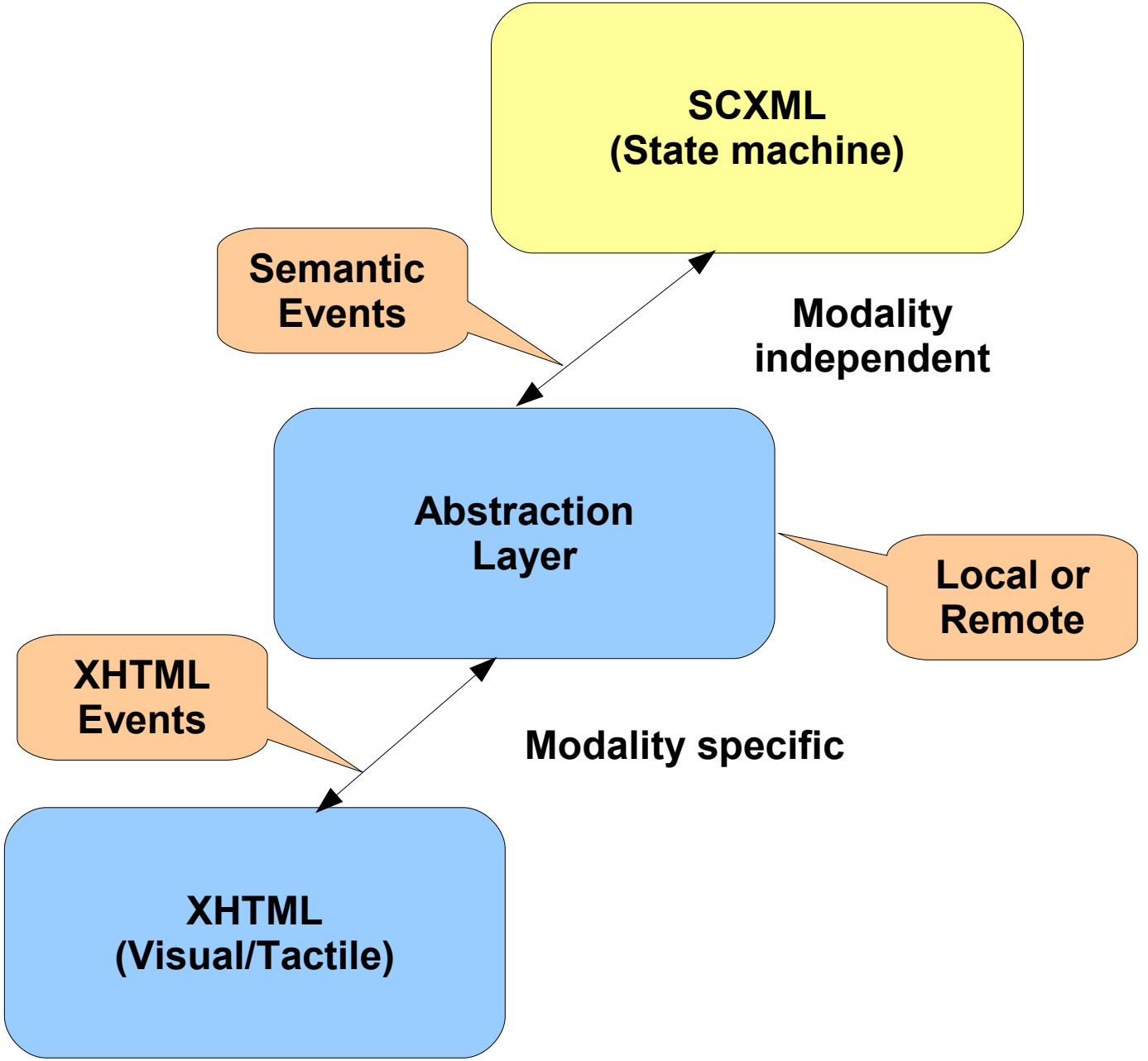
An XML grammar for serializing DOM events

- **Remote event listeners**
- **Remote event dispatch**



DOM = Document Object Model

Abstraction layer for Events



Adaptation

- Describing applications in a way that makes them easier to run on a wide range of devices
- Dynamic adaptation to user preferences, device capabilities and environmental conditions
  - Server-side use of rich meta-data for adaptation
    - tailor content to match screen size
  - Client-side access to hierarchy of properties and the means to make changes
    - expose battery level within web page UI
    - client side mashup based on access to device location
    - change audio settings from web page UI

Policy-based Adaptation

- Author markup in device independent representation
  - authoring format is freed from browser restrictions
  - high level events in place of low level scripts
- Describe policies for adaptation to classes of devices
  - what layout, images, style sheets, scripts, etc.
  - skinning apps as combo of markup, CSS, script
- Adaptation process executes policies for specific delivery context
  - e.g. generate HTML4 if appropriate
  - split content for low memory devices
  - exploit client APIs for rich web apps (e.g. Ajax)

Ubiquitous Web Applications WG

- Home page http://www.w3.org/2007/uwa
- Follow on to former Device Independence WG
- Plus broadened focus on Ubiquitous Web Applications
- Looking for people interested in working on
  - enabling applications across multiple devices
  - content adaptation for multi-channel delivery
- UWA WG Charter
  - http://www.w3.org/2006/10/uwa-charter.html
  - chair: Dave Raggett <dsr@w3.org>
  - team contact: Stéphane Boyera <boyera@w3.org>

Ubiquitous Web Applications

Questions?

This talk is available at **http://www.w3.org/2007/Talks/0926-dsr-WDC/slides.pdf**