

# Control and Understanding: Owning Your Home Network

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# Home Networking is Mundane

- Another channel through which everyday life happens
  - 300 million people worldwide have broadband connections to the Internet
  - 51% of UK households now have a broadband connection
- Yet, the most returned consumer electronics item (25%)
  - Consumers cite technical complexity as the largest barrier to home networking
- The (software) technology has not made the leap!
  - Still managed in terms of protocols and services
  - Shopping, not the web, not HTTP

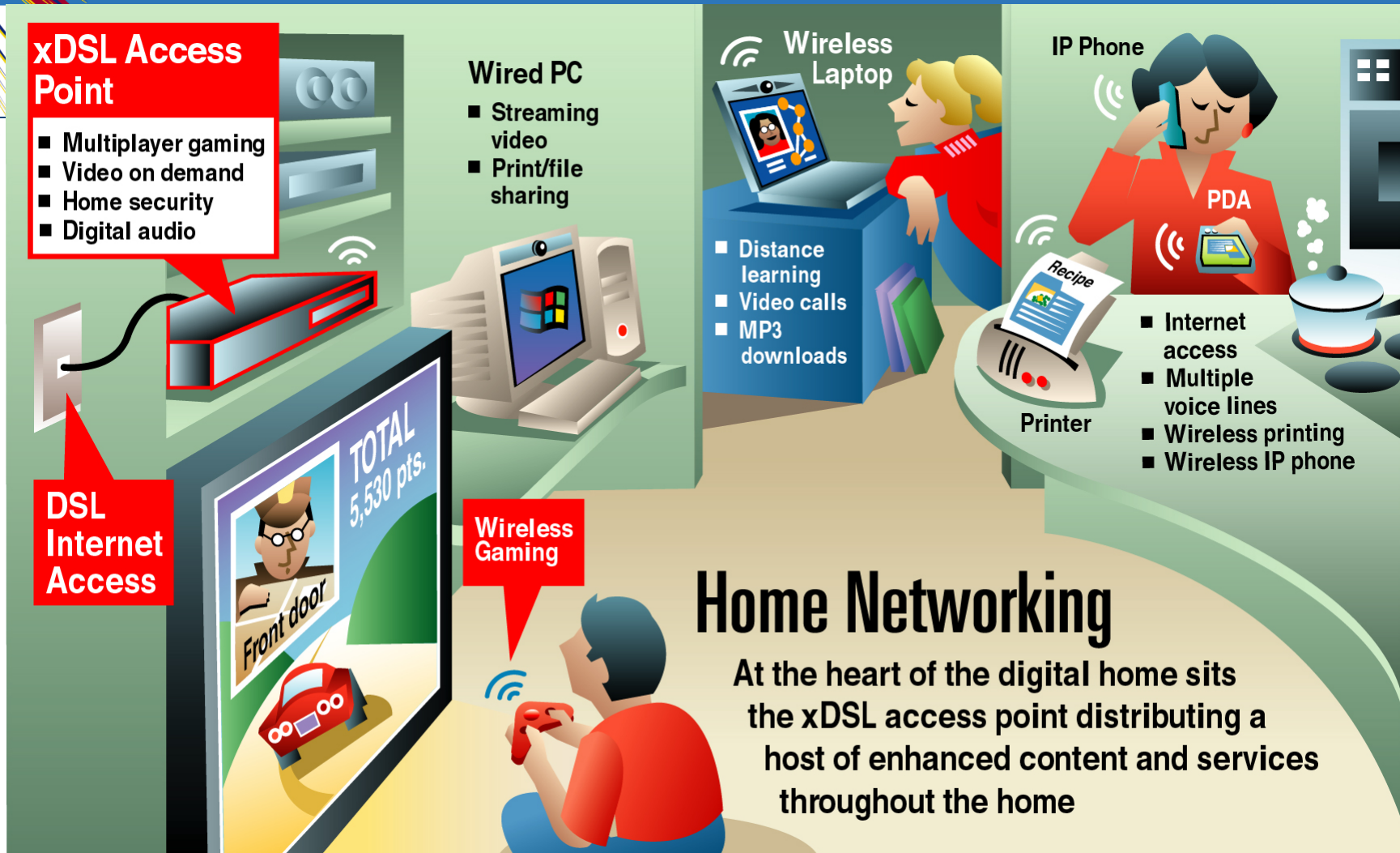




# So What's the Problem?

- Most, if not all, the technology has been appropriated
  - Networks have moved out of corporate and managed environments to the home virtually unchanged
  - Internet protocols and tools designed in the '70s for trained system administrators
  - Disinterested householders have become reluctant network administrators
- Must enable top-to-bottom connections to be made
  - Making the network **intelligible** (not intelligent)

# Future Visions vs. Lived Reality









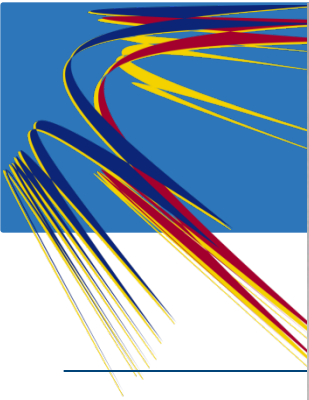






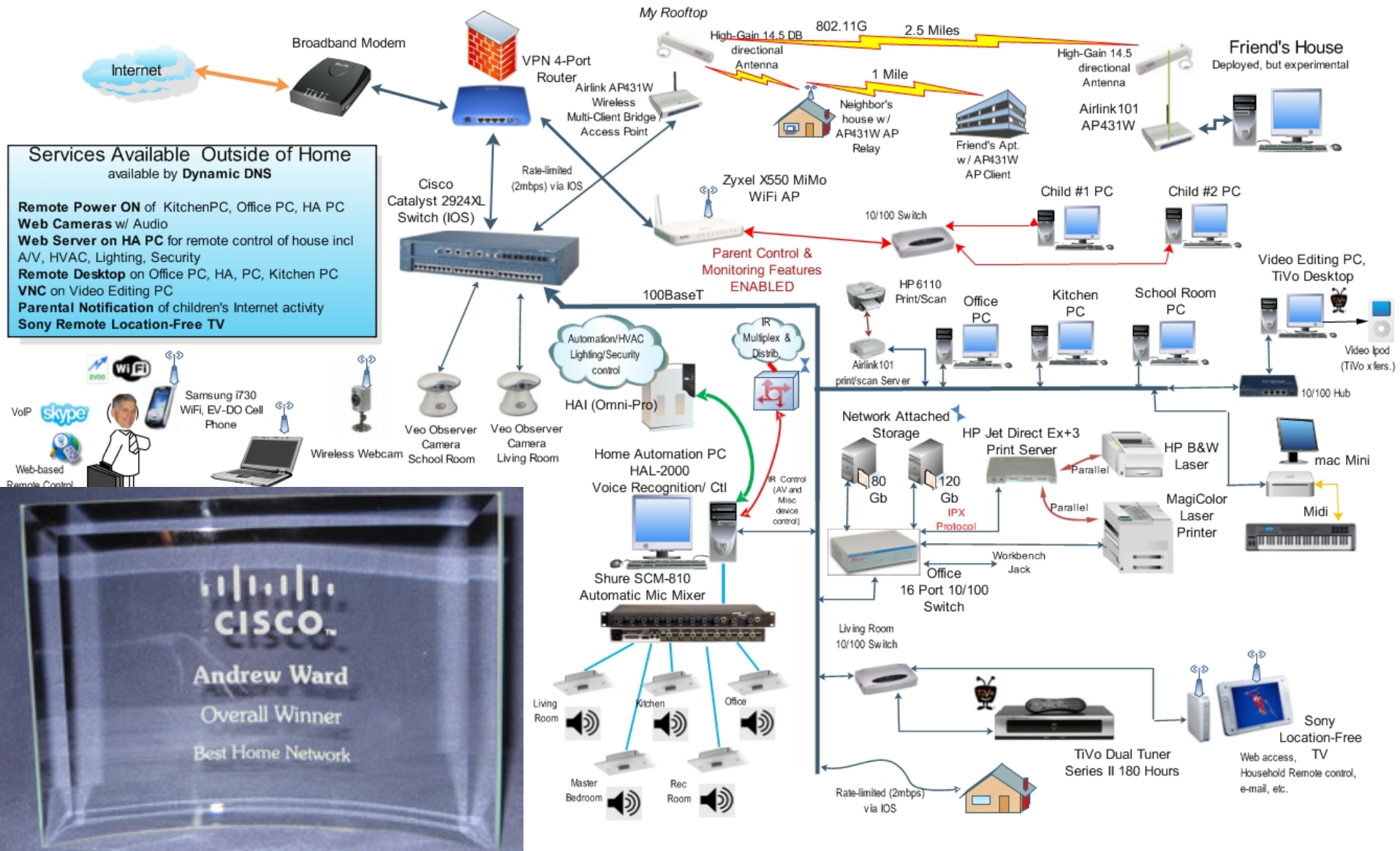




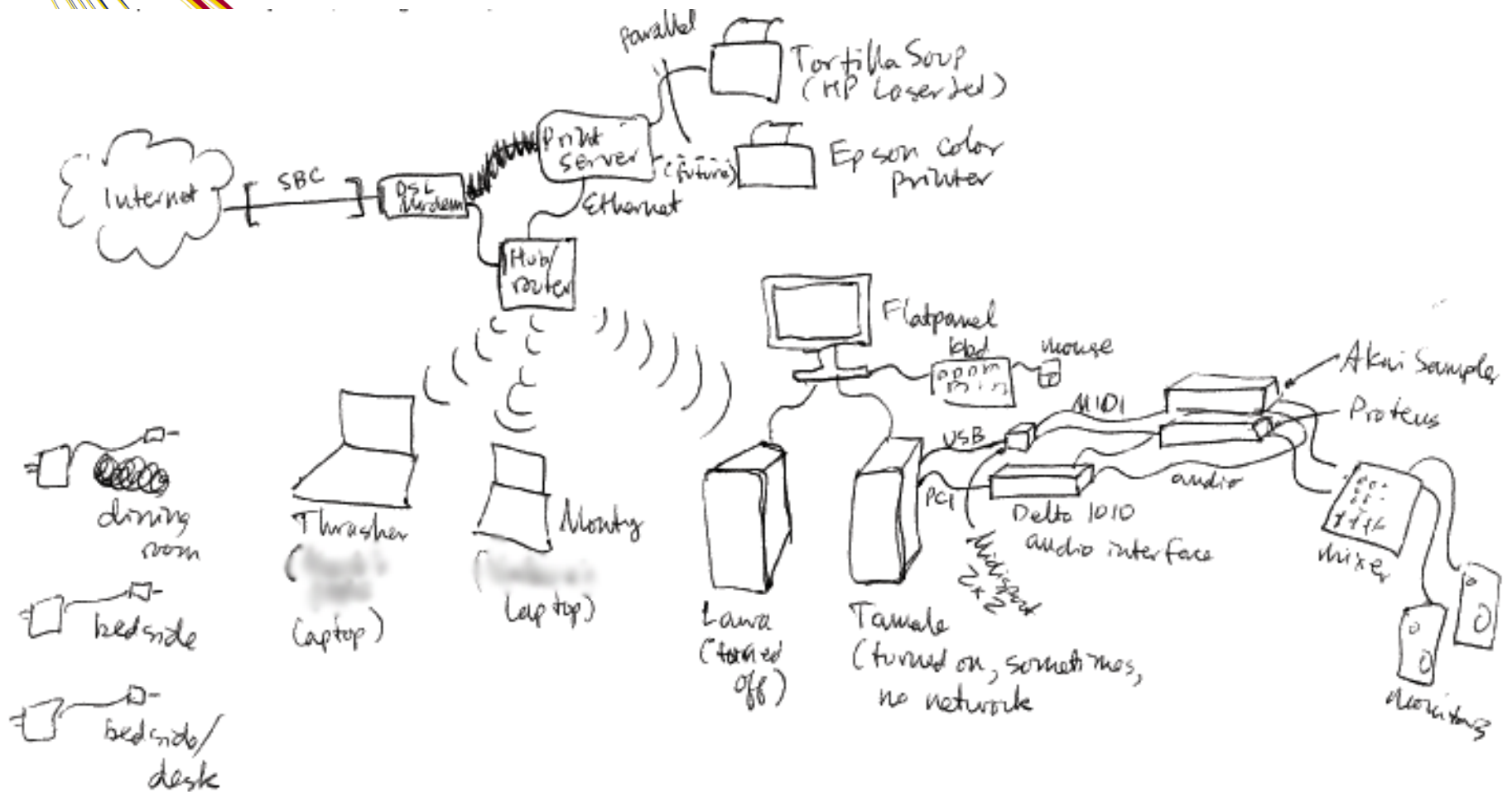




# Conceptions of the Network

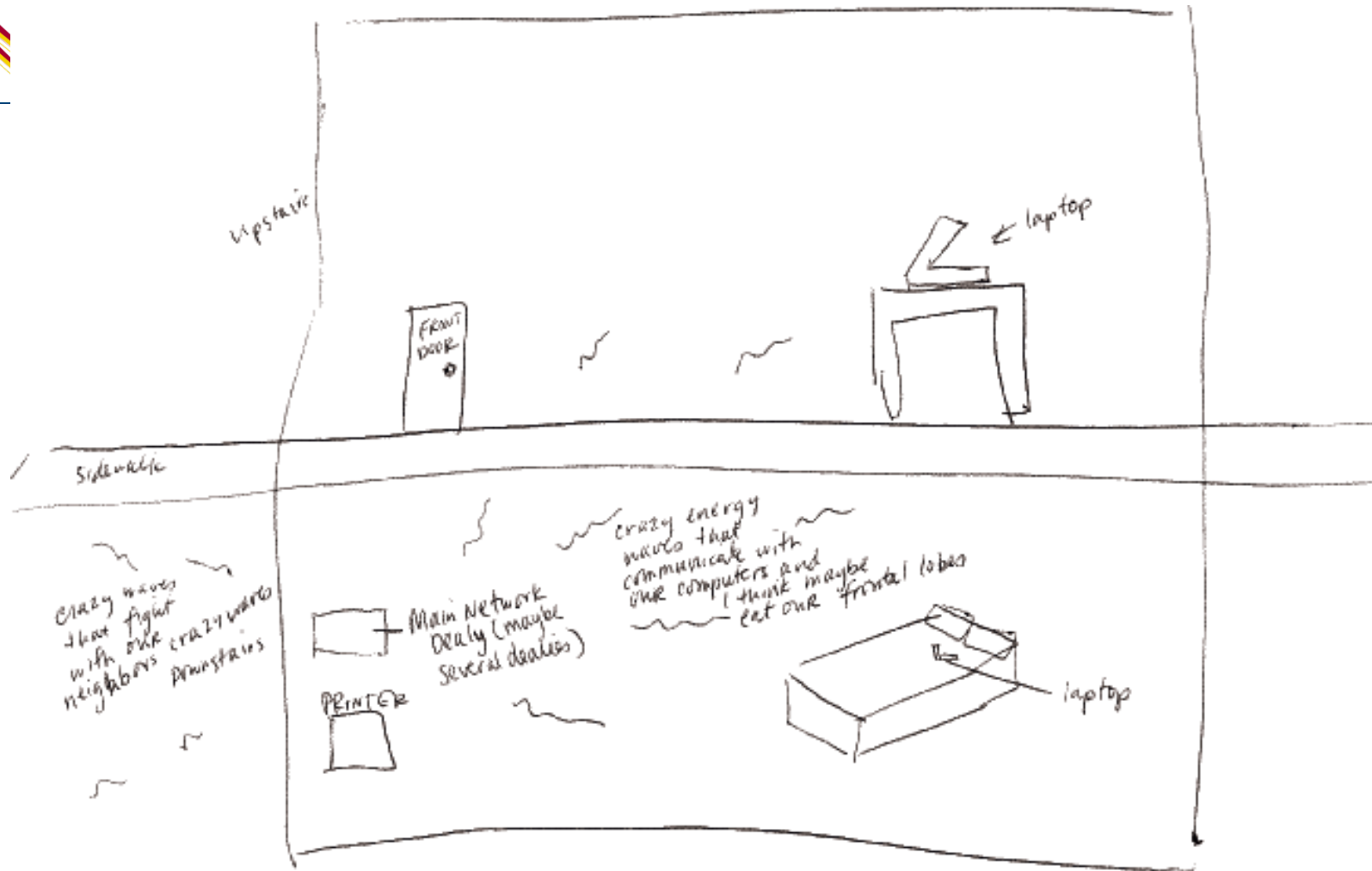


# Inhabitants' Perspective (1)

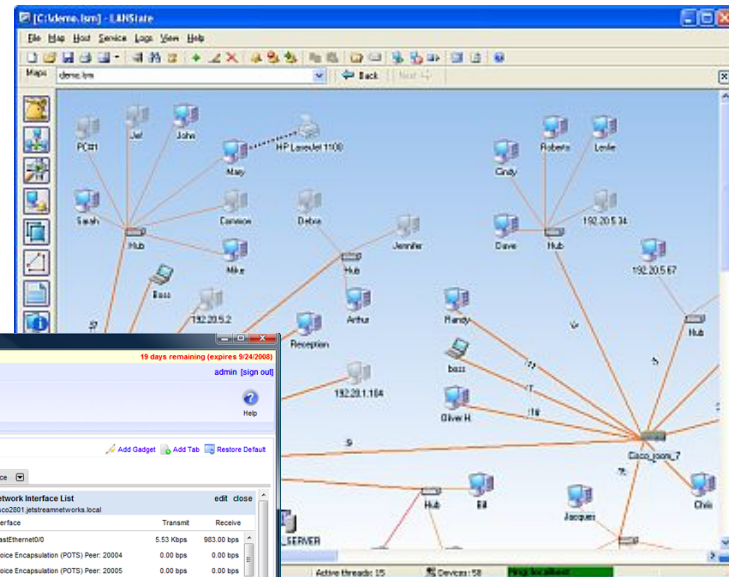
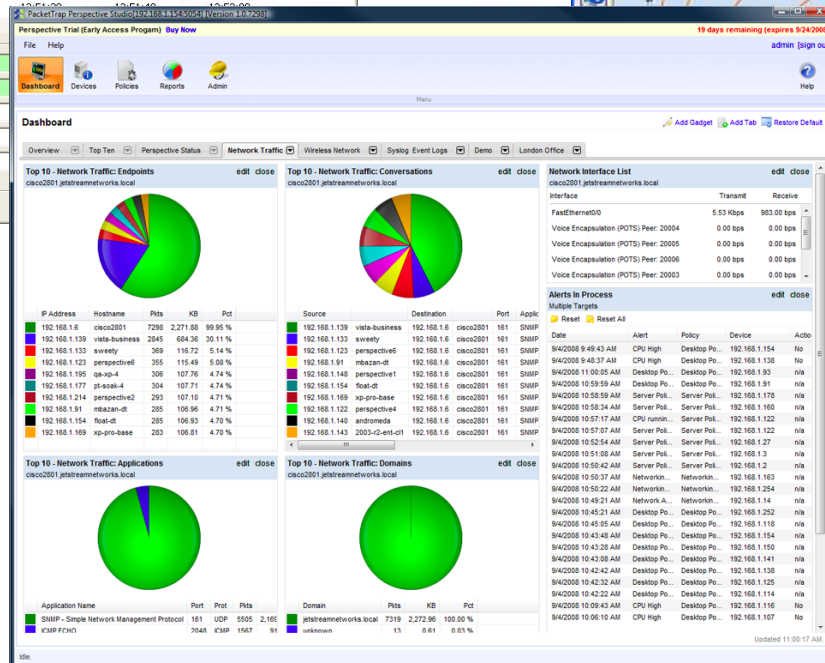
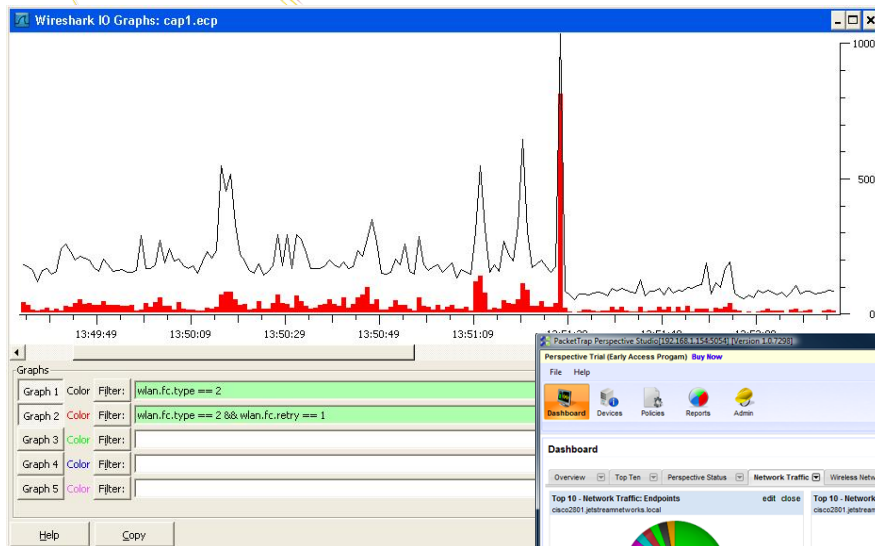


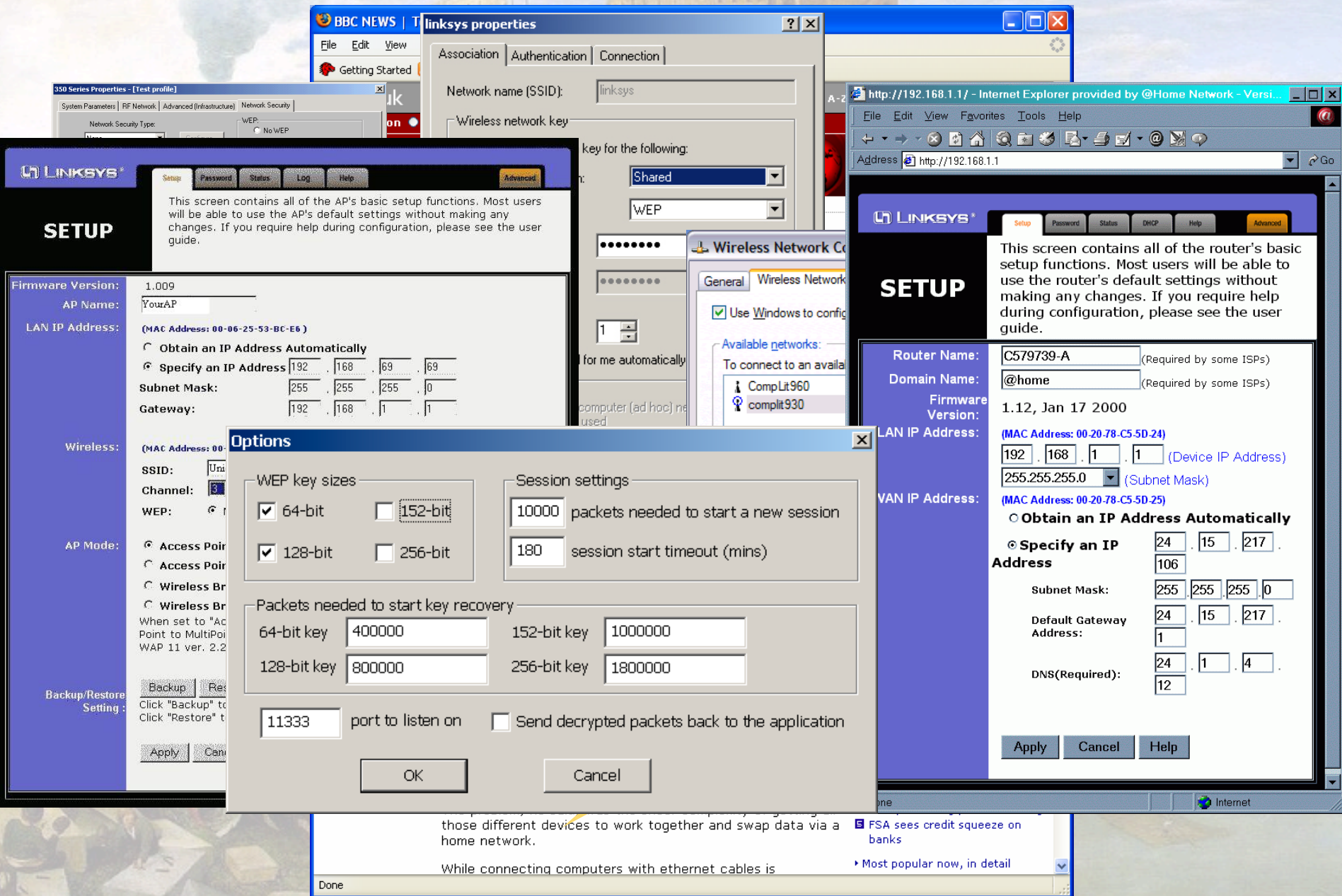


# Inhabitants' Perspective (2)

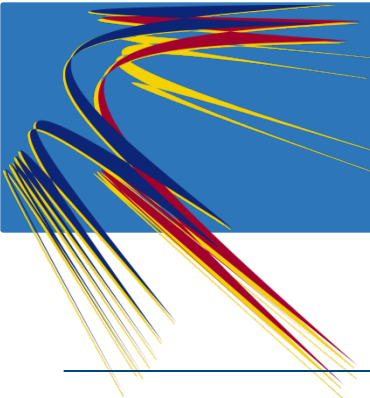


# Network Engineers' Perspective









# Understanding Home Networks

- **Ethnographic studies of 24 homes**
  - Technology tours
  - Semi structured interviews
  - War Stories and Network Sketches
- **How do people use their home networks?**
- **How do people manage their home networks?**





# Heterogeneous, Fluid, Mundane

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- Heterogeneous collection of devices
  - 5—15 devices in most homes
  - UK average is 4.6
  - PCs, Laptops, Mobiles, Games consoles, Media Streaming, Cameras, Radios
- Device ownership and access rights are very fluid
- Digital “housework” is an **unremarkable** feature of everyday life



# Four Key Challenges

*“I would like to see an accumulative/historical record of bandwidth usage. The current month/week/day so I can see patterns of use of time... This is important to me because we keep exceeding the Internet allowance. It has gone up 5 fold because we have an international student living with us. I don't think she believes it's her who's eaten up all of the allowance!”*

*“I see myself as using the Internet to bring in income, so I can justify that pretty well everything that I do takes priority.”*

*M: ... we have had big rows about T stealing the Internet. E said to him “You've stolen the Internet!” coz he's uploading to YouTube and the whole thing just like grinds to a halt for everybody else. We have had a “You put it on overnight T when nobody else needs it”.*

*One thing that I try to do is to schedule my work around them.. if they are watching TV on their machine or using Skype I tend to back off from the network for a while and let them do that. it tends to be an all or nothing sort of thing.. they can do anything on the network or nothing...*

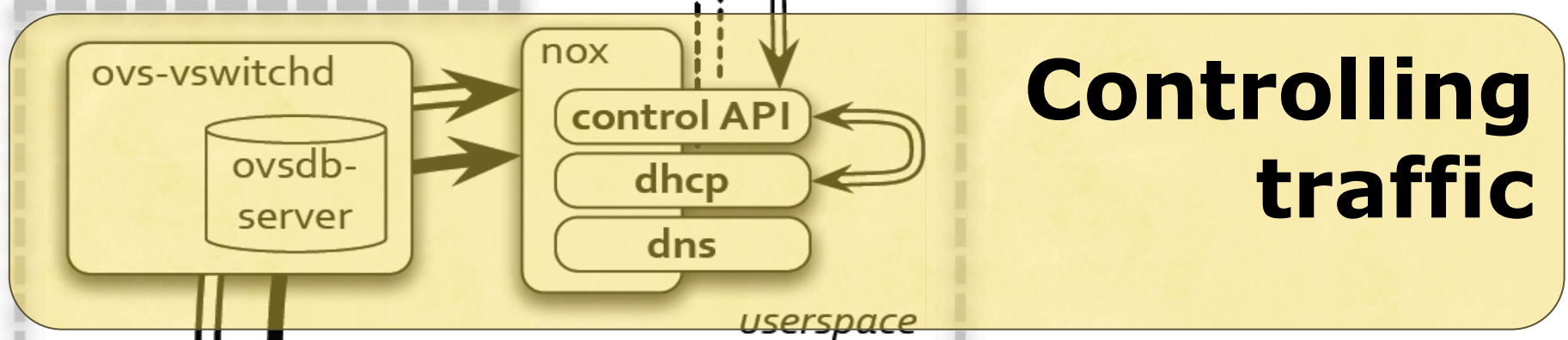
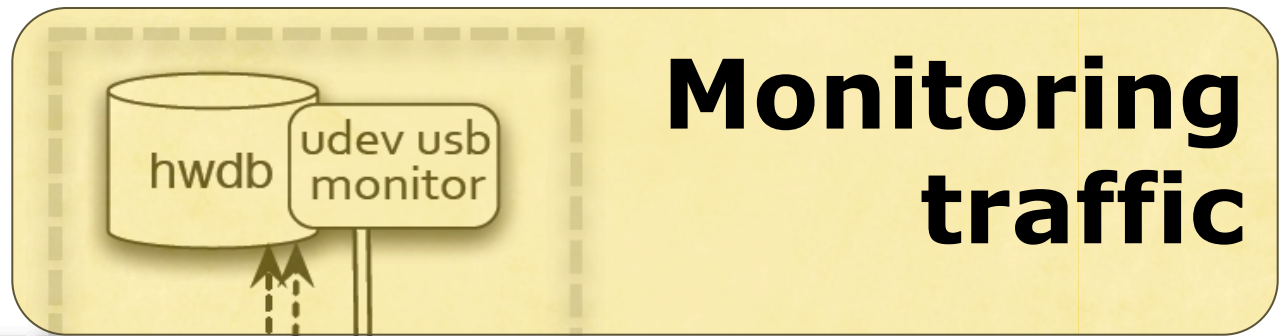
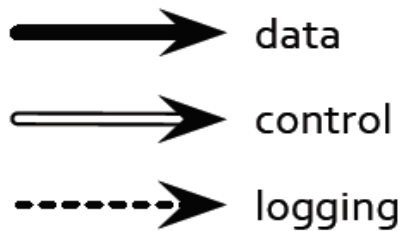
*D: ... Joe's mum doesn't like given out the password.. Joe doesn't know it ... and his Dad uses the Internet for work ...”*

*N: Joe's mum is worried that ... she doesn't like giving the password out ... I don't care cause the kids only really use it. ... I was wondering about getting one of those 3G things to let him get on the network to play that World of Warcraft without worrying Joe's mum*

# Technology Platform

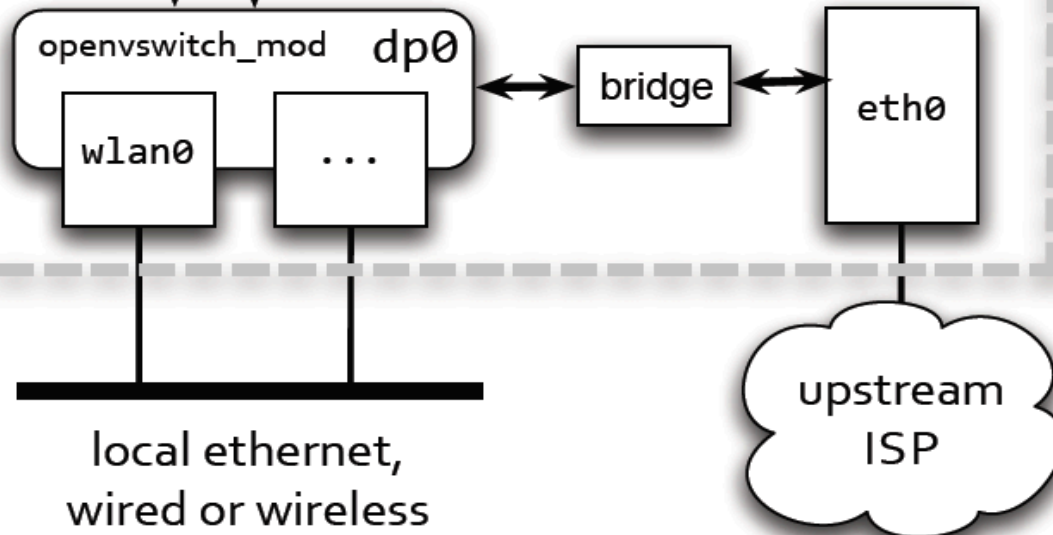
- Exploit the gateway role of the home router
- Designed and built a novel home router infrastructure
  - eeePCs running Linux & hostapd
- Enabling direct interaction with the infrastructure
  - APIs to support a range of UIs: phones, tablets, browsers
  - Custom pub-sub system (HWDB)
  - Control via OpenFlow/NOX
  - Policy management engine





userspace

kernel



# Simple API

- Web API exposes mechanisms to application developers
- Allows exploration of alternative models and approaches

## Method

## Function

/permit: <eaddr>

Permit access by specified client

/deny: <eaddr>

Deny access by specified client

/status: [eaddr]

Retrieve currently permitted clients, or status of specified client

/dhcp-status/

Retrieve current MAC—IP mappings

/whitelist: <eaddr>

Accept associations from client

/blacklist: <eaddr>

Deny association to client

/blacklist-status/

Retrieve currently blacklisted clients

/permit-dns: <eaddr> <domain>

Permit the device access to given domain

/deny-dns: <eaddr> <domain>

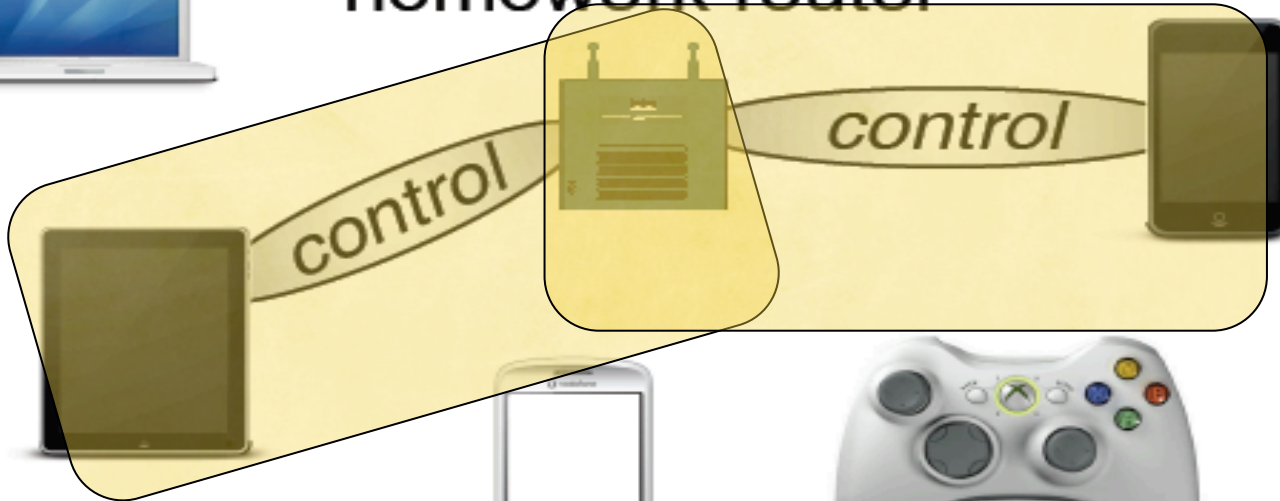
Deny access to the given domain by the specified device



home network



homework router



# Measurement/Interaction

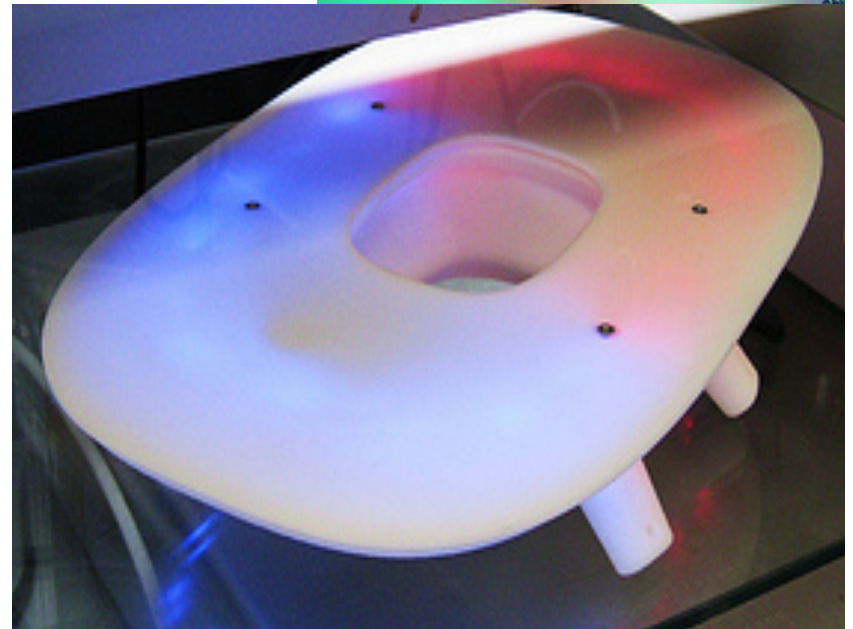
- Time series database capturing traffic in real time
- User actions can be captured alongside network traffic
- Notification service to allow users to be informed about traffic

*"with [] it was really unclear what she was doing on the network.. it was good to be able to show her it was her machine using the bandwidth"*



# Physical Nature of the Home

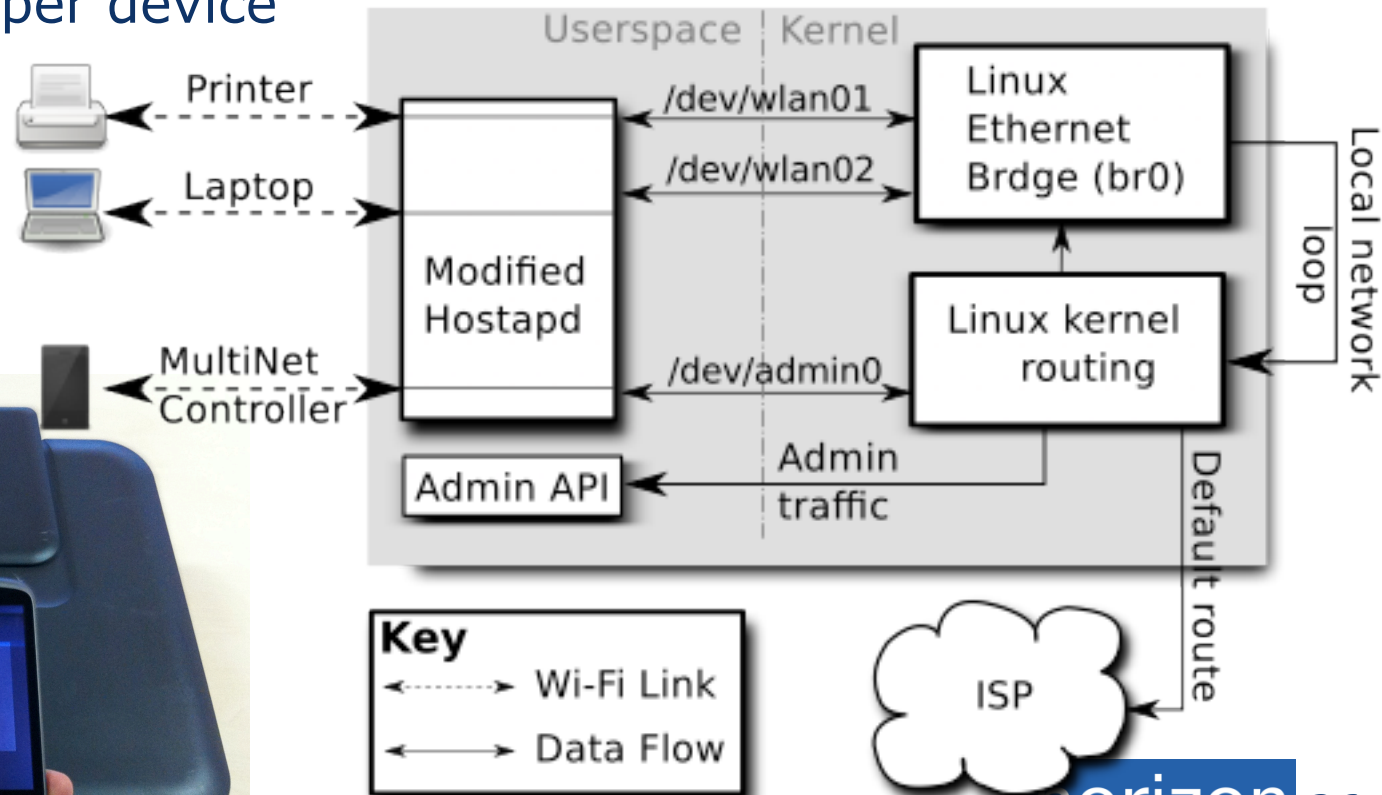
- Physical access control is the norm
  - “The bag of keys” is a virtue
- USB Keys and Physical Markers used for security
- Physical Devices provide ambient awareness





# MultiNet: Easy, Secure Association

- Use a controller to associate devices to the network
- Create a VAP per device



# MultiNet Usability




- Users asked to construct a network consisting of three consumer devices:
  - HP Deskjet 3050A e-All-in-One Printer
  - Logitech Squeezebox Radio
  - Samsung laptop running Windows 7
- Compare connecting devices using WPS Direct and MultiNet





# User Study

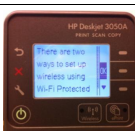
- 16 participants, ten male and six female
  - Ten were the home network admin
  - Twelve had never used WPS before
  - Six had never used QR Codes
- Home networks ranged from 3 devices to 15 (mean 5.6)

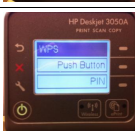
## Connecting the HP DeskJet 350A Using

- 

To start the process p
- 

Select 2. Wireless set
- 

Select 2. Wi-Fi Protected Set Up (WPS)
- 

Select OK
- 

Select "Push Button" and follow the onscreen instructions.

The device is connected when the blue Wi-Fi light stops flashing

## Connecting the HP DeskJet 350A Multinet

- 

Locate the device QR-code
- 

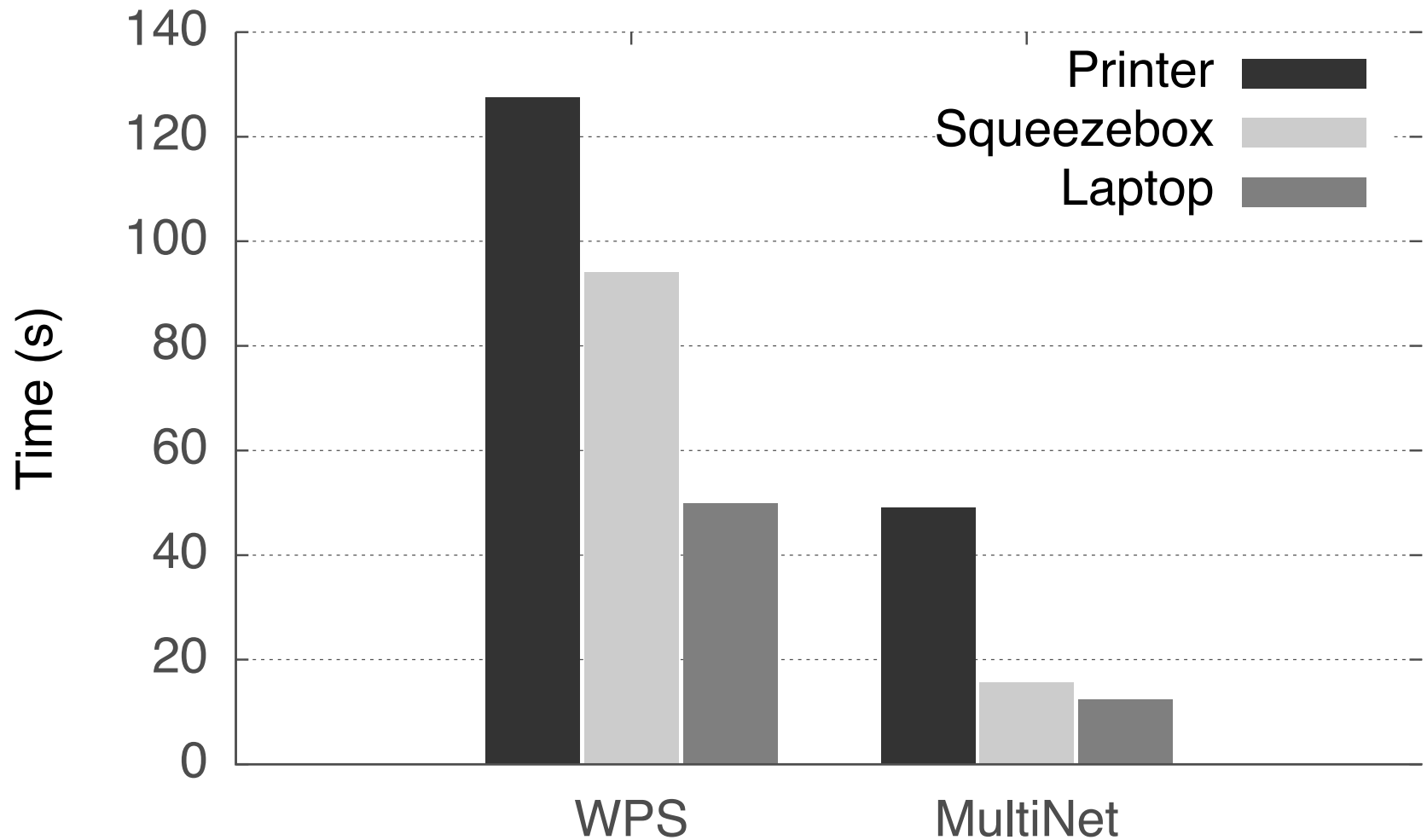
On the satellite controller select "add new device"
- 

a) Align the QR-Code in the centre of the screen  
b) Hold the satellite controller still for a few seconds.  
c) A beep will sound and you will be returned to the main screen
- 

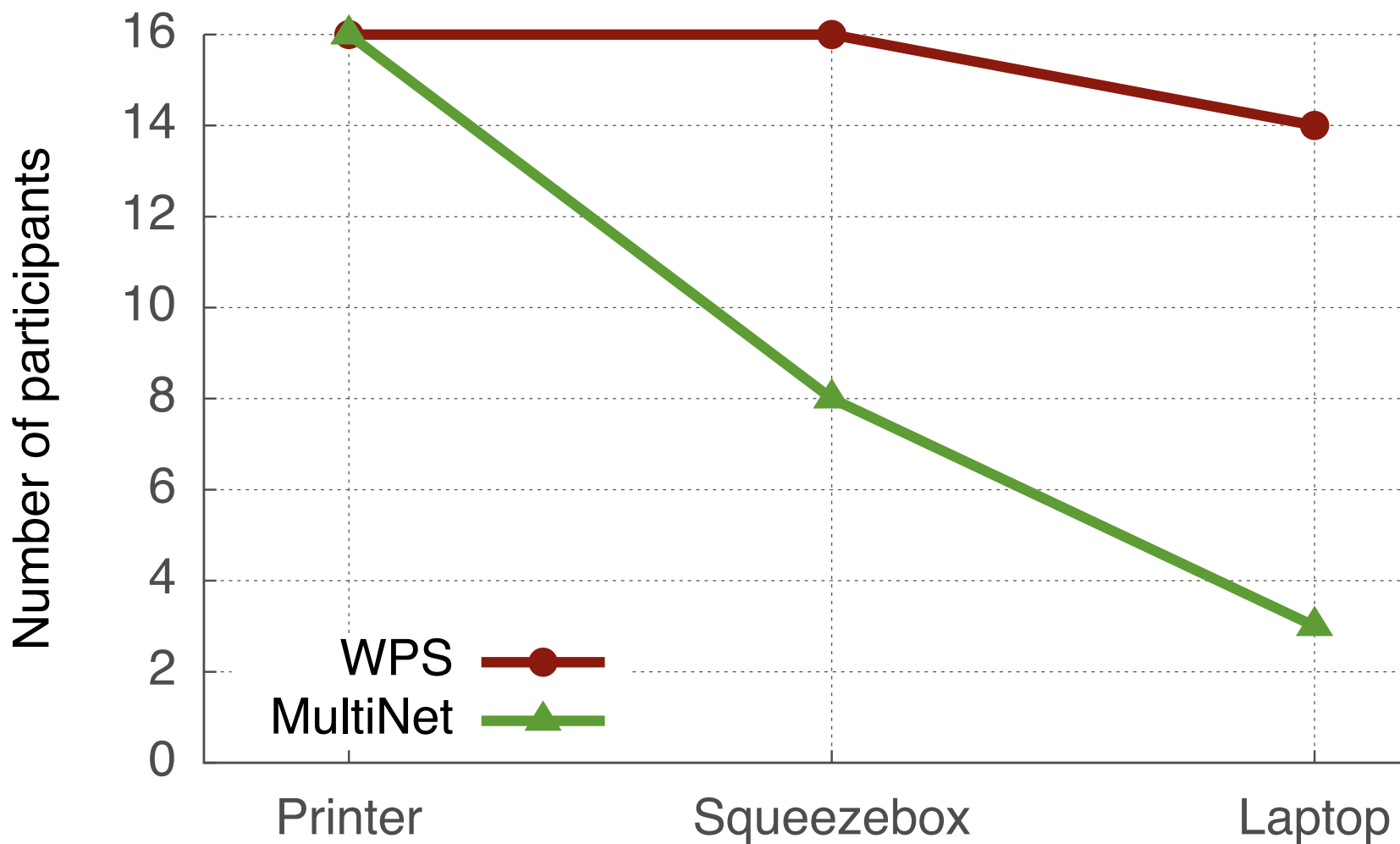
Turn the printer on using the power button 
- The device is connected when the blue Wi-Fi light stops flashing



# Configuration Times

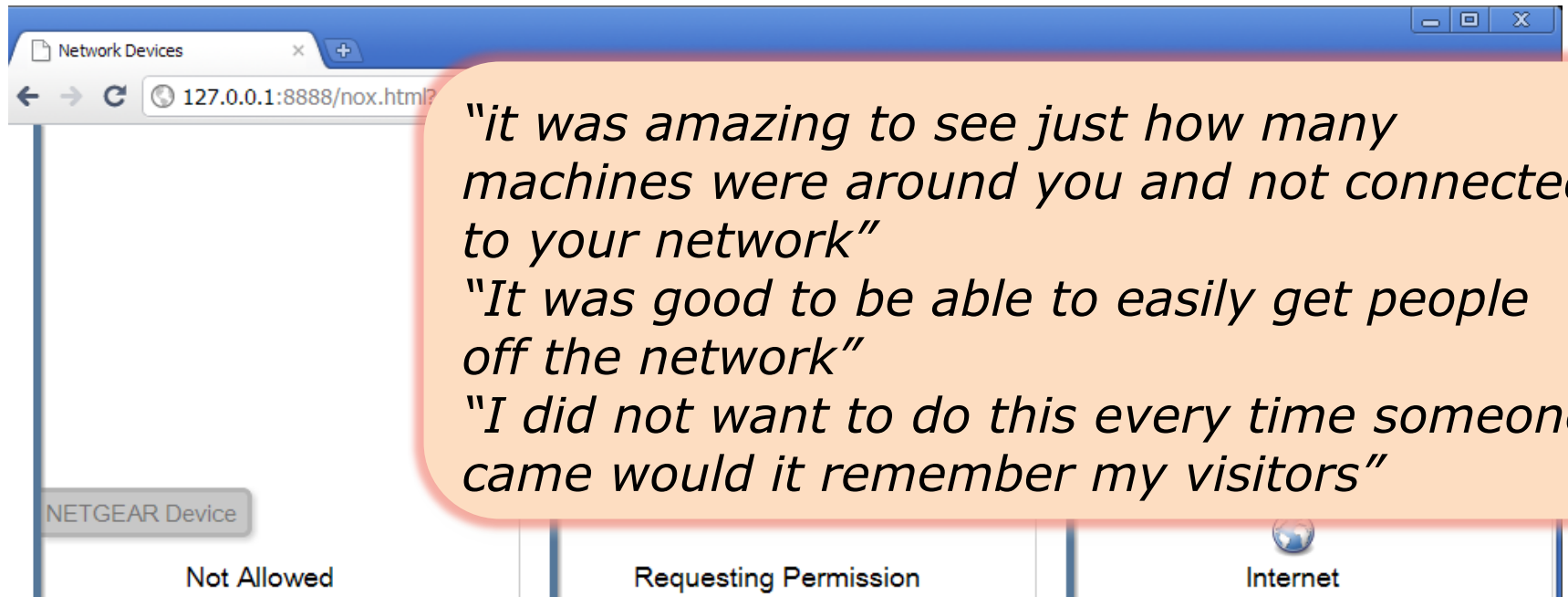


# Use of Instructions



# Putting People in the Protocol

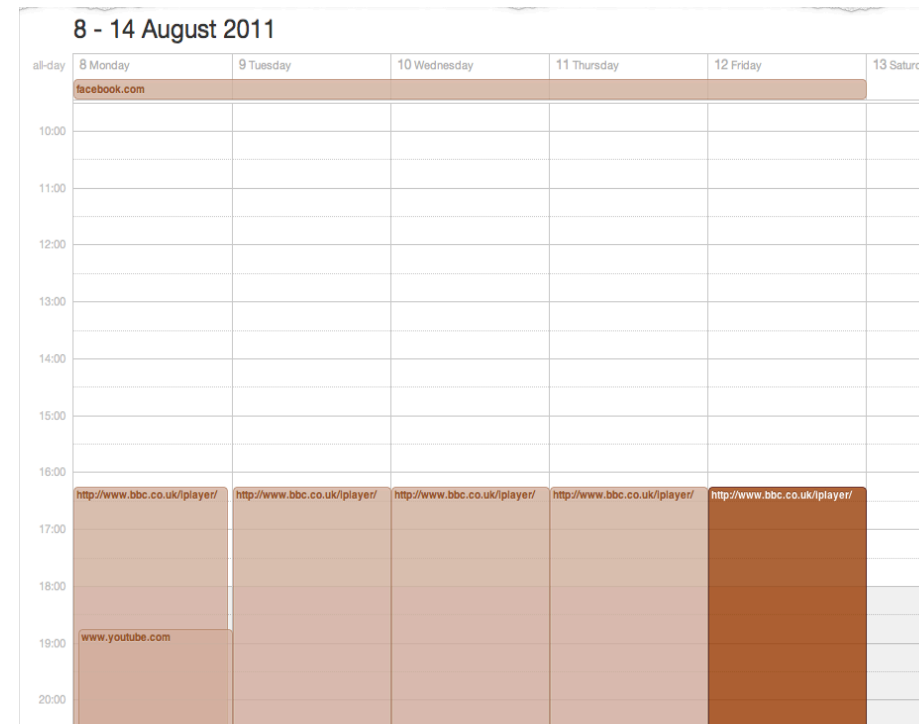
- Amended DHCP to allow user involvement
  - User's permission requested via the DHCP service
  - Situated display where people drag and drop to permit





# Exploiting Localised Services

- Locally determined name resolution
  - Users can police Internet access
  - Can set up dynamically resolved rules for connectivity
- Can link DNS to other services
  - Notification when a site is accessed sent to others

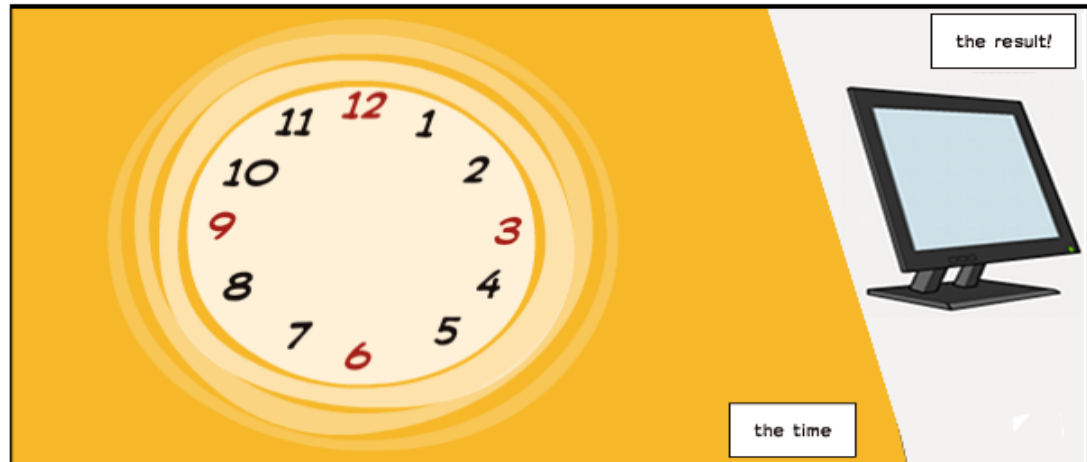
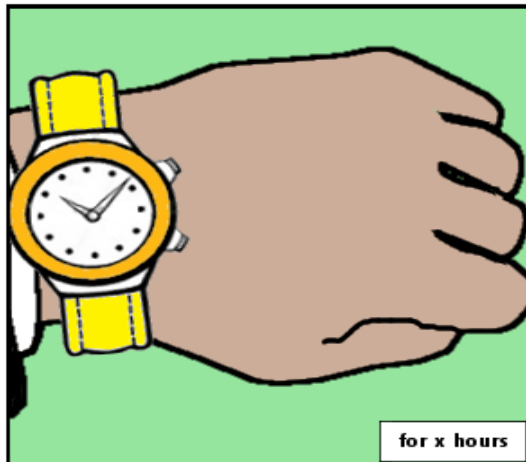
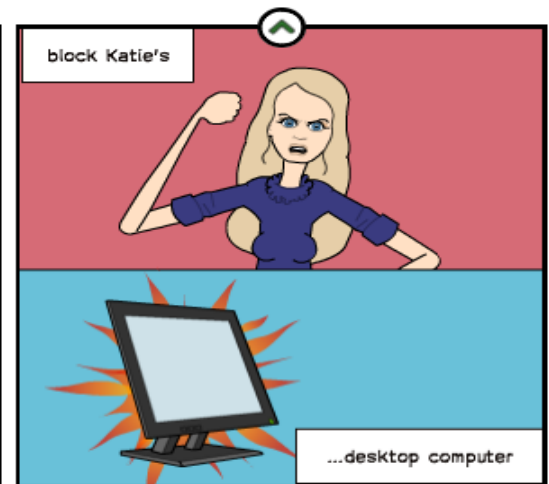
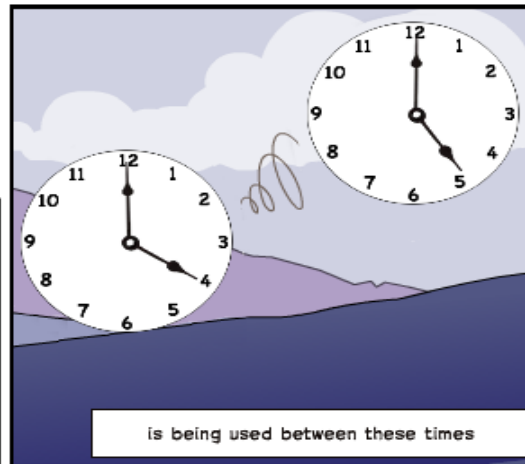
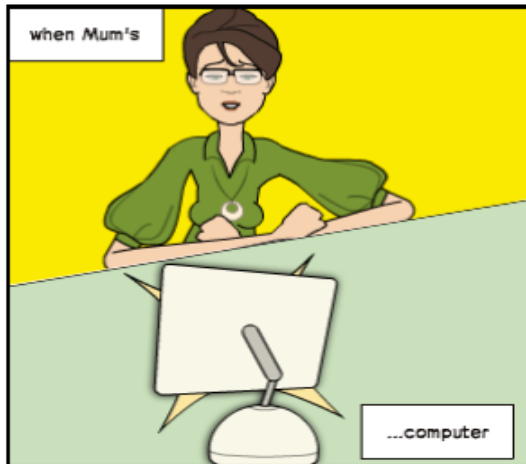


# Policies

iPad

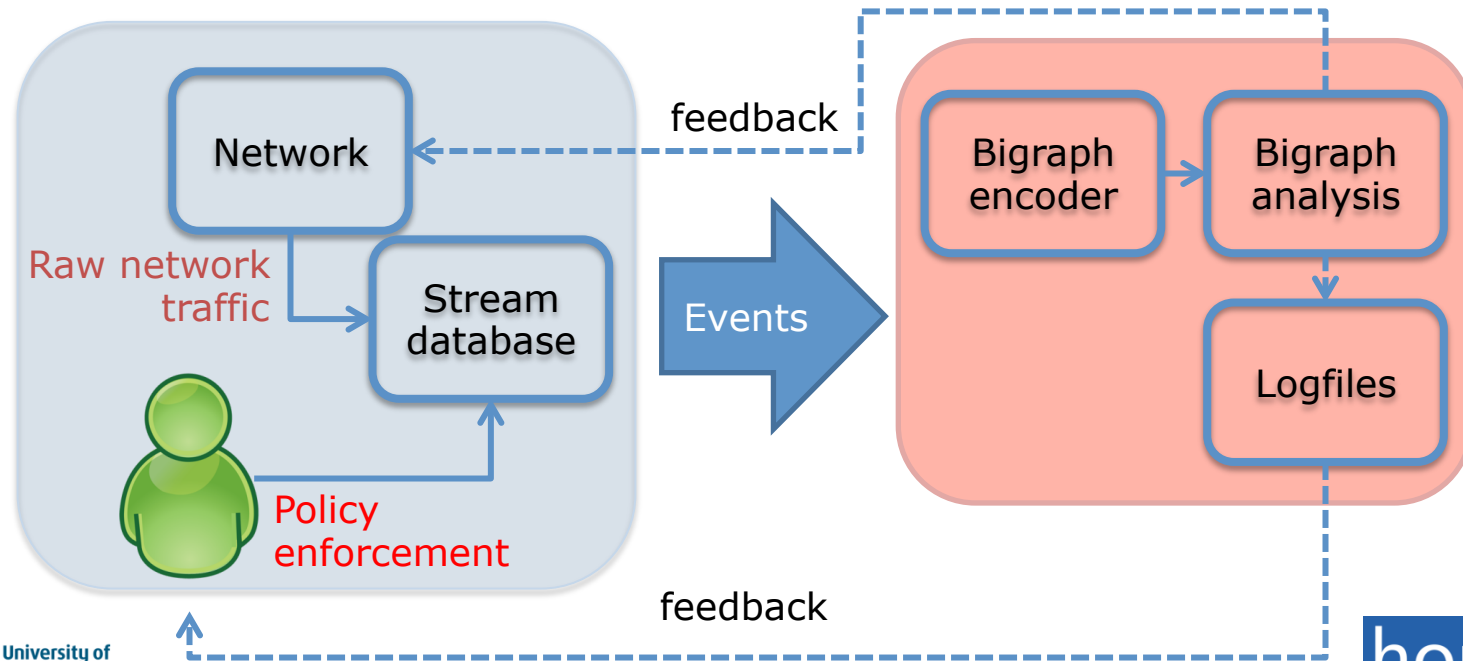
12:21

48%



# Bigraphs: Formal Modelling

- A formal modelling approach proposed by Robin Milner
  - Locality, connectivity and composition as core concepts
  - Equivalent visual and algebraic representations
- A flexible model of behaviour in terms of “reactions”







# Interplay: Policy vs. Events

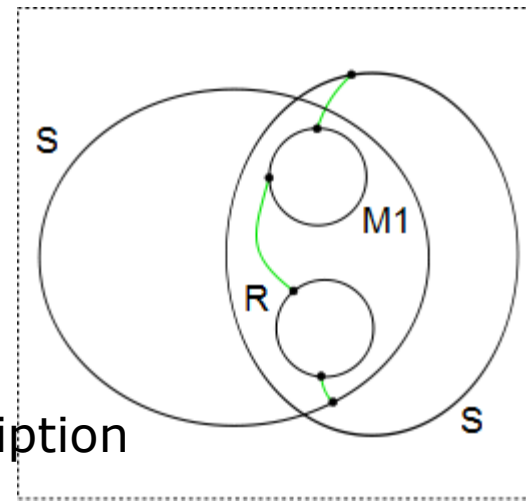
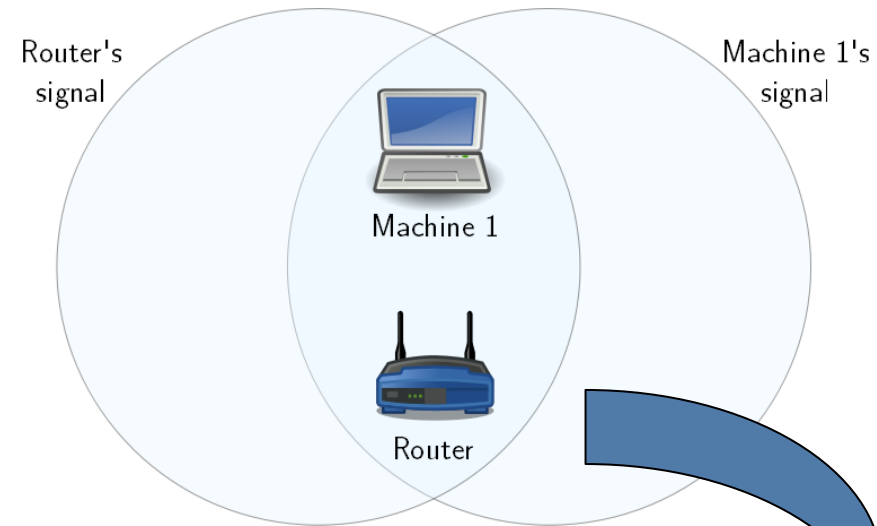
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- Network and policy events occur in any order in the system
- Interpret policies as properties the system must always satisfy
- Network events can invalidate this, e.g.,
  - All machines are blocked
  - A new machine is added
  - New machine is not blocked
- Active policies are enforced after a network event
- Full prototype of live modelling and analysis is implemented
- Results indicate models can be generated/analysed every 2s

# Example: Static WLAN

- Encode Machine 1 and Router by nodes R and M1
- Overlapping wireless signals are represented by S-nodes
- R and M1 are linked to their signals
- Router can sense Machine 1 signal and vice versa
  - Intersection of signals
- R and M1 linked as they are part of the WLAN

## Informal Description



## Formal Description



# Deployments

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- Router and interface deployments for 4—6 months
- Traffic displays are like home energy displays
  - Novelty Effect followed by no engagement
- Surfacing traffic introduces domestic discord
  - Networks are intertwined with the home's moral ordering
  - Surfacing traffic is far from neutral
- Privacy in the network
  - Records and history need to be carefully managed
- Managing the network **is** managing the household
  - Users desire involvement





# Summing Up

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- Home networks have become mundane
  - Another channel through which everyday life happens
  - Really no longer special
- Digital Economy is predicated on effective home networks
  - The delivery of services built on the Internet and delivered to people's homes



# Work Still To Do

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- But the (software) technology has not made this leap!
  - Still managed in terms of protocols and services
  - **Shopping**, not browsing the web, not using HTTP
  - The user doesn't draw a distinction between service (name resolution) and the network (IP forwarding)
- To do better we need the enabling technologies to allow these top-to-bottom connections to be made
  - Making the network **intelligible** (not *intelligent*)
  - Support “interaction within the infrastructure”
  - To complement HCI emphasis on interactive technologies



# Broader Lessons Learned?

- Designing to meet these challenges needs multiple skillsets
  - Ethnography, HCI, Systems, Networking, Theory, ...
- This requires greater dialogue between communities
  - **Within computer science**
  - Just throwing results over the fence doesn't work
  - Engineers need to know about ethnography
  - Ethnographers need to know about technology
- Else we will continue to make useless things
  - By imposing ridiculous demands on technology, or
  - By implementing unusable/inappropriate technology



# Questions?

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