Control and Understanding: Owning Your Home Network

Dr. Richard Mortier

Horizon Digital Economy Research Institute/
School of Computer Science
University of Nottingham
• 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
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

Home Networking
At the heart of the digital home sits the xDSL access point distributing a host of enhanced content and services throughout the home.
Conceptions of the Network

Services Available Outside of Home
available by Dynamic DNS

Remote Power ON of Kitchen PC, Office PC, HA PC
Web Cameras w/ Audio
Web Server on HA PC for remote control of house incl
A/V, HVAC, Lighting, Security
Remote Desktop on Office PC, HA, PC, Kitchen PC
VNC on Video Editing PC
Parental Notification of children’s Internet activity
Sony Remote Location-Free TV

CISCO
Andrew Ward
Overall Winner
Best Home Network

Tivo Dual Tuner
Series III 180 Hours

Network Attached
Storage
HP Jet Direct Ex:3
Print Server
MagiColor
Laser Printer
HP B&W Laser
Printer
Office

16 Port 10/100 Switch

Tivo Location-Free TV
Web access, Remote control, e-mail, etc.

Shure SCM-810
Automatic Mic Mixer

Living Room
10/100 Switch

Parental Control & Monitoring Features ENABLED

Cisco Catalyst 2924XL
Switch (IOS)

VPN 4-Port
Router

Airlink AP431W
Wireless
Multi-Client Bridge
Access Point

ZyXel XS50 MiMo
WiFi AP

10/100 Switch

HP 6110
Print/Scan
Office

School Room
PC

Kichen PC

Child #1 PC

Child #2 PC

Video Editing PC, Tivo Desktop

Friend’s House
Deployed, but experimental

Friend’s Apt. w/ AP431W AP Client

High-Gain 14.5
directional Antenna

1 Mile

Neighboor’s House w/ AP431W AP Relay

High-Gain 14.5
directional Antenna

2.5 Miles

My Rooftop

Rate-limited (2mbps) via IOS

HAI (Omni-Pro)

Multiplex & Decode

Rate-limited (1mbps) via IOS

Voice Recognition/ Ctrl

HAL-2000

Home Automation PC

Samsung i730
Wi-Fi, EV-DO Cell Phone

Voice Observer
Camera
School Room

Voice Observer
Camera
Living Room

Web-based
Remote Control

VoIP

Skype

Webcast

Shure SCM-810
Automatic Mic Mixer

Living Room
10/100 Switch

Master Bedroom

Bed Room

Living Room

Office

Rec Room
Inhabitants’ Perspective (1)
Inhabitants’ Perspective (2)
Network Engineers’ Perspective
The state of home networking is pretty dismal for the average consumer, Gartner says. The problem with home networking is the sheer complexity of getting all those different devices to work together and swap data via a home network.
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 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
Monitoring traffic

Controlling traffic

Data
Control
Logging

hwdb
udev
usb
monitor

nox
control API
dhcp
dns

userspace

kernel

openvswitch_mod
dp0

bridge

eth0

upstream
ISP

local ethernet,
wired or wireless
Web API exposes mechanisms to application developers
Allows exploration of alternative models and approaches

<table>
<thead>
<tr>
<th>Method</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>/permit: &lt;eaddr&gt;</td>
<td>Permit access by specified client</td>
</tr>
<tr>
<td>/deny: &lt;eaddr&gt;</td>
<td>Deny access by specified client</td>
</tr>
<tr>
<td>/status: [eaddr]</td>
<td>Retrieve currently permitted clients, or status of specified client</td>
</tr>
<tr>
<td>/dhcp-status/</td>
<td>Retrieve current MAC—IP mappings</td>
</tr>
<tr>
<td>/whitelist: &lt;eaddr&gt;</td>
<td>Accept associations from client</td>
</tr>
<tr>
<td>/blacklist: &lt;eaddr&gt;</td>
<td>Deny association to client</td>
</tr>
<tr>
<td>/blacklist-status/</td>
<td>Retrieve currently blacklisted clients</td>
</tr>
<tr>
<td>/permit-dns: &lt;eaddr&gt;</td>
<td>Permit the device access to given domain</td>
</tr>
<tr>
<td>/deny-dns: &lt;eaddr&gt;</td>
<td>Deny access to the given domain by the specified device</td>
</tr>
</tbody>
</table>
• 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 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 WPS

1. To start the process press the Wireless button
2. Select 2. Wireless settings
3. Select 2. Wi-Fi Protected Set Up (WPS)
4. Select OK
5. 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

1. Locate the device QR-code
2. On the satellite controller select “add new device”
3. 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
4. Turn the printer on using the power button
5. The device is connected when the blue Wi-Fi light stops flashing
Use of Instructions

Number of participants

Printer | Squeezebox | Laptop

WPS

MultiNet
• Amended DHCP to allow user involvement
  – User’s permission requested via the DHCP service
  – Situated display where people drag and drop to permit

“it was amazing to see just how many machines were around you and not connected to your network”
“It was good to be able to easily get people off the network”
“I did not want to do this every time someone came would it remember my visitors”
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
How to setup the router to provide information to help users control the network?

- Focus on non-technical, deliberately playful interface
- Exploit sequential art as a means of setting up the system
- Personalised to individual families
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

- 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
• 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

- 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
• 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
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?

http://www.horizon.ac.uk/

http://www.cs.nott.ac.uk/~rmm/

richard.mortier@nottingham.ac.uk