Virtual Public Networks

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The Internet is for Everyone

- Vint Cerf:
  - “but it won’t be if it isn’t affordable by all that wish to partake of its services, so we must dedicate ourselves to making the Internet as affordable as other infrastructures so critical to our well-being”

- Tim Berners-Lee:
  - “would like to see everybody given a low-bandwidth connection by default”

- UN Human Rights Council:
  - “All people should be allowed to connect to and express themselves freely on the Internet”
Global Digital Divide

Source: ITU (2012)
Fixed Broadband as a Proportion of Monthly Income

- **Cheapest:**
  - Macau (0.30%)
  - Israel (0.33%)
  - Hong Kong (0.49%)
  - USA (0.5%)
  - Singapore (0.55%)

- **Most Expensive:**
  - Central African Republic (3891%)
  - Ethiopia (2085%)
  - Malawi (2038%)
  - Guinea (1546%)
  - Niger (967%)
Digital Divide in Developed World

- 10% of UK population do not have Internet access

Nottingham Citizens Survey, 2011
Outline

- Home Network Sharing
  - Public Access Wifi Service (PAWS)

- Virtual Public Network (VPuN) Architecture
  - Architecture Overview
  - Home Network Setup
  - Access Point Control API

- Related Work

- Conclusions and Future Work
Home Network Sharing
Public Access Wifi Service (PAWS)

- Basic level of Internet access (Lowest-Cost Denominator Networking)
  - Less-than-best-effort (LBE) access to all

- Public Internet access by opening up and sharing home networks
  - Exploit unused capacity in home broadband networks

- PAWS trial deployment in Nottingham
  - 50 households sharing their Internet connection
Sharing Home Networks

Home network user

Access link

Internet

Home Network

ISP
I can share 2 Mbps from 22:00 to 6:00
Sharing Home Networks

Home network user

I can share 2 Mbps from 22:00 to 6:00

Home Network

Access link

Virtual Public Network (VPuN)

ISP

Internet
Sharing Home Networks

I can share 2 Mbps from 22:00 to 6:00

Home network user

Access link

Virtual Public Network (VPuN)

Internet

PAWS client
Sharing Home Networks

I can share 2 Mbps from 22:00 to 6:00

PAWS client

Virtual Public Network (VPuN)

Home network user

Access link

ISP

Internet

Best Effort

Less than Best Effort
VPuN Requirements

- Bandwidth isolation
  - PAWS clients should not be allowed to hog the bandwidth

- Confidentiality
  - Traffic eavesdropping by collocated devices should be prevented

- Authentication
  - Clients should be able to authenticate themselves with the PAWS network

- Accountability
  - Sharers should not be accountable for the actions of PAWS clients

- Minimal configuration overhead for users and ISPs
  - VPuN configuration and management should be outsourced to third parties
**VPuN Management and Control**

- **Home Network**
  - User
  - PAWS client

- **Internet**
  - ISP
  - Best Effort
  - Less than Best Effort

- **VPuN Operator**
  - (Local government, NGO, etc.)

- **Virtual Public Network (VPuN)**

**Access link**
Virtual Public Networks

VPuN Benefits

- Capitalizing unused bandwidth
- Wider Internet access in developing regions
- Better recovery during emergency situations and natural disasters
- New opportunities for application developers
  - Reward point management
  - Social media based access
VPuN Architecture
VPuN Architecture Overview

- Status Aggregator
- Rule Aggregator
- Triggers
- User Rules
- Traffic Status
- VNO Rules
- Network Operator
- VPuN Operator (VNO)
- OSN/News Feed
- PAWS Clients
- Control Layer
  - Controller
  - APM
- Sharing Policy Layer
  - SPEL
  - Translation

External Status

User Rules

Aggregator

Rule Aggregator

VPuN Clients

VNO Rules

Triggers

Status

Virtual Public Networks
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Sharing Policy Expression Language (SPEL)

- XML-based schema for expressing sharing policies:

```xml
<rule id> 1 </rule id>
<name> Share when I sleep </name>
<condition>
    time_of_day > 22:00 AND time_of_day < 6:00
</condition>
<action value = SHARE>
    <data_cap value = 1>
        units = GB
    <data_cap>
    <rate_value = 2>
        units = Mbps
    <rate>
</action>
<expire> 00:00:00 31 Nov 2013 IST </expire>
```
Home Network Setup

ISP

Gateway

OF Datapath

PAWS traffic

Sharer traffic

PAWS IP

Router

Sharer IP

Router

Sharer AP

PAWS AP

Home Network
**Access Point Control API**

- **User_On/User_Off**:
  - AP→VPuNO:
    - AP notifies VPuNO about the connection/disconnection of PAWS clients

- **User_Config**:
  - VPuNO →AP:
    - VPuNO configures resource parameters for a PAWS client

- **Get_User_Stats**:
  - VPuNO →AP:
    - VPuNO requests traffic usage information
Enabling Technologies

- Switch datapath:
  - OpenvSwitch
  - Click Modular Router with OpenFlow element

- AP configuration:
  - OpenWrt

- Switch and AP control:
  - OpenFlow controller (e.g., NOX)

- PAWS client authentication:
  - EAP-TLS
Related Work
Related Work

- Rural Wireless Network Management:
  - S. Hasan et al., *Enabling Rural Connectivity with SDN*, ACM DEV 2013
  - S. Surana et al., *Beyond pilots: Keeping rural wireless networks alive*, USENIX NSDI 2008

- Security for Wireless Community Networks:
  - M. Radenkovic et al., *Providing Security for Wireless Community Networks*, ACM MOBICOM LCDNet 2013
Conclusions and Future Work
Conclusions and Future Work

- Virtual Public Networks:
  - Enabler for wider Internet access
  - Outsourcing control and management using SDN
    - Incentive for sharers and network operators

- Future Work:
  - VPuN platform implementation:
    - Translation of SPEL expressions
    - AP control and queue management
  - PAWS network load balancing
  - PAWS client mobility
Thank you!

LCDNet: http://www.cl.cam.ac.uk/~as2330/lcd/index.html
PAWS project: http://www.publicaccesswifi.org