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GREEN

Global Research into Environmentally Efficient Networking

http://www.caia.swin.edu.au/green

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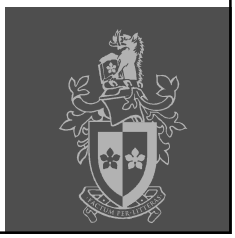

Outline

- GREEN introduction
- Equipment
- Experimental methodology
- Preliminary modem power measurements
- Issues
  - Oscilloscope error specification too flexible
  - Inconsistencies in modem power measurements
  - TCP/UDP traffic not fully utilising bandwidth
- Conclusion and lessons learnt

GREEN introduction

- Members
  - Grenville Armitage (Project leader)
  - Thuy Nguyen (Research Fellow)
  - Adam Black (Research Assistant)
- GREEN project scope
  - How does IP traffic affect the power consumption of networking equipment
    - Is there a relationship between network traffic and power consumption?
    - Can networks be made more power efficient

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GREEN introduction cont

- Recent work
  - Power consumption in consumer ADSL routers as a function of:
    - Traffic conditions
    - Network configuration
    - Modem temperature

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Equipment

- Tektronix TDS 2014 digital storage oscilloscope (DSO)
- Instek GPC-1850D power supply
- Unix PC's
  - With the FreeBSD operating system
- 3 x ADSL Modem / Routers

Equipment cont

- Tektronix TDS 2014 DSO (digital storage oscilloscope)
  - Measures voltage signals
  - 8-bit vertical resolution
  - Four separate input channels
  - 9-Pin RS232 serial port for remote administration
- The oscilloscope's display is divided by horizontal and vertical divisions.
  - Horizontal = Time
  - Vertical = Voltage
- The vertical scale, vertical position, and timebase are all configurable via the front control panels or RS232

Equipment cont

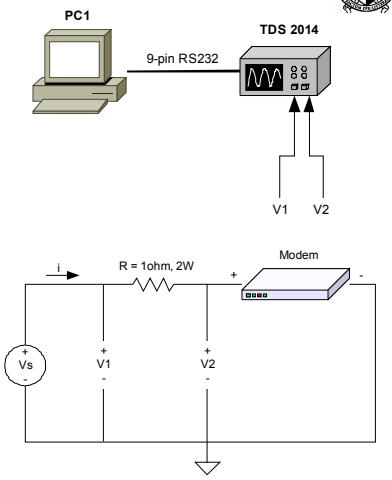
- Instek GPC-1850D power supply
  - Two-independent output channels
  - Voltage supply or current supply. 0 – 18V, 0 – 5A.

Equipment cont

- Cisco 837
  - ADSL 1
  - 4-Port FastEthernet
- Linksys AG041
  - ADSL 1
  - 4-Port FastEthernet
- Linksys WAG54G V3
  - ADSL 1 / 2+
  - 4-Port FastEthernet
  - Wireless 802.11g / 802.11b

Power measurement methodology

- The DSO does not measure power directly. Instead we set up a circuit as shown to the right and measure V1 and V2 with the oscilloscope.
- V_s is supplied by the Instek GPC-1850 power supply
- V2 is the potential difference over the modem
- i = (V1 – V2) / R
  P = V2 * i
- The power consumption of the modem is therefore:
  P = V2 * (V1 – V2) / R



Power measurement methodology cont

- The Tektronix DSO has a front panel LCD which can display voltage waveforms
- This is not sufficient. We wish to log instantaneous voltage samples over extended periods of time
- This can be done via the oscilloscope's RS232 interface

Power measurement methodology cont

- Instructions are sent to the oscilloscope as plain text ASCII characters. The oscilloscope has many available instructions. Some of them include:
  - `curve?`
  - `trigger force`
  - `ch<n>:position [POSITION]`
  - `ch<n>:scale [SCALE]`

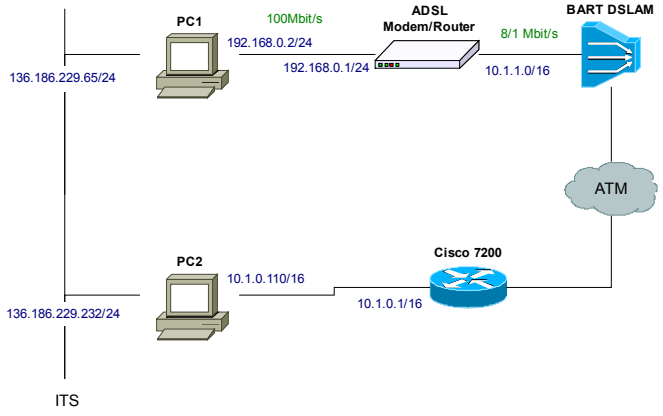
Power measurement methodology cont

- To transfer voltage data from the oscilloscope's to the PC we use the `curve?` Query
- Data is sent and received from the oscilloscope using a python script and pyserial module.
- Voltage data received from the oscilloscope is encoded as a stream of one-byte binary integers.
- Convert samples to ASCII and store in plain text file for later analysis

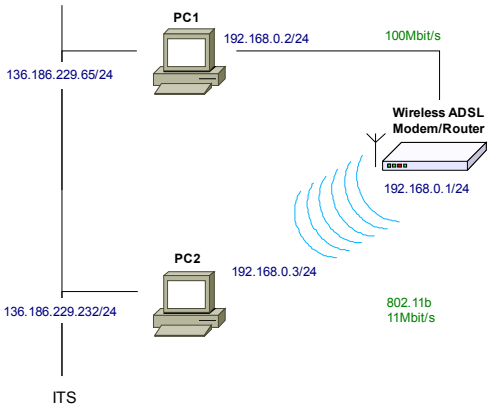
Modem power testing methodology

- Several factors should be considered when assessing the power consumption of the modems
- Traffic conditions / type
  - Idle
  - TCP (NTTCP)
  - UDP (NTTCP)
- Traffic direction
- Network topology

Modem power testing methodology cont



Modem power testing methodology cont



Modem power testing methodology cont

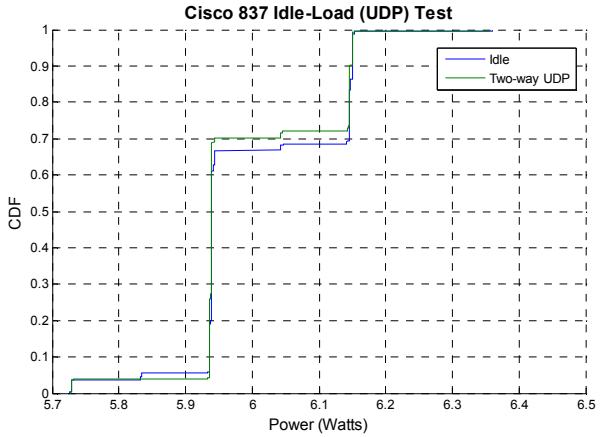
- PC1 was responsible for:
  - Monitoring and recording values from the oscilloscope
  - Initiating traffic transfers using NTTCP
  - Recording tcpdump data
  - Starting and stopping experiments
- PC2 was remotely controlled by PC1 over the ITS connection using SSH and was responsible for:
  - Collecting tcpdump data
  - Starting NTTCP as a daemon

Preliminary modem power measurements

ADSL Traffic

Packet size – 40 bytes

Packet delay (DS/US) – 0.5ms / 2.5ms



Preliminary modem power measurements cont

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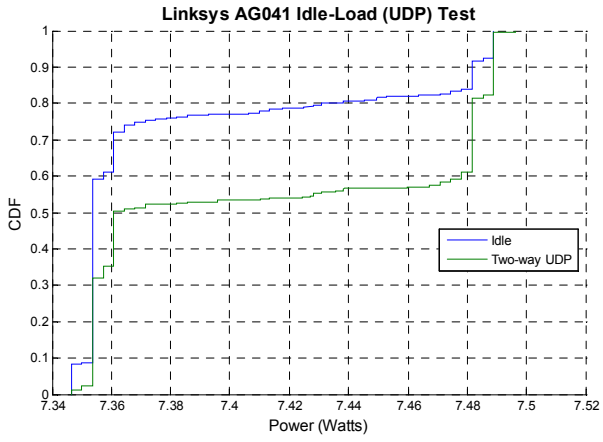

Preliminary modem power measurements cont

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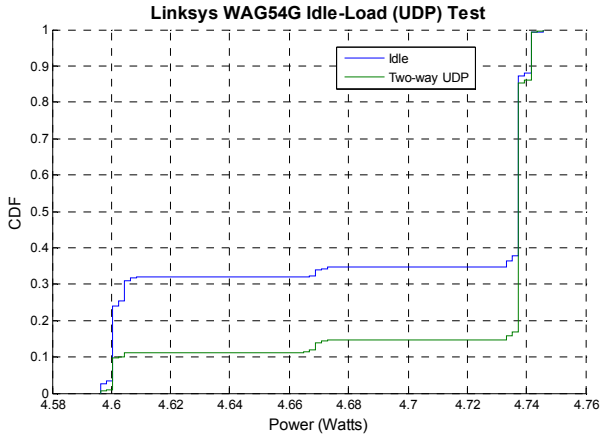
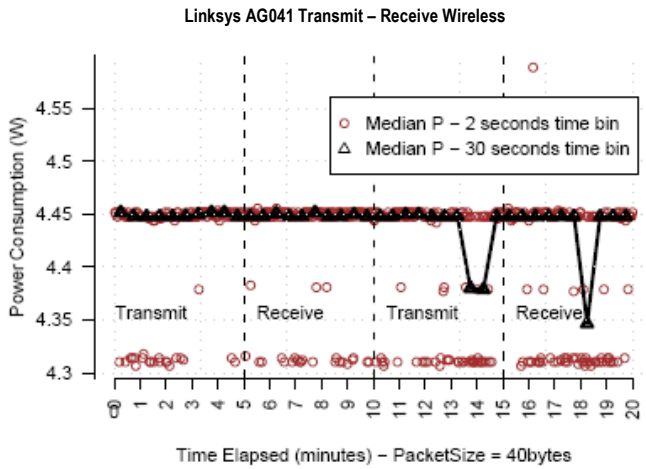


Preliminary modem power measurements cont

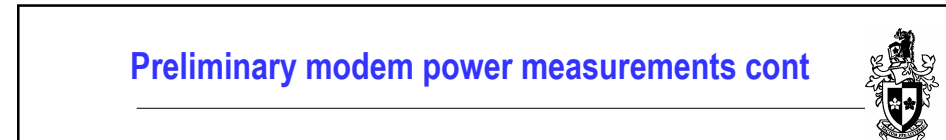
Wireless

Packet size – 40 bytes

Packet delay – 5ms



Preliminary modem power measurements cont

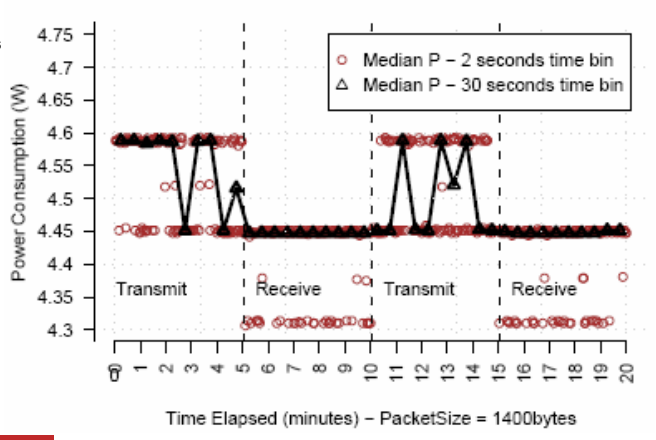


Linksys AG041 Transmit – Receive Wireless

Wireless

Packet size – 1400 bytes

Packet delay – 5ms



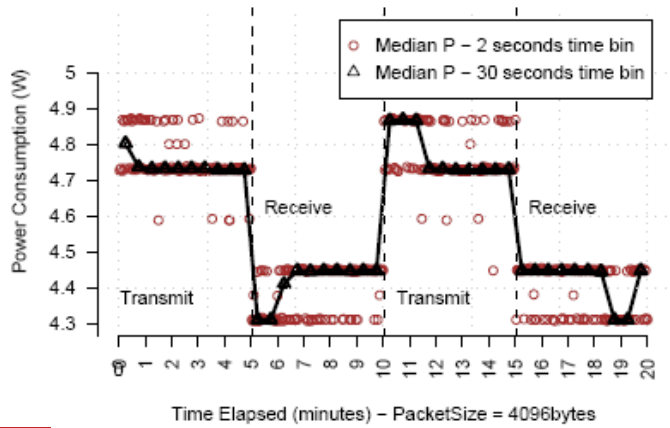
Preliminary modem power measurements cont

Linksys AG041 Transmit – Receive Wireless

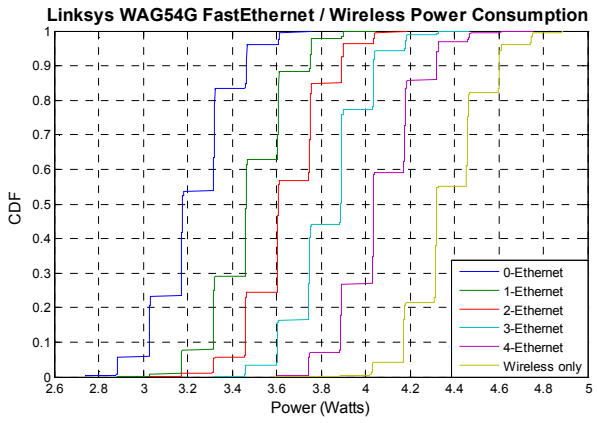
Wireless

Packet size – 4096 bytes

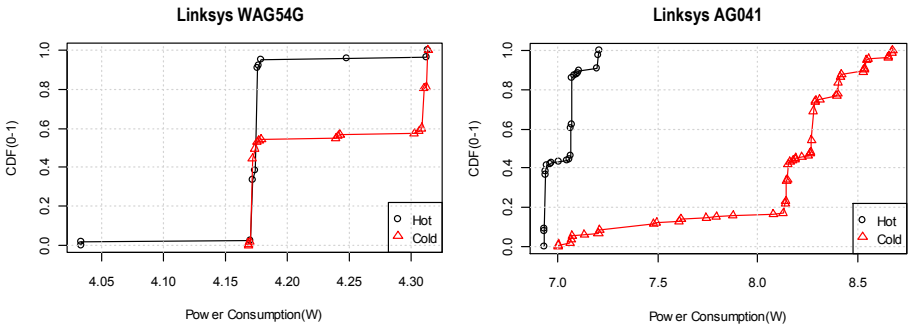
Packet delay – 5ms



Preliminary modem power measurements cont



Preliminary modem power measurements cont

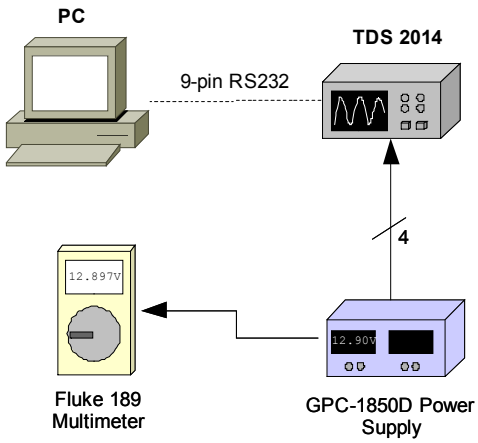


Issues

- Oscilloscope error specification too flexible
  - Oscilloscope requires calibration to reduce error margin and compensate for fixed error
  - Define a relationship between the input and output voltage of the oscilloscope
  - The three modems operate at different voltages. Need to calibrate the oscilloscope separately for each range of voltages
  - Use the Instek GPC-1850D to supply various DC signals into the oscilloscope
  - Measure the signal using the oscilloscope and a Fluke 187 digital multimeter (0.025% + 2 digits accuracy)

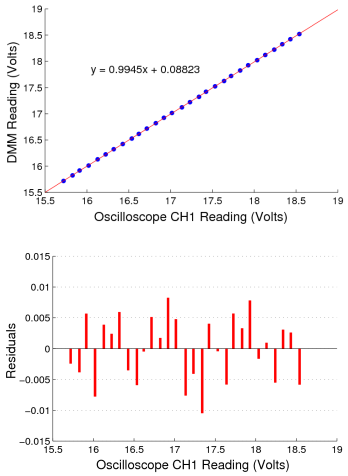
Issues cont

Calibration Testbed



Issues cont

- To the right we have the calibration curve and residuals for the Cisco 837 modem, which operates at 18VDC
- The oscilloscope's reading is plotted against the multimeter's reading
- The linear regression line is calculated and the residuals are plotted
- Error can be estimated from the maximum residuals



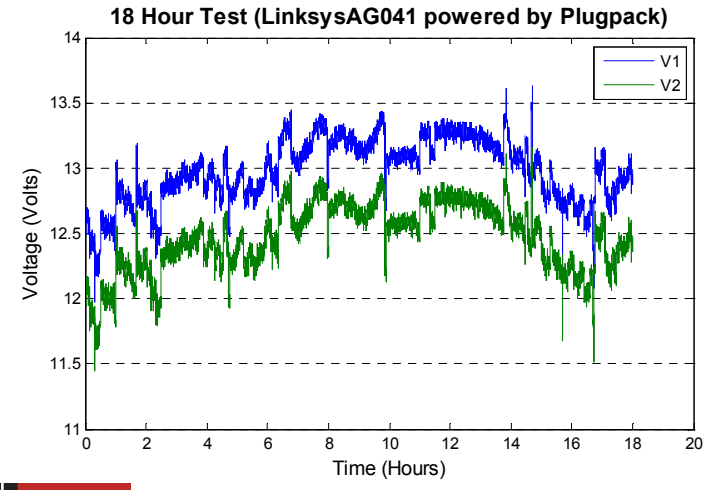
Issues cont

- Calibration issues
  - How repeatable is the calibration curve?
  - Does temperature affect the oscilloscope? Does a 2 degrees C increase void the calibration?
  - Does the oscilloscope exhibit the same behaviour two month later? 6 months later?

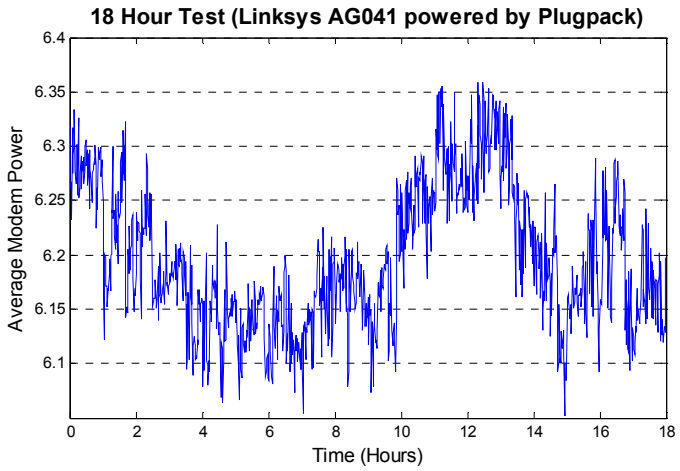
Issues cont

- Inconsistencies in power measurements
  - Two identical tests on the same modem, executed two hours apart resulted in significantly different power measurements
  - Initially we used the modems' plugpacks instead of the power supply to power the modems. Some of the plugpacks were poorly regulated, any change on the AC side was reflected on the DC side
  - We performed an overnight test on the Linksys AG041 modem while being powered by the manufacturers plugpack. We kept the modem idle and recorded the power consumption overnight with all the network ports disconnected

Issues cont



Issues cont



Issues cont

- TCP/UDP traffic not fully utilising bandwidth
  - Python script to log oscilloscope data was hogging CPU cycles
  - This caused NTTCP to transfer data slower, in some cases the use of the python script resulted in a 30% reduction in the traffic rate
  - Only the wireless/transmission tests should be significantly affected.
  - In the future the python script and nttcp process could be isolated from each other on separate PC's

Conclusion and lessons learnt

- Generally the modems don't seem particular affected by ADSL traffic. No processor throttling?
- Each additional FastEthernet connection consumes power
- Enabling wireless consumes power
- Don't have your modem operating inside a fridge
- Wireless transmission traffic results in the largest noticeable difference in power consumption
- The accuracy of equipment must be considered as well as the results
- Instrument precision vs cost
- Ensure tests are operating as expected (NTTCP)