

# Campus Wi-Fi Upgrades and Quality Assurance

Update October, 2013

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# Upgrades

- Upgrades of entire campus Wi-Fi infrastructure to dual band a/b/g/n in progress (excluding Colleges)
- Campus Wi-Fi upgrade
  - <http://www.bulletin.uwaterloo.ca/2013/mar/15fr.html>
  - Information Systems & Technology (IST) is in the final year of a 3-year, \$1.2M upgrade to wi-fi in all academic and administrative buildings across campus...
- Residence Wi-Fi upgrade
  - <http://www.bulletin.uwaterloo.ca/2013/sep/18we.html>
  - Housing announces \$1.9M ResNet upgrade ...

# Infrastructure

- Aruba for Wi-Fi
- Cisco for core routing and NAT infrastructure
- HP for access layer wired infrastructure
- Sandvine for traffic management
- Gartner Magic Quadrant for the Wired and Wireless LAN Access Infrastructure  
Published: 13 June 2012
- We are using leading vendors for network infrastructure



# Design

- The design of Wi-Fi for a new building, or re-design of Wi-Fi in an existing building, starts with loading floor plans and information about building materials in Airmagnet Survey Professional
- Including capacity information about lecture rooms and meeting rooms
- Pre design walk through of building (for existing buildings)



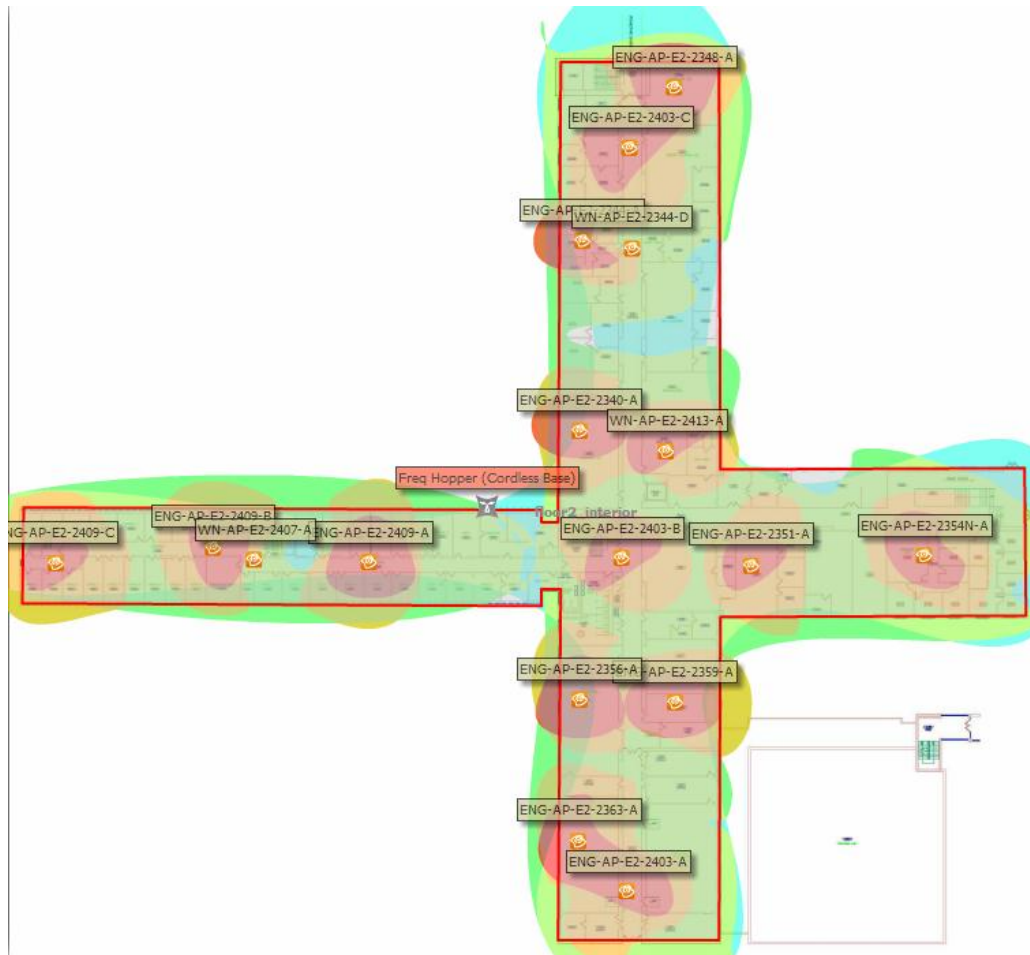
# Airmagnet Survey Professional

- Place access points onto the floor plans (predictive modeling) to meet the following conditions:
  - Access points in classrooms to provide approximate capacity of 50% of seats using wifi and maximum 25 devices per radio: limitation being there are only 3 2.4Ghz channels
  - minimize co-channel interference by adjusting predictive model (while maintaining coverage)
  - predictive modeling is done to meet a signal requirement of -79dbm on the DWA-160 adapter, (-70dbm on an average adapter)

# Installation

- Walkthrough to make sure locations are reachable
- Update the design as needed, make sure coverage will still be met
- Install cabling as needed
- AP deployment is done (includes entering locations into Airwave Management Platform)

# Airwave Management Platform





# Airwave

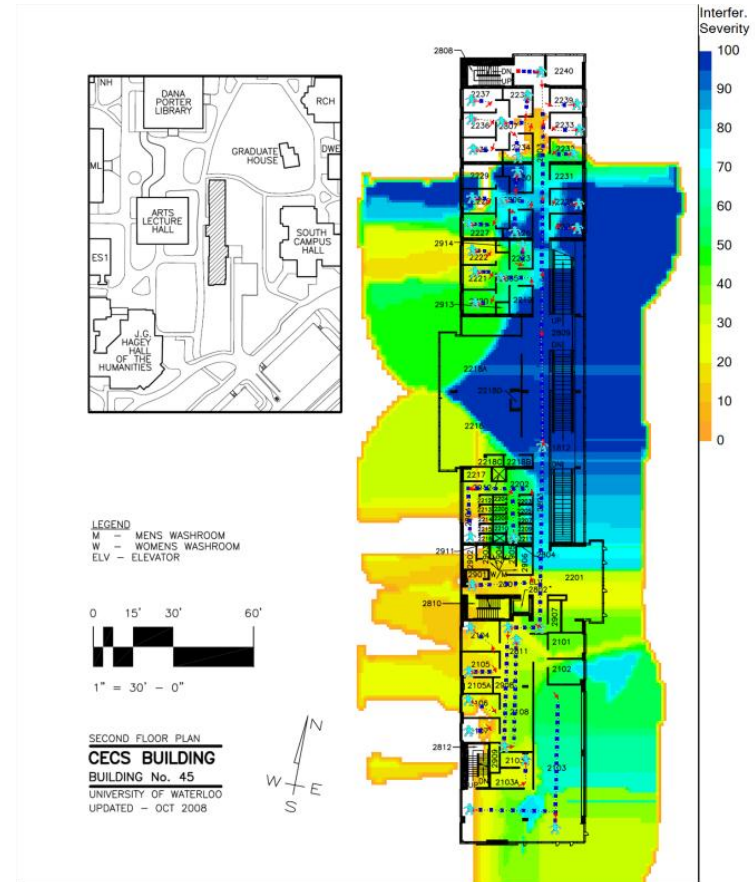
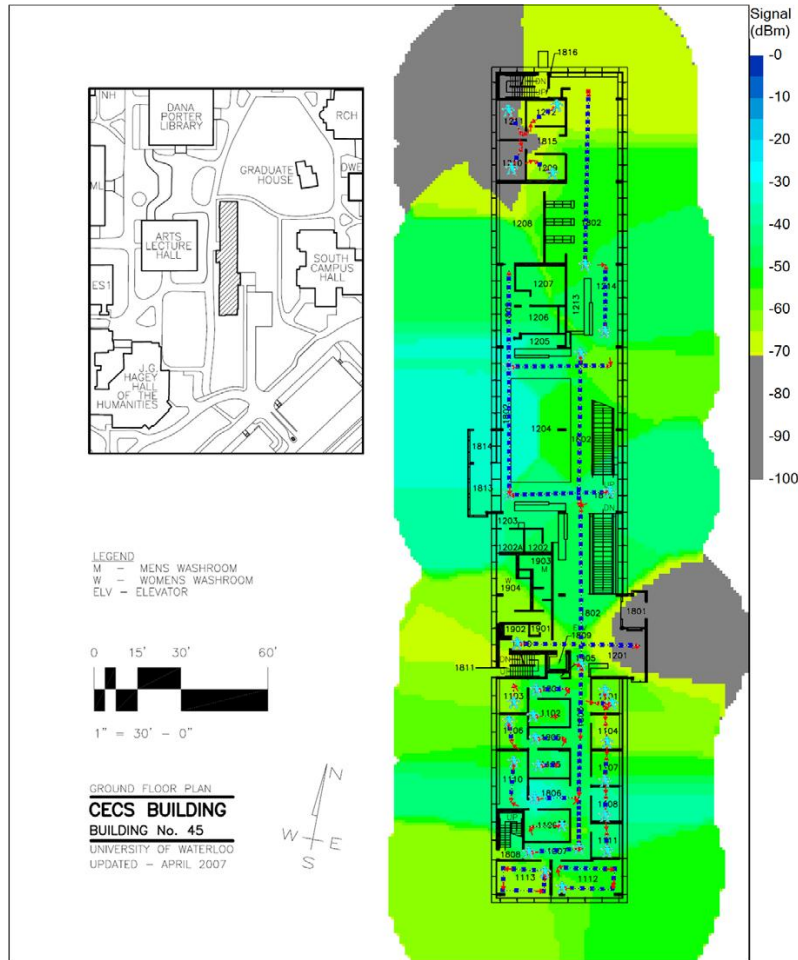
- Airwave contains floor plans and AP locations for entire campus
- Provides coverage heatmaps, usage history, userids, noise and throughput history on each AP radio
- And much more

# Post Install Survey

- Post install survey with Airmagnet is done in the public areas that are accessible (hallways near offices, classrooms if not in use, labs if allowed to enter)
  - Includes coverage and co-channel interference on both 2.4GHz and 5Ghz band
- Adjustment to AP power levels if necessary to reduce co-channel interference or increase coverage
- Building marked as complete

# Coverage and Co-channel Interference

Diagram on left is 2.4GHz coverage. Diagram on right is co-channel interference on 2.4GHz.  
There is typically no co-channel interference on 5GHz band.



# Ongoing Quality Assurance

- The use of leading network technology, a validated design approach, commitment in staff time and priority in budget, assures a robust campus Wi-Fi infrastructure.
- We also monitor the infrastructure, monitor some elements of user experience (where possible), conduct random spot tests, conduct satisfaction surveys, and track usage of all elements of the Wi-Fi infrastructure.
- All of the IST staff that manage UW's Wi-Fi infrastructure are regular users of the service.
- We investigate user reported issues, and can enhance coverage if determined to be an issue
- Unfortunately...
  - Interference from non Wi-Fi sources, and rogue APs can impact service.
  - Issues on client devices (driver bugs, poor implementations, etc) can impact end user experience.

# Infrastructure Monitoring

- Monitoring health of core controllers, routers, and traffic management, with automated alerting
- Detecting and replacing failed APs, through automated alerting
- Detection of heavily used APs and locations, and addition of APs if needed (if possible, given limitations of 2.4GHz spectrum)

# Spot Tests

- IST co-op student visits areas of campus and tests Wi-Fi service
- Approximately 6-10 hours per week.
- Approximately 20-30 areas visited per week (typically higher student load areas)
- Combination of subjective tests, and non subjective tests
- Results recorded in a database with locally developed spot test tool and system

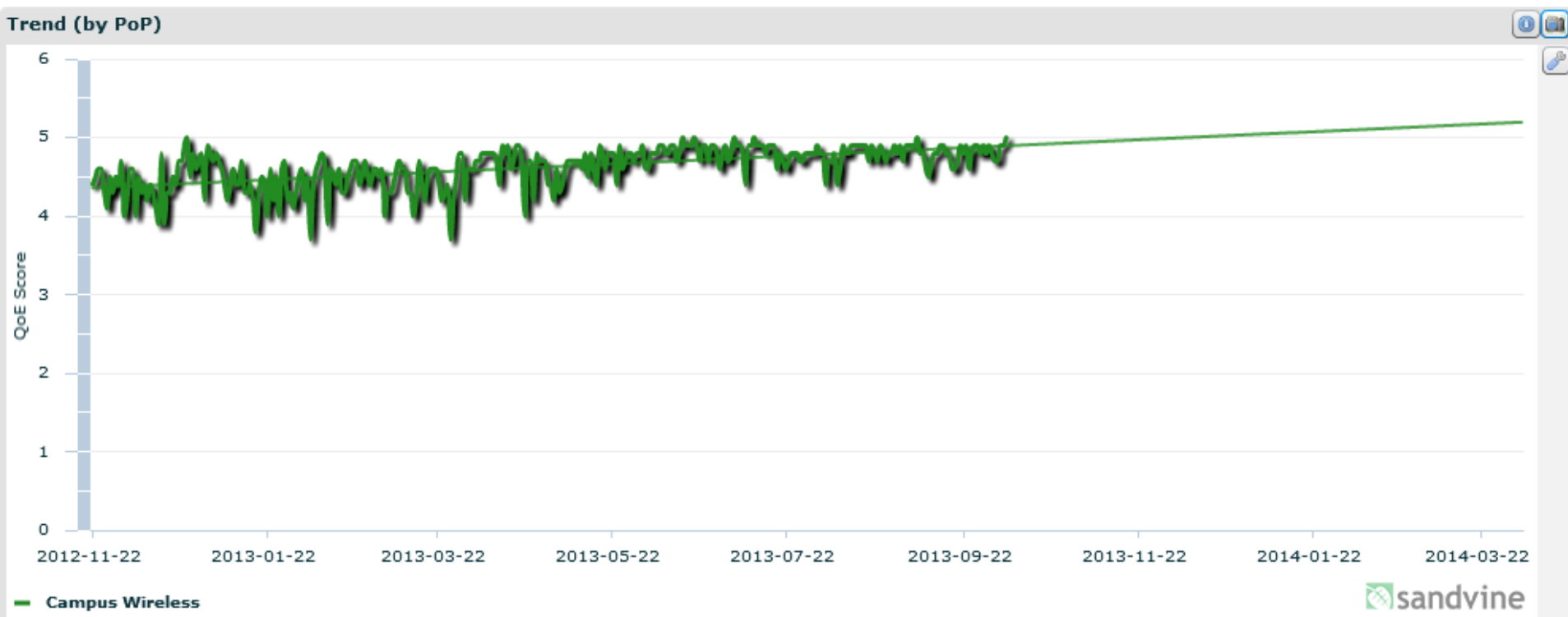
# Spot Tests – What We See

(this highlights the challenge of a low quality 2.4GHz adapter in a high load area)

Band	Adapter	Success Rate
5Ghz	Intel(R) Centrino(R) Ultimate-N 6300 AGN	100
2.4Ghz	Intel(R) Centrino(R) Ultimate-N 6300 AGN	90.9
2.4Ghz	Intel(R) Centrino(R) Wireless-N 1000	100
2.4Ghz	D-Link DWA-160 Xtreme N Dual Band USB Adapter(rev.A2)	28.6

# Quality of Experience

- Sandvine provides video quality of experience through its 'Real Time Entertainment Dashboard'
- This provides an estimate of the users quality of experience by examining traffic behaviour through network
- Below shows youtube quality on campus Wi-Fi (out of 5)
- Improvement aligns with campus Wi-Fi upgrade





# Client Evaluation of Service (at the point of service)

- We randomly invite approximately 60 active Wi-Fi users per day to visit a web page and provide feedback
- Campus and Residence results are maintained separately
- Sample e-mail:

Your input on the University of Waterloo's Residence Wi-Fi service is requested

We'd like you to visit:

<https://istns.uwaterloo.ca/wifiservicereport?key=58032dda3c469893376d76e4c523599>

and answer a few questions, and submit the results. No userid or password is required.

Your participation is voluntary. You will not be sent any followup e-mail, or another invitation to participate, within two years.

If you'd like to participate, please complete the survey before Oct 09, 2013 23:59:59

Individual responses will be kept confidential, and destroyed after two years. Summary data which excludes individual responses may be published.

Please do not reply to this e-mail

# Example shown for Campus Wi-Fi

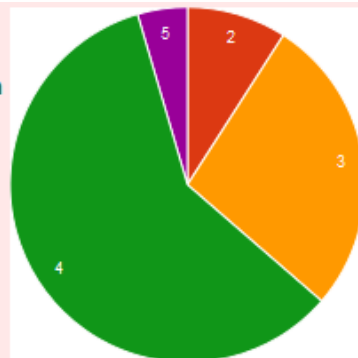
	<b>Campus</b> <b>Wi-Fi service report</b>	Bruce Campbell bruce@connect.uwaterloo.ca
Please rate your overall satisfaction with the University of Waterloo's Campus Wi-Fi service ( <b>excluding residences</b> )		<input type="radio"/> Very Satisfied <input type="radio"/> Satisfied <input type="radio"/> Neither Satisfied nor Dissatisfied <input type="radio"/> Dissatisfied <input type="radio"/> Very Dissatisfied <input checked="" type="radio"/> decline
Do you ever encounter difficulty connecting or using the University of Waterloo's Campus Wi-Fi service ( <b>excluding residences</b> )		<input type="radio"/> I rarely or never encounter any difficulty <input type="radio"/> I occasionally experience some problems <input type="radio"/> It works about as often as it does not work <input type="radio"/> It sometimes works <input type="radio"/> It never works <input checked="" type="radio"/> decline
If there is a location with poor Wi-Fi coverage, please tell us		<input type="text"/>
download speed on 129.97.109.69 (kilobits per second)		73894.4
Comments - anything you'd like to add or suggest is welcome		
<input type="text"/>		
<input type="button" value="Submit"/>		
Individual responses will be kept confidential, and destroyed after two years. Summary data which excludes individual responses may be published.		
For more information on UW's Wi-Fi, or to submit an incident report, please visit <a href="http://wifi.uwaterloo.ca/">http://wifi.uwaterloo.ca/</a>		

# Survey – What We See

- About 11% of users respond to the Campus Wi-Fi survey
- About 18% of users respond to the Residence Wi-Fi survey
- Can view total responses in pie chart form
- Results for Campus (excluding residences), and Windows operating system, shown...

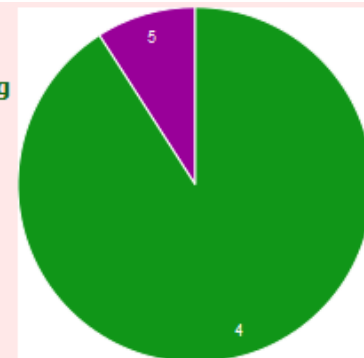
**q1 - Please rate your overall satisfaction with UW's Campus Wi-Fi service**

5 Very Satisfied  
4 Satisfied  
3 Neither Satisfied nor Dissatisfied  
2 Dissatisfied  
1 Very Dissatisfied  
0 decline



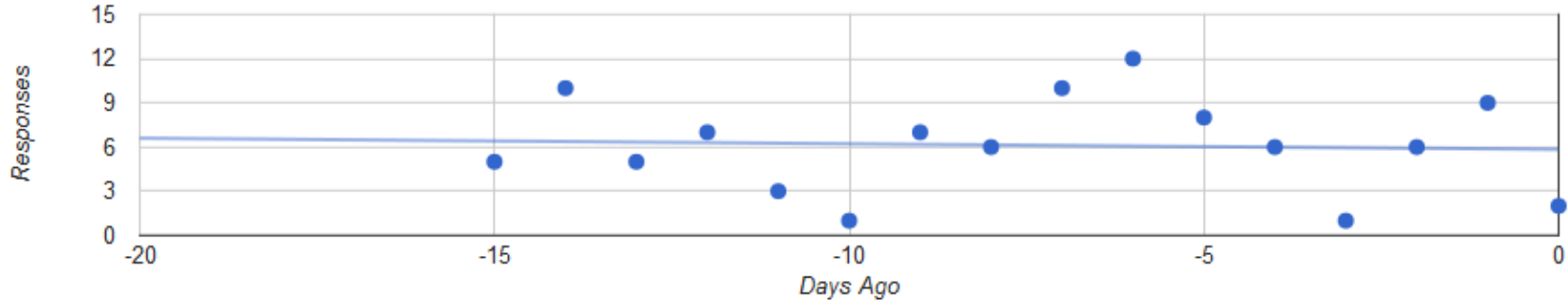
**q3 - Do you ever encounter difficulty connecting or using UW's Campus Wi-Fi service ?**

5 I rarely or never encounter any difficulty  
4 I occasionally experience some problems  
3 It works about as often as it does not work  
2 It sometimes works  
1 It never works  
0 decline

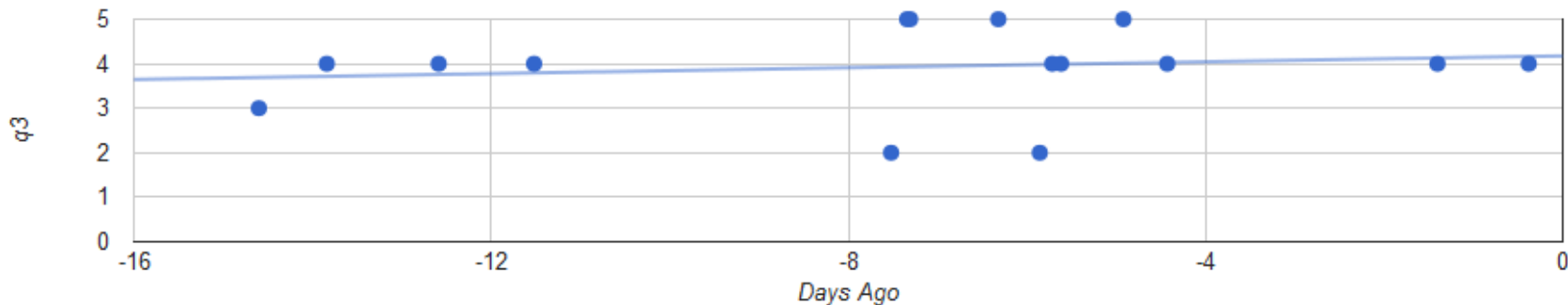


# Survey Results

- Number of responses by day



- Scatter plot and trend line (residence V1 shown)



# Interference

- Wi-Fi uses radio frequency to communicate between the access points and user devices
- It uses unlicensed frequency spectrum
- The University has [guidelines](#) regarding use of the Wi-Fi spectrum
- There are significant sources of interference, particularly on the 2.4GHz band, from:
  - Rogue (or private) access points installed without following the [Approval Process](#)
  - Microwave ovens
  - Many models of cordless base station phones
  - Nearby access points of our own on the same channel (this is called co-channel interference, and is a particular problem on the 2.4GHz band where there are only 3 non-overlapping channels)
- When another device is using the same frequency as UW's Wi-Fi in an area, even at low power levels, Wi-Fi in the area can stop working until the interference is gone

# Interference from Rogues

- ‘On channel’ Rogues, that is rogue access points using the same channels (e.g. 1,6,11) as our APs, are able to gracefully share the bandwidth with our APs in some cases, because the rogues and our APs recognize and respect each others control frames.
- However, the bandwidth is still shared between the rogues and our APs.
- And there is still increased potential for communications to be garbled requiring retries in the presence of on channel rogues.
- If there are more than a few rogues in an area, even if they aren’t doing anything, significant bandwidth can be used by the beacon frames, which are broadcast repeatedly at the lowest data rate (1mbps for ‘b’).

# Off Channel Rogues and non Wi-Fi interference

- Rogues not operating on the usual channels completely disrupt our Wi-Fi in the area (and vice versa), and they don't recognize each others control frames.
- They just see radio noise, garbling the traffic, then try re-transmitting.
- Similarly, non Wi-Fi interference (e.g. microwave ovens and cordless base station phones) can completely disrupt Wi-Fi operating at the same frequency.

# Interference

- The body of knowledge on interference is significant, and includes vendor neutral and vendor material, some examples:
  - [http://www.cwnp.com/cwnp\\_wifi\\_blog/the-wise-article-series-interference-from-non-wifi-sources-part-1/](http://www.cwnp.com/cwnp_wifi_blog/the-wise-article-series-interference-from-non-wifi-sources-part-1/)
  - [http://www.cwnp.com/cwnp\\_wifi\\_blog/the-wise-article-series-interference-from-non-wifi-sources-part-2/](http://www.cwnp.com/cwnp_wifi_blog/the-wise-article-series-interference-from-non-wifi-sources-part-2/)
  - [http://www.cisco.com/en/US/prod/collateral/wireless/ps9391/ps9393/ps9394/prod\\_white\\_paper0900aecd807395a9.html](http://www.cisco.com/en/US/prod/collateral/wireless/ps9391/ps9393/ps9394/prod_white_paper0900aecd807395a9.html)
- ...The technical support engineers at a major Wi-Fi infrastructure vendor reported to Cisco that in a recent service call to a major customer they found almost 20 sources of interference, contributing to over 50 percent of the problems on the customer's Wi-Fi network...*



# Interference

- Other University's experience with interference can be found online
- <https://answers.uchicago.edu/page.php?id=22027>

*...Interference also plays a major role in the quality of the user experience. The radio frequencies used in Wi-Fi are also used by many other types of devices. These devices include cordless phones, wireless headsets, wireless microphones, wireless cameras, etc. When these devices are in operation in the same vicinity as a Wi-Fi network, they can cause interference. Interference can also come from sources such as microwaves. The presence of interference can result in a client showing a connection but not being able to perform network operations, slowing down network operations, or completely disconnecting the client from the wireless infrastructure. Interference is often transient, which makes it difficult to find the source...*

# Interference

- <http://www.it.northwestern.edu/ecommm/2013-winter/students/wifi.html>

*...With all University-owned housing covered by wireless Internet service, you may be wondering why your connection is sometimes spotty. Rather than call the NUIT Support Center, you might think you can solve the problem yourself (or with a somewhat tech-savvy roommate) and install a personal wireless router in your room.*

*Guess what? You just killed the Internet for the rest of your hall.*

*Ok, that may be a slight exaggeration, but with the way large wireless networks like Northwestern's are set up, individual wireless routers hog a large portion of the available Wi-Fi frequency space and interfere with the University-supplied Wi-Fi network, leaving your hallmates cursing your name when their connections drop...*

# Interference

- Our Wi-Fi system detects interference, and can adjust the channel of the AP automatically in some cases
- But...
  - There are only 3 channels in the 2.4GHz band
  - There are minimal options for working around interference. For example the leakage from a typical microwave oven is 30 times more powerful than the average laptops Wi-Fi radio.
  - Unless someone finds and removes (or shields) the interference, it can continue to cause Wi-Fi performance problems.

# Interference – what we are doing

- We have updated the [Guidelines](#) for use of the wireless spectrum, with both CTSC and UCIST support
- We have activated some features in the Wi-Fi system to block access to non approved Rogue APs (where possible). But this does not eliminate the interference from beacon frames.
- We have acquired directional antenna equipment to start to locate interference sources, with a goal of asking the owners of such sources to remove it, or change to non interfering technology (e.g Dect 6.0 cordless base station phone to remove 2.4GHz base station phone).

# End user devices

- Issues on end user devices (laptops, smartphones, notebooks, etc) can affect the quality of service
- Driver bugs and poor implementations can affect service, even if the device works fine on a home Wi-Fi network
  - Home Wi-Fi networks use WPA PSK while enterprise Wi-Fi networks use WPA2 Enterprise, the latter being harder to implement correctly
- Examples
  - <http://support.apple.com/kb/HT5730>
    - *Compatibility improvements when connecting to certain enterprise Wi-Fi networks*
  - <http://www.neowin.net/news/intels-wi-fi-adapters-connectivity-issues-continue>
    - *The Windows 7/8 [disconnection errors appearing with Intel Centrino 6230/6235 adapters](#) are still a problem area, and users are becoming increasingly annoyed with the way Intel are handling the issue.*
  - <http://en.community.dell.com/support-forums/network-internet-wireless/f/3324/t/19496748.aspx>
    - *Wifi problem XPS15 L521X - Killer Wireless-N 1202...*
    - *...spoke to Dell about my wifi issue and they identified it as the antenna...*

# End user devices

- If you are experiencing a problem on your device...
  - Ensure the drivers are up to date
  - Do some web searches of your computer make/model and/or Wi-Fi chipset, plus the text **wireless problems** (or equivalent) to see if anyone else is having a problem
  - And/or take the device to a campus IT helpdesk

# If you are experiencing a problem...

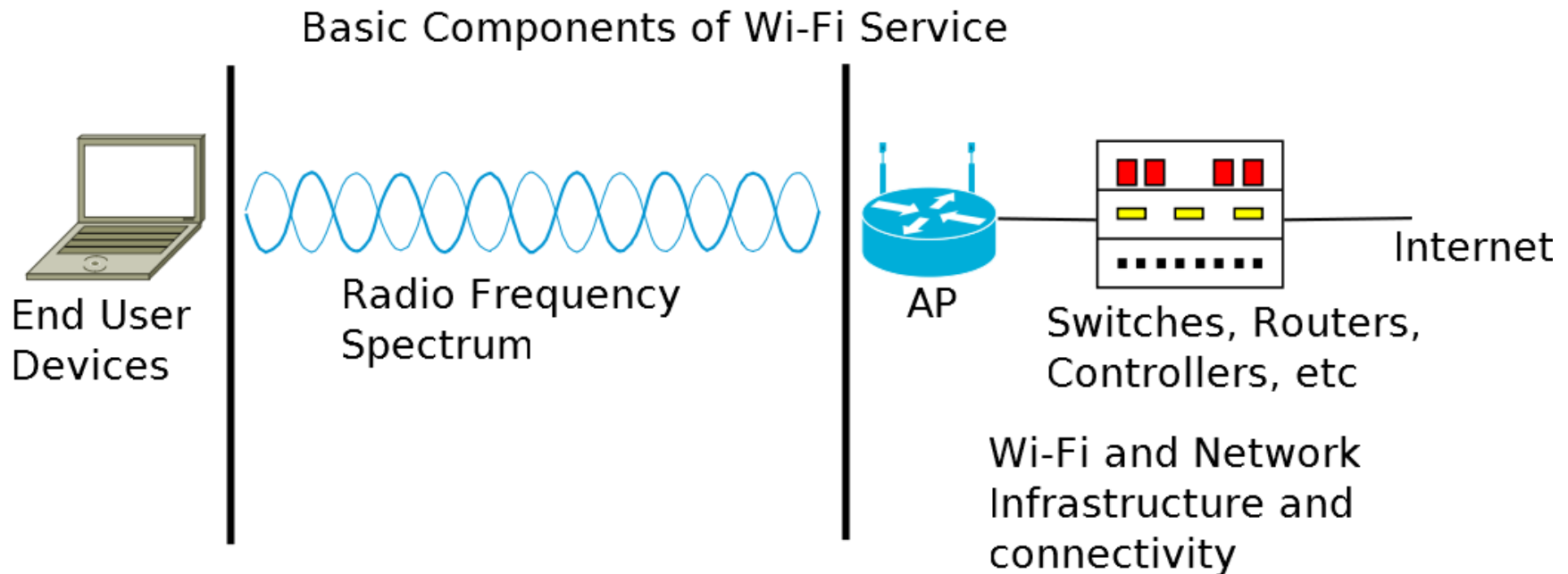
- How do you know if the issue is on your device, is caused by interference, is due to a coverage gap, or high usage in the area, or something else ?
- You probably won't know, so report the issue, and/or visit a campus IT help desk, so everything can be investigated.
- In almost all cases, the investigation starts with the end user device itself, checking drivers and settings.
- If you would like to submit a *Wi-Fi incident report*, you can use this tool:
  - <http://wifi.uwaterloo.ca/protected/incidentreport.php>

# Wi-Fi – What can influence service ?

- Wi-Fi is communication between endpoints, over the air, using radio waves.
- If it doesn't work as expected, then...
  - There is something wrong on an endpoint, or
  - There is something wrong between the 2 endpoints
  - (or a combination)
- In addition...
  - Wi-Fi technology itself is subject to limitations, e.g. number of channels, bandwidth
  - We have policies that influence service, e.g. bandwidth caps, requiring a password



# Wi-Fi – What can influence service ?



- Policies (traffic limits etc)
- Wi-Fi technology (channels, power limits, etc)

# Wi-Fi – What can influence service and what we are doing

Factor	What we do or need to do
Wi-Fi and related infrastructure	<ul style="list-style-type: none"><li>• Use of leading vendor technologies</li><li>• Validated design</li><li>• Monitoring, testing</li><li>• Ongoing commitment in time and budget</li></ul>
Radio Frequency Spectrum	<ul style="list-style-type: none"><li>• Policy in place</li><li>• Monitor for interference</li><li>• <b>We need to increase capability and priority to locate and have interference sources removed</b></li></ul>
Wi-Fi technology limitations	<ul style="list-style-type: none"><li>• Outside of our control</li></ul>
Our policies	<ul style="list-style-type: none"><li>• Review and increase bandwidth as needed</li></ul>
End user devices	<ul style="list-style-type: none"><li>• Help desk support for common devices</li><li>• <b>We need to increase awareness of factors affecting Wi-Fi service, among campus IT staff and end users</b></li><li>• <b>We need to ensure campus help desks and campus wide front line client support staff are aware of the devices their users use, and can support these devices adequately</b></li></ul>