Outdoor Wireless at MIT

FINAL REPORT

May 12, 2005

TEAM WIRELESS

OUTDOOR WIRELESS AT MIT

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I. IS&T Project Introduction

Background
As the academic year comes to an end, IS&T's goal of having wireless network connectivity in all indoor locations on campus, including but not limited to, dormitories, labs, as well as classrooms, has almost been entirely realized. While IS&T took steps over the past two years towards accomplishing this goal, they began to notice that quite a number of community members were accessing the MIT network via wireless signal bleeding from indoor access points to outdoor locations; people did not want to be constrained by the indoors when wanting to access the Internet.

Thus a new vision for IS&T was born: an entirely wireless MIT campus, where wireless Internet connectivity was available from one end of campus to the other, indoor as well as outdoor.

Objective
IS&T is quite aware that a complete campus-wide wireless connectivity implementation is quite a laudable goal, and will indeed take some time. However, IS&T acknowledged that MIT needs to be on the forefront of technology and communications, and thus decided to begin with a pilot program to begin during the summer of 2005.

From initial observations on IS&T's part combined with a dose of commonsense IS&T has picked three locations in which to deploy the pilot programs:

- Student Center Steps and Surrounding Area
- Killian Court
- Stata Center Atrium and Surround Area

Based on lessons learned from the pilot, IS&T plans to incrementally deploy wireless connectivity in other outside key locations until every area on campus is covered. The speed at which this vision will be realized has yet to be determined, and will be heavily influenced by the success of the pilot as well as feedback from the community.

The goal of an entirely wireless campus is to provide MIT community members the ability to continuously and consistently access the network through mobile devices such as laptops and PDAs as they move across campus. The ability to access the Internet anywhere on campus, whether indoors and outdoors, not only increases flexibility in work style and improves efficiency, but allows computer users previously restricted to the indoors to get out and work in a more healthy and open atmosphere: the great outdoors. This becomes even more important as wireless devices begin to proliferate the consumer market and become more important to the way we work.

Deliverables
Short term: Pilot Plan, Summer of 2005
Long-term: Campus-wide Implementation, September 2005 - ?

II. Team Wireless Project Introduction

Background
In the Spring of 2005, student teams in the 15.568 Practical IT Management class were paired up with current IS&T projects and asked to play a role in assisting the IS&T project. Team Wireless was matched with IS&T's project for the implementation of outdoor wireless internet connection. The Team met with Project Champion Theresa Regan, MIT's Director of Operations & Infrastructure Services, and discussed the scope and goals of this student project.

Objective
IS&T's large scale project involves numerous components. To better evaluate the situation and environment in which IS&T is launching outdoor wireless, it needs information from many ends, such as what kind of technology is available, which vendor is most appropriate for MIT, what kind of special environmental considerations (weather and architecture) do we need, etc.

Team Wireless' role is to address two of these areas. Specifically, we will provide IS&T with relevant information regarding

- The future of wireless technology
- Other current outdoor wireless implementations

To accomplish this, we will conduct research on two ends

- Outdoor Wireless Technology
  - Research outdoor wireless technology
  - Interview vendors
- Environment for Implementation
  - Interview universities

IS&T's Outdoor Wireless project wished to understand the future of outdoor wireless, such as which standards are used and what new technologies are being developed, so that upcoming implementations would not soon become obsolete. We would gain understanding about future technology through academic research and through interviewing vendors on what they foresee on the horizon.

Many implementation issues can be planned for by observing other current outdoor wireless implementations and learned from their experiences. Therefore, Team Wireless will interview other universities which have implemented outdoor wireless.

We will bring outside information to the inside without knowing the intimate details of IS&T's plans. We will add value to the IS&T project by informing and supplementing them with the results of our research. The MIT Process Handbook aims to collect information on all different types of business processes so when one has questions regarding a specific kind of process, he can look up that process and see how others have previously dealt with that process. Similarly, the information we gather will serve as a base for IS&T so when they are implementing outdoor wireless, they can reference to our report and find useful information, such as what other universities chose for their vendors or how other universities solved problems regarding architectural obstructions of signals.

Deliverables

Deliverable	Due Date
Project Plan	March 3, 2005
Status Report	March 17, 2005
Status Report	March 31, 2005
Status Report	April 14, 2005
Status Report	April 28, 2005
Project Presentation	May 3, 2005
Final Written Report	May 12, 2005

This final written report gathers all our findings and summarizes what we have accomplished within the timeframe provided for this project. We all provide many suggestions on where IS&T should go from here, and what special considerations they need in moving forward.

For a more detailed timeline of our project, please refer to our Gantt chart in Appendix A. The Gantt chart was adopted as recommended in Randolph and Posner's "What Every Manager Needs to Know about Project Management".

III. Technology Overview

Wireless Basics

Wireless network connectivity has finally become main-stream and it is difficult these days to purchase a laptop that doesn't come equipped with the necessary hardware to harness the power of wireless. It is important to understand some of the basic concepts of how wireless works as well as certain technological terms that are used throughout this report. Therefore, we are going to walk through a communication between an MIT student using a wireless laptop on the Student Center steps and a professor using a desktop in his office, as illustrated in figure 1.

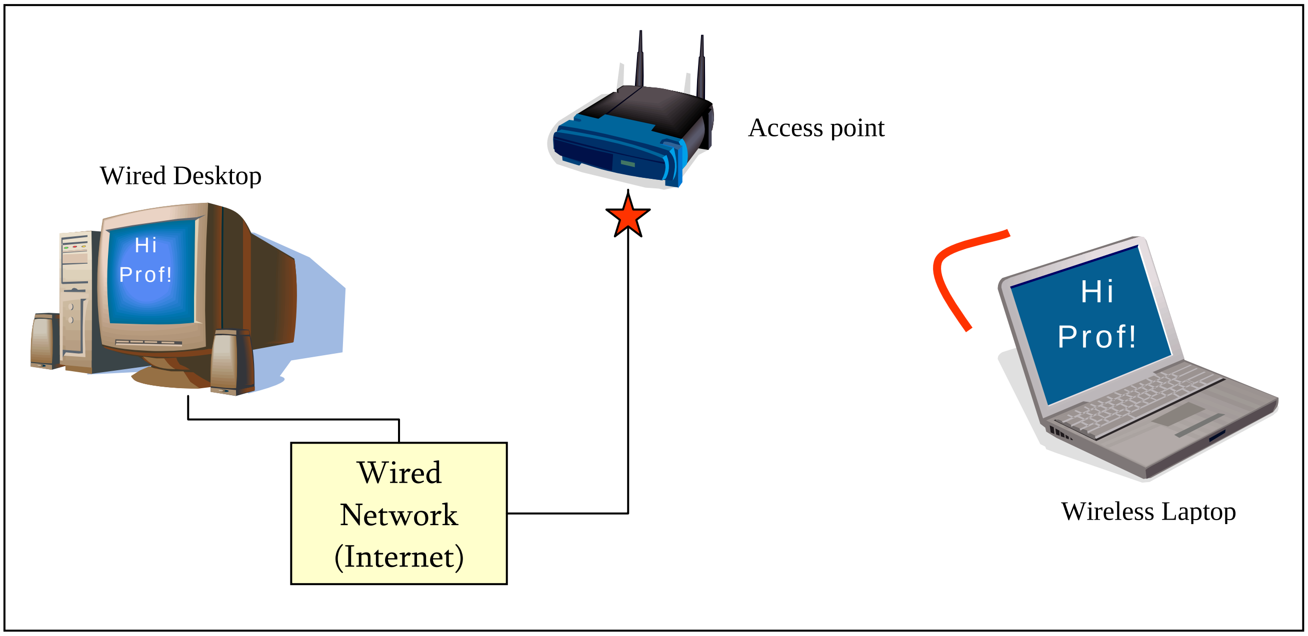

Figure 1: Wireless Basics

The student with the laptop attempts to send a message to his professor. First, the computer converts the message to its digital format to be stored temporarily on the computer. Then, the wireless card in the laptop takes that digital information and converts it to a radio signal that is sent out into the air, the be picked up by the associated access point. This access point is connected to the wired MIT network which is, in turn, connected to the rest of the internet.

Once the access point receives the signal sent from the laptop, it takes it and converts the radio signal back into its digital form and sends it along to the appropriate switches on the network, which eventually makes its way to the professor's desktop computer.

Wireless Bridges

Another important wireless feature to understand is that of wireless bridges. Basically, wireless bridges allow a service provider to extend the range of a wireless signal by bouncing signals off of multiple access points configured to be wireless bridges.

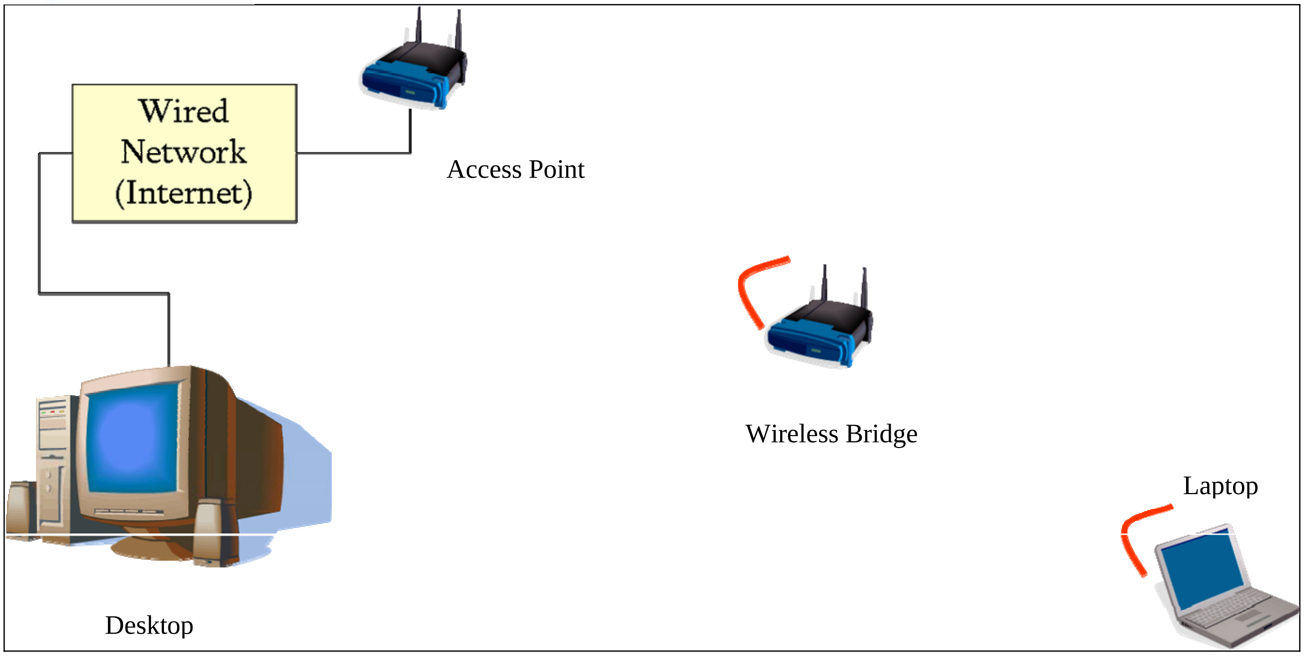

Figure 2: Wireless Bridges

To illustrate the use of wireless bridges, please refer to figure 2. Let's say that the student with the wireless laptop is in the middle of Briggs field with his laptop, and the distance between his laptop and the access point mounted on the outside of Simmons Hall is farther than the wireless signal is able to travel. However, there is a wireless bridge in the middle of the field which is configured to take signals sent to it and send it out farther in certain directions, thus enabling a signal from the laptop to reach the access point at Simmons and vice versa.

Wireless Standards

Today, the most widely used standards are the **802.11a/b/g** protocols. While **a** and **g** are the faster protocols, **b** and **g** are interchangeable and are composed of cheaper hardware. Additionally, the range on the **b** and **g** protocols are somewhat farther than the **a** protocol. Currently, **g** is considered the gold standard, being the fastest most-widely used protocol available today.

Future Wireless Technologies and Standards

There are a number of new protocols on the horizon. **802.16**, also known as Wi-Max, is a protocol that hopes to extend the distance of wireless signals to 10-20 miles, thus providing "Last Mile Broadband Connections" to consumers who cannot connect to a wired solution for fast Internet connections. In the near future IS&T does not have to worry about this new technology much because the wired infrastructure is already implemented on campus and should be utilized to its fullest potential. However, in the far future the current wired infrastructure could become fully saturated, thus opening the doors to new technologies that provide additional bandwidth to users on campus through other means than buried wires.

802.11n is basically a step up from the 802.11g protocol, providing double the throughput. However, it operates on the 40 MHz Channel, which is restricted in countries such as Europe and Japan. Therefore, standard adoption is not likely in the coming years until these important countries change their policies.

802.11i is a wireless protocol that provides more secure wireless communications. At the present time, all wireless implementations on campus are un-encrypted and therefore this protocol may not be of much interest to IS&T. However, with the potential extension of wireless connectivity to public areas like Massachusetts Avenue and Kendal Square, IS&T might want to consider enhanced encrypted wireless communications with this new protocol.

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IV. Vendor Research

Procedure

1. Inquire Project Champion for MIT's current indoor wireless vendors
2. Research on-line for outdoor wireless vendors
3. Contact vendors with list of specific questions (phone & e-mail)
4. Compile analyze results
5. Make recommendation

The list of specific questions asked to vendors includes the following:

- What solution do you offer for outdoor wireless internet access? What kind of access points is used?
- MIT's current wireless network has a central remote management system where individual computer connections can be shut down from this central system if problems arise. How will your access points be able to blend in with our current system?
- What are some qualities that make you a strong candidate for MIT to choose as a vendor?
- Do you have experience with implementing outdoor wireless internet on college campuses?
- What is your pricing and how does it compare to competitors?
- What do you see as the future trend of outdoor wireless technology?

Information & Comparison

Vendors contacted:
Enterasys, Avaya, smartBridges, D-Link, InPath Devices, National DataComm Corporation, Lucent, Cisco, 3Com, Symbol, Proxim, NetGear, and Firetide
* For contact information of these companies, please see References.

Enterasys and Avaya are MIT's current vendors for indoor wireless. Unfortunately, Entersys' outdoor wireless solutions are discontinued, and we were unable to get in contact with Avaya.

Vendors who cooperated with the project:
smartBridges, D-Link, InPath Devices

	smartBridges	**D-Link**	**InPath Devices**
Outdoor Wireless Solution	airBridge and airPoint PRO series	DWL-1700 AirPremier Outdoor 2.4 GHz Wireless Access Point	CPE 2473 Wireless Bridge
Pricing	$350 each	$820 each	$379 each
Standard Used	802.11 b (new product coming out in May will have 802.11 a/b/g)	802.11 a/b/g	802.11 b
Experience with Universities	Yes	Yes	Yes
Compatible with MIT's Current Wireless Network	Yes	Yes	Yes

Vendor	**Key Advantages**
D-Link	• Extreme weather protection – built in heater and temperature sensor, Watertight Aluminum housing, Lightning Protection, and PoE (Power Over Ethernet) • Quality name brand • 128-bit WEP encryption • IEEE 802.1x port-based network access control with RADIUS servers for user authentication
InPath	• Easy installation - integrated radio and antenna • Low price – Cisco uses same OEM but much more expensive
smartBridges	• Experience in all areas (Low power, commercial, wide areas, high humidity, below zero temperatures, outside city limits, revenue generation, residential) • Remote management system • Supports VoIP

Vendor Recommendation

As Team Wireless was only able to receive full response from 3 vendors, we are still in an early phase of evaluating vendors; therefore, we cannot tell IS&T exactly which vendor to work with. However, of the 3 vendors, we can draw a preliminary conclusion of which vendor we would prefer out of these three.

Future Trends	Compatibility with MIT	Weather duration	Experience in installation	Advanced technology

Lower price range	Higher price range
smartBridges	D-Link

Considering future trends of technology, compatibility with MIT, weather duration, experience in installation, and advanced technology, we recommend that

1) If MIT is aiming for a lower price range and looking for a more economical solution, to work with smartBridges, and

2) If MIT is fine with a higher price range and wants to go with a more established and more brand-name vendor, to work with D-Link.

Next Steps for Vendor Research

- Interview more vendors
    - Speaking with vendors can help better understand options for technology and support.
    - As a student project group, we had limited contacts. We are confident that vendors would be much more willing to work with MIT's IS&T.
- Allow vendors to evaluate MIT's specific circumstances
    - When speaking to vendors, they often asked specific questions about MIT's current systems and environment. By allowing vendors to identify unique attributes of MIT, IS&T will be able to evaluate how vendors will handle these circumstances.
- Bring vendors on campus to give price quotes
    - This will allow IS&T to conduct a price-benefit analysis on different vendors.
    - Bringing the vendors on campus to present their best solution and bid for the project will hopefully make it more cost-efficient for MIT.
- Research retail channels
    - Certain vendors actually use retailers to sell their products.
    - IS&T should evaluate purchasing options and see which channel will provide the best future support, since IS&T is relying on the vendor to provide future support and maintenance of the outdoor wireless.

V. University Research

Procedure

1. Research on-line for universities with outdoor wireless technologies
2. Contact universities through email correspondence with a list of specific questions
3. Compile and display information
4. Make preliminary recommendations
5. Suggest next steps

Since IS&T would use our research on universities as a reference to MIT's outdoor wireless implementation, we thought the most relevant questions would fit under the following three categories: vendor selection, implementation process, and other considerations. All of the questions were derived from the interests of our Project Champion.

- Vendor Selection
  - Whom did you choose as your vendor?
  - What criteria did you set forth in order to select the vendor?

- Implementation Process
  - What is the outdoor wireless infrastructure of your campus?
  - How long did the implementation take?
  - What were some of the implementation problems you experienced, if any?
  - How has the weather affected outdoor wireless functionality
  - How did you take into account structural interference?

- Other Considerations
  - Are there items you wish you knew before you started the implementation?
  - How does the university cope with visitors on campus who use the wireless technology?

Due to time and resource constraints, we used a static email interview structure. The information collected from the interviews can give IS&T a snapshot into how other universities use their technology. For a deeper information, personal or phone interviews should be conducted in the future to obtain more specific information that could be relevant to MIT's implementation.

Information & Comparison

Team Wireless contacted seventeen universities through email asking questions ranging from vendor selection to infrastructure set-up. Our team tried to specifically research universities in the Boston and northeast area in order to understand how others dealt with similar weather and campus challenges. Unfortunately, the only universities we could find are similar to MIT externally (weather conditions) and internally (integrated campus and city) were Carnegie Mellon University, Columbia University, University of Pennsylvania, and University of Pittsburgh. In general, the locations of outdoor wireless campuses are sporadic in geographic location. Since we could find limited amount of universities that have implemented this technology, team wireless believes that MIT would still be a pioneer in this technological movement.

Universities Contacted

Bowling Green State University, Carnegie Mellon University, Central Washington University, Columbia University, Drew University, Georgia Institute of Technology, Goucher University, Florida A&M University, Louisiana State University, University of Arkansas, University of California , Irvine, University of Iowa, University of Nevada, Reno, University of Pennsylvania, University of Pittsburgh, University of South Carolina, and University of Virginia
*For contact information of these universities, please see References.

Universities who cooperated with the project:

Carnegie Mellon University, Columbia University, Georgia Institute of Technology, Louisiana State University, and University of Virginia

The following chart aggregates the important university data.

University	**Vendor**	**Infrastructure**	**Weather**	**Visitor Policy**
Carnegie Mellon University	AT&T (currently Proxim)	Internal Bleeding + External Antennas	Irrelevant	Guest Registration: access to only internet
Columbia University	Lucent (currently Proxim)	External Antennas	Irrelevant	Guest Registration: access to only internet
Georgia Institute of Technology	Digital Atlantic (currently Proxim)	Outdoor Switches	Irrelevant	No non-authenticated wireless networks
Louisiana State University	Cisco	External Antennas	None	Guest Registration: access to only internet
University of Virginia	Cisco Aironet	Bridge Antennas	None	No non-authenticated wireless networks

Vendor

Each university chose a different vendor at the time of purchase. Each university identified potential vendors and worked together to devise customized solutions for its campus. We recommend that MIT follow a similar procedure for vendor selection.
* Refer to the Vendor Research section for more information.

Infrastructure

The three main technologies that the universities currently have in place are external antennas, bridge antennas, and outdoor switches. The universities stressed how the coverage landscape dictates the type of technology needed. For example, a large open field (ie Briggs Field) needs to be covered by bridge antennas in order for the signal to reach across the open space. The collaboration between the vendor and university will determine the appropriate technology for a given space.

Weather

Since the ferocious winter months inhabit Boston for most of the year, IS&T was wondering how weather may affect the wireless signal. Fortunately, most universities found no signal degradation or irrelevant signal degradation due to the weather. In stormy weather conditions, usually there aren't any individuals who are trying to access wireless outdoors.

Visitor Policy

Universities mainly followed two visitor policies. Georgia Institute of Technology and University of Virginia require that wireless users must register with the school. The other universities as well as MIT have a guest registration option. Specifically, MIT allows visitor use for up to fourteen consecutive days. Team wireless believes that the current policy should remain for outdoor wireless as well. The policy is flexible for individuals who stay temporarily on campus as guests of MIT. At the same time, the policy is secure because visitors only have access to the internet and not to user/password information.

The universities also shared their knowledge from the implementation of their outdoor wireless. The chart below displays an array of diverse implementation problems and solutions to structural interference.

University	Implementation Problems	Solutions to Solutions to Structural Interference
Carnegie Mellon University	Limited RF available in the 2.4 Ghz band	Trial & error AP placement
Columbia University	Limited RF available in the 2.4 Ghz band	Design around potential obstacles
Georgia Institute of Technology	Mistakenly experimented with new technology Antennas on historical buildings	None
Louisiana State University	None	Add another antenna
University of Virginia	Antennas on historical buildings	Relocate APs Power up APs Add another antenna

Implementation Problems

- Limited RF available in the 2.4 Ghz band:
  At the 2.4 Gz band, microwaves, cordless phones, and Bluetooth devices cause interference. The universities overcame such problems with strategic placement of access points and the use of multiple access points.

- Mistakenly experimented with new technology:
  Georgia Institute of Technology experimented with new technology from Digital Atlantic to cut costs and avoid laying down hard-wired ethernet. They set up the infrastructure, but the actual wireless internet did not work and the company went under. In the end, Georgia Institute of Technology had remove Digital Atlantic's work and set up the hard-wired ethernet.

- Antennas on historical buildings:
  Georgia Institute of Technology had a problem with putting antennas on the steep roofs of their historical buildings, so they put a switch on top of their library to cover the whole area. In addition, historical buildings have restrictions on installing such devices. MIT might run into this issue further down the road with the campus-wide installation when covering areas by the Alumni Pool and Lobby 10.

Solutions to Structural Interference

- Trial & error AP placement:
  Carnegie Mellon University used a method of placing access point at an opposite end as the rest of the access points and then moving it closer to the rest until it leaves no coverage gaps. With the additional access point, they repeated the process.

- Design around potential obstacles:

As stated above, Georgia Institute of Technology had a problem with putting antennas on the steep roofs of their historical buildings, so they put a switch on top of their library to cover the whole area.

- Relocate access points:
  The access points can be moved to increase performance level. The optimal method is the trail & error process.

- Power up access points:
  The strength and coverage area can be changed to accommodate structural interference.

- Add another antenna:
  Louisiana State University implementation plan was to set up additional antennas when and where they are needed.

Many of the issues seen at the other universities look as though they might also be problems that may arise at MIT. It would be useful to talk to the universities beforehand to have some scenario planning (Class 12 discussion on March 15: CareGroup). This will allow IS&T to prevent these issues from coming up or at least know how to handle the problems that may arise during the implementation.

Preliminary Recommendations

From the information we received, Team Wireless has developed several recommendations that MIT should consider when rolling out the Pilot Program in June.

Install access points out of sight

Access points can be easily stolen or damaged if exposed to human contact. Placing access points out of sight would lengthen the life of access points.

Deploy 802.11g technology if possible

Protocol 802.11g is currently the fastest, most widely used protocol. For the future, team wireless believes that .11g will be the pervasive protocol for outdoor wireless. Additionally, the indoor wireless protocol is .11g; therefore, choosing .11g would maintain signal consistency from indoors to outdoors.

Create site surveys

Planning for access point coverage for the desired location is imperative in order to maximize the signal given potential obstructions. Creating site surveys will ensure effective access point placement and limit the trial and error process.

Test access points by trial and error

Since each area is unique, the only way to get the best layout of access points is with the process of trial and error. Carnegie Mellon University used a method of placing access point at an opposite end as the rest of the access points and then moving it closer to the rest until it leaves no coverage gaps. With the additional access point, they repeated the process.

Add up to three access points for one area

For a given location, up to three access points should be used depending on interference types. After installing three access points, the 2.4 GHz channel becomes oversaturated and each additional access point yields diminishing marginal returns to the signal.

Use stable and flexible technology

This point of advice is to reiterate common sense. Even though Team Wireless has done its best to forecast some technological trends, there could be new enhancements or other technological advances that we may have overlooked. As such, IS&T should adopt flexible technology that can easily be modified to include upcoming technology.

Next Steps for University Research

Interview more universities regarding MIT's specifics
Due to time and resource constraints, the static email interview structure can give IS&T a snapshot into how other universities use their technology. However, more research dynamic (ie personal or phone interviews) should be conducted in the future to obtain more specific information that could be relevant to MIT's implementation and gather details on concerns exposed in initial research. In addition, as a student project group, we had limited contacts. From the comments we received during our final presentation, we are confident that vendors would be much more willing to speak to MIT's IS&T. Since more research can always be helpful, IS&T should just limit itself to speaking to the five universities we interviewed in more detail in addition to speaking to any schools with a similar landscape and climate (ie University of Pennsylvania).

Gather special circumstances of implementation areas
Multiple universities stated that each area was unique and thus would have to have a custom access point layout as a result of interference (ie whiteboards, concrete buildings, and water) and area characteristics (ie how level the land is and estimated usage). Once the information is gathered, IS&T should talk to the vendors regarding how we can overcome each problem. It may be beneficial to start this early because of our unique architecture.

Understand future funding for upgrades
Depending on IS&Ts future plans and options going to be available in the future, IS&T has to weigh the advantages and disadvantages of upgrading later versus repairing new technology glitches that come up from using new technologies now. For example, Georgia Institute of Technology experimented with new technology from Digital. They set up the infrastructure, but the actual wireless internet did not work and the company went under. In the end, Georgia Institute of Technology had reverted back to the stable technology but with time and resources lost. MIT might face similar pressure to be at the leading edge, but it might be less risky for MIT to go with a more flexible plan such as Louisiana State University. They have an ongoing implementation process where they add access points when they see a need for it.

The university research done by our team is a good general stepping stone for MIT's IS&T to build off of. With the given information in the report, we hope to give IS&T some points to focus on when moving forward with their outdoor wireless implementation.

VI. Future Considerations for IS&T

DHCP Lease Visitor Policy

IS&T's current policy on leasing IPs to visitors on campus is to provide them full access to the network for 14 days per a given year. This policy may have worked when wireless access was restricted to indoors, but once wireless is available outdoors, especially near public areas like Massachusetts Avenue and the Kendall T Station, the MIT network will most likely receive a number of additional wireless connections from non-MIT community members.

Although IS&T has implemented an extensive remote management system for wireless Access Points and DHCP leases which enables them to deny access to specific machines connected to the network, the increase in visitors may drastically increase the load on the remote management system. Instead of bolstering the remote management system, IS&T may want to consider revising their Visitor policy, by:

- Reducing the amount of time a visitor has access
- Implement a more extensive registration process
- Limit visitors to certain ports (i.e. only allow them to browse the web)
- Monitor visitor connections more closely

Pilot Program Success Metrics

Although this question is a bit out of the scope of our project, it is important to evaluate the success of the three pilot locations for outdoor wireless deployment. One obvious way is to measure the load on the newly deployed access points. If these access points are well saturated, then the locations chosen were good ones.

Another means of determining whether the pilot program is a success is by conducting surveys before and after the deployment of the outside wireless locations gauging the satisfaction of community members with wireless connectivity. Additionally, it would be useful to see what percentage of the community is aware of the outdoor wireless availability a couple of months after deployment.

Identifying Key Outdoor Locations

IS&T must make a serious effort in determining the ideal locations for outdoor wireless and prioritize them. In determining the pilot locations, IS&T simply observed where people were using bleeding signals. For future locations, we recommend that IS&T survey the community for outdoor locations where they would find wireless access useful. IS&T should take into consideration:

- Places to sit
- Shade (most laptop screens become extremely washed out in the sun)
- Power outlets (batteries only last for so long)

Building Interference

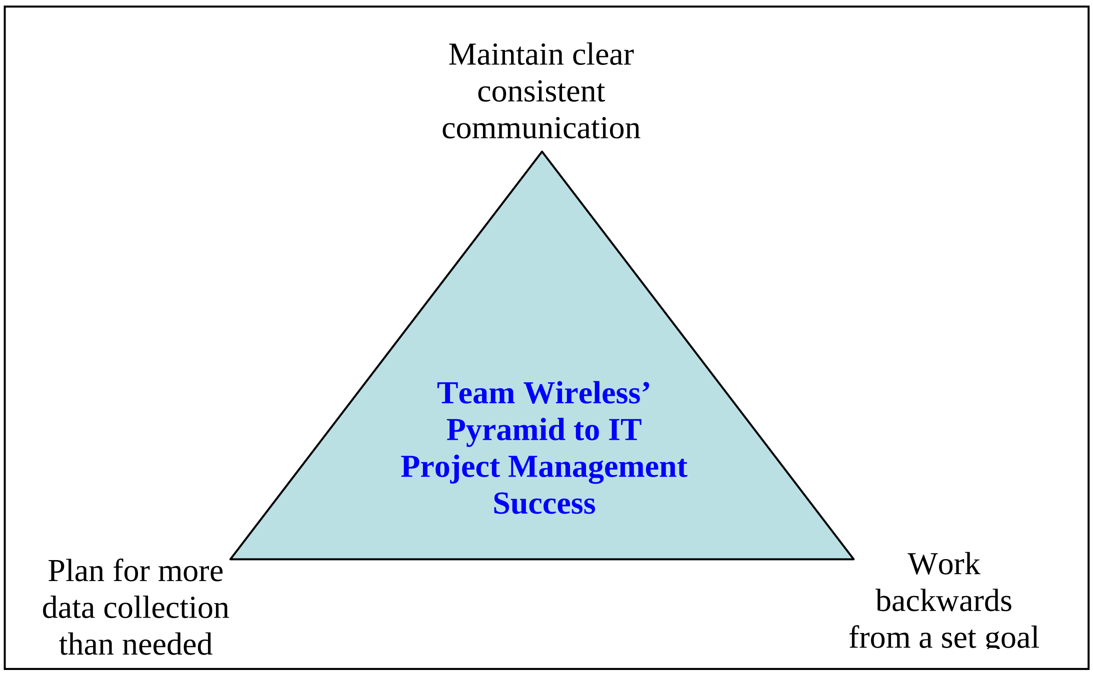
There are a number of very unique buildings around MIT made out of special materials, such as Simmons and Stata. IS&T must figure out what affect unique building materials have on signal strength and interference, and can look at the experiences of other universities who deployed outdoors.

Future Technologies

IS&T must always be wary of future technologies that could have a profound impact on their outdoor wireless implementation, such as the introduction of new protocols that may be widely adopted. Additionally, IS&T must pay attention to the increased proliferation of wireless devices in the form of wirelessly enabled PDAs and handhelds. In the future, there may be hundreds of people with wireless handhelds passing by access points at one time; what affect will this have the wireless network? IS&T should also take advantage of the convergence of technologies, such as the advent of wireless Voice over IP (VoIP) equipment in the past couple months.

VII. Lessons Learned

The Outdoor Wireless Team enjoyed working on this project for IS&T. The project allowed us to apply what we learned in class, such as the use of Gantt Charts to keep track of deadline and the use of status signals. We also really appreciated the very important people such as Steve Winig were supportive and interested in our project. It made us feel as though they were really listening and that our work would be useful to them. However, work equivalent to the work before the project on top of status reports and other deliverables made it hard for the team to focus on the project.



Maintain clear consistent communication
It is extremely important to have proper communication between team members and with others involved in the project. As a team, we communicated well and thus we were all on the same track. However, we were not able to meet with a key stakeholder in the project and so for a little bit we were not able to move forward. Nevertheless, after meeting with the stakeholder, we were able to make up the time we lost.

Plan for more data collection than needed
Out of the fourteen vendors contacted and seventeen universities contacted, we only received information from three vendors and five universities. In addition, since the schools do not know what is pertinent to MIT, we had to filter out a lot of data. We did not plan for such a small response rate. In the beginning, we only contacted a few expecting responses from most of them. But after seeing our response rate, we contacted more vendors and universities. If we had know this and planned accordingly to gather the information earlier, we might have been able to follow up with additional questions to gather specifics regarding their responses.

Work backwards from a set goal
As Professor Gibson mentioned in class, it is important to figure out what you want in the deliverables and then work backwards to get the results you need. We did not do this initially. After out initial presentation, our team met to figure out what we wanted as our end result. If this was a larger project, a useful tool in measuring performance would be the Balanced Scorecard. It's "a set of measures that gives top managers a fast but comprehensive view of the business" in four perspectives: financial, customer, internal business, and innovation and learning as stated in "The Balanced Scorecard – Measures that Drive Performance" by Robert S. Kaplan and David P. Norton..

VIII. References

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XI. Acknowledgements

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Evan critiqued our status reports and gave us suggestions on how to progress with our project.

Steven Winig (IS&T)
Sr. Proj Manager & Special Assistant to IS&T VP
Steve gave our group great perspective on how to widen our project scope to enhance our report to IS&T.

Jerry Grochow
Vice President for Information Services & Technology
Jerry commented on our presentation and gave us helpful feedback that will help us on future team projects and presentations.

15.568 class
The class asked pertinent questions that helped our team focus on the direction of our project.

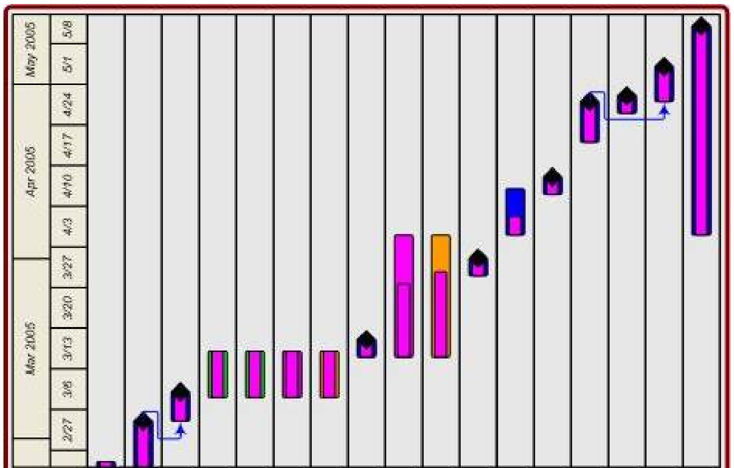
Participating Universities & Vendors
The universities and vendors mentioned in this report supplemented our team with the necessary data that made this project possible.

To all of the individuals above, thank you for your time and help!
Sincerely,
Team Wireless.

XII. Appendix A: Wireless Team Project Gantt Chart

Outdoor Wireless GANTT Chart

ID	Task Name	Start	Finish	% Complete	Duration	Resource Names
1	Meet with Champion	2/24/2005	2/24/2005	100%	1d	All
2	Initial Project Plan	2/24/2005	3/3/2005	100%	6d	All
3	Revised Project Plan	3/4/2005	3/8/2005	100%	3d	All
4	Online Technology Research	3/8/2005	3/15/2005	100%	6d	Harel
5	Collect information from IS&T on current wireless implementation	3/8/2005	3/15/2005	100%	6d	Harel
6	Vendor Research	3/8/2005	3/15/2005	100%	6d	Janice
7	University Research	3/8/2005	3/15/2005	100%	6d	Jessica, Ashvini
8	Status Report	3/15/2005	3/17/2005	100%	3d	All
9	Field Research on Vendors	3/15/2005	4/4/2005	60%	15d	Janice
10	Field Research on Universities	3/15/2005	4/4/2005	70%	15d	Jessica, Ashvini
11	Status Report	3/29/2005	3/31/2005	100%	3d	All
12	Analysis & Preliminary Conclusions	4/5/2005	4/12/2005	40%	6d	All
13	Status Report	4/12/2005	4/14/2005	100%	3d	All
14	Revise & Practice Presentation	4/21/2005	4/27/2005	100%	5d	All
15	Status Report	4/26/2005	4/28/2005	100%	3d	All
16	Final Presentation	4/28/2005	5/3/2005	100%	4d	All
17	Final Report to MIT IS&T	4/5/2005	5/10/2005	100%	26d	All



TEAM WIRELESS
OUTDOOR WIRELESS AT MIT

XIII. Appendix B: Final Presentation Slides

Outdoor Wireless Internet at MIT

15.568
Prof. Gibson

TEAM WIRELESS
Janice Lin
Jessica So
Ashvini Thammaiah
Harel Williams

Agenda

Background → Technology Overview → University Research → Vendor Research → Next Steps → Key Factors

Lessons Learned | Q & A

Background: IS&T's Project

Context:
- MIT looking to expand wireless availability to outdoors
- Project Champion: Theresa Regan, Director of Operations & Infrastructure Services
- Motivation: provide students additional gathering locations

Objective:
- Short term: Pilot program by the end of the summer for Stratton Student Center, Stata Center, & Killian Court
- Long term: Provide wireless internet for all MIT outdoor locations

Background: Team Wireless' Project

Context:
- Provide IS&T with relevant information regarding
  - future of wireless technology
  - other current outdoor wireless implementations

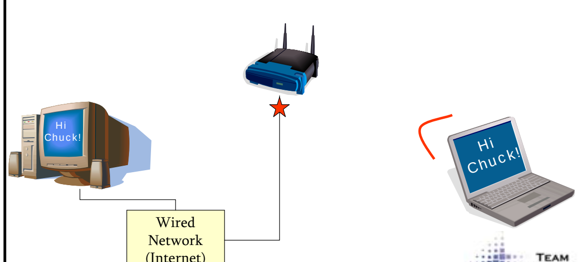
Objective:
- Technology
  - Research outdoor wireless technology
  - Interview vendors
- Environment
  - Interview universities

Agenda

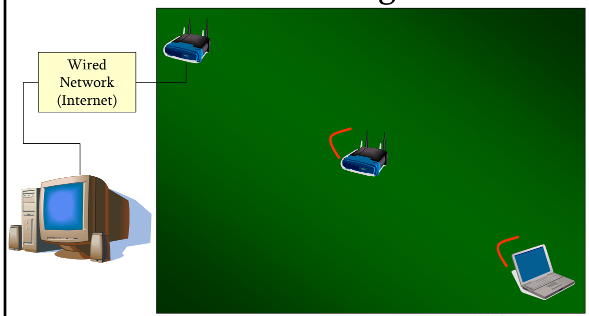
Background → Technology Overview → University Research → Vendor Research → Next Steps → Key Factors

Lessons Learned | Q & A

Wireless Basics



Wireless Bridges



Wireless Standards

- Current Standards: 802.11a/b/g
  - a: 5 GHz Band, 54 Mbps
  - b: 2.4 GHz Band, 11 Mbps
  - g: 2.4 GHz Band,
- Future Protocols
  - 802.16: “Last Mile Broadband Connections”
  - 802.11n: 5 GHz Band, 40 MHz Ch, 108 Mbps
  - 802.11i: Better security

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Lessons Learned | Q & A

Research from Universities

University	Vendor	Infrastructure	Weather	Visitors
U of Virginia	Cisco Aironet	Bridge Antennas	None	No non-authenticated wireless networks
Columbia	Lucent (currently Proxim)	External Antennas	Irrelevant	Guest Registration: access to only internet
Carnegie Mellon	AT&T (currently Proxim)	Internal Bleeding + External Antennas	Irrelevant	Guest Registration: access to only internet
Georgia Tech	Digital Atlantic (currently Proxim)	Outdoor Switches	Irrelevant	No non-authenticated wireless networks
Louisiana State	Cisco	External Antennas	None	Guest Registration: access to only internet

Research from Universities

University	Implementation Problems	Solutions to Solutions to Structural Interference
UVA	Antennas on historical bldgs	Relocate, Power up, Use another antenna
Columbia	Limited RF available in the 2.4 Ghz band	Design around potential obstacles
Carnegie Mellon	Limited RF available in the 2.4 Ghz band, Interference Issues	Trial and Error of AP placement
Georgia Tech	Mistakenly Experimented with new Technology, Antennas on historical bldgs	N/A
Louisiana State	None	Add another antenna

Research from Universities

Action	Justification
Install AP’s out of sight	To avoid AP damage from human tampering
Deploy for protocol 802.11g if possible	To benefit from the fastest, most widely used protocol
Create accurate site surveys	To understand how potential obstacles will affect performance
Test AP placement by trial and error	To optimize individual building coverage areas
Add up to 3 AP’s to cover same area	To minimize interference
Use stable and flexible technology	To prepare for better future technology

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Lessons Learned | Q & A

Research from Vendors

Vendor	Outdoor Wireless Solution	Standard	Experience With Universities
D-Link	DWL-1700 AirPremier Outdoor 2.4 GHz Wireless Access Point $820 each	802.11 a/b/g	Yes
InPath	CPE 2473 Wireless Bridge $379 each	802.11b	Yes
smartBridges	airBridge and airPoint PRO series $350 each	802.11b (Next month will come out with 802.11 a/b/g)	Yes

Research from Vendors

Vendor	Key Advantages
D-Link	·Extreme weather protection –built in heater and temperature sensor, Watertight Aluminum housing, Lightning Protection, and PoE (Power Over Ethernet) ·Quality name brand ·128-bit WEP encryption ·IEEE 802.1x port-based network access control with RADIUS servers for user authentication
InPath	·Easy installation - integrated radio and antenna ·Low price – Cisco uses same OEM but much more expensive
smartBridges	·Experience in all areas (Low power, commercial, wide areas, high humidity, below zero temperatures, outside city limits, revenue generation, residential) ·Remote management system ·Supports VoIP

Research from Vendors: Recommendations

Future Trends | Compatibility with MIT | Weather duration | Experience in installation | Advanced technology

Lower price range: smartBridges

Higher price range: d-Link

Agenda

Background → Technology Overview → University Research → Vendor Research → **Next Steps** → Key Factors

Lessons Learned | Q & A

Recommendation on Next Steps: University Research

Recommendation	Reasoning
Interview more universities regarding MIT's specifics	To gather details on concerns exposed in initial research
Gather special circumstances of buildings	To conduct research on how to overcome each problem
Understand future funding for upgrades	To weigh upgrading later versus repairing new technology glitches

Recommendation on Next Steps: Vendor Research

Recommendation	Reasoning
Interview more vendors	To better understand options for technology and support
Allow vendors to evaluate MIT's specific circumstances	To identify unique attributes of MIT and how vendors will handle them
Bring vendors on campus to give price quotes	To conduct cost-benefit analysis on different vendors
Research retail channels	To evaluate purchasing options and choose channel with best future support

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Key Factors to Consider for Implementation

- DHCP Lease Visitor Policy
- Building Interference
- Popular Outdoor Locations
- Future Technologies:
  - Wireless VoIP
  - Handheld Devices

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Lessons Learned | Q & A

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Lessons Learned

Maintain clear consistent communication

Team Wireless' Pyramid to IT Project Management Success

Plan for more data collection than needed

Work backwards from a set goal

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Agenda

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Lessons Learned | **Q & A**

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Thank You

- Theresa Regan
- Professor Gibson
- Evan Mamas
- 15.568 class
- Steven Winig
- Participating Universities & Vendors

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Q & A

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