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iSPOTS. How Wireless Technology is Changing Life on the MIT Campus

keywords wireless Internet, Wi-Fi, 80211, WLAN, Geographic Information Systems, urban dynamics, Massachusetts Institute of Technology

iSPOTS

How Wireless Technology is Changing Life on the MIT Campus

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Abstract

The aim of this paper is to present research in progress within the iSPOTS project, which monitors and collects data of WiFi usage on the Massachusetts Institute of Technology campus. Instead of simply mapping WiFi availability, as in increasingly common wireless-sniffing exercises, the project is one of the first to use and analyze LOG files from the Institute's Internet service provider. The aim is to create a better understanding of the daily working/living patterns of the academic community, which are rapidly changing due to the emergence of WiFi itself. The MIT wireless network of over 2300 access points is one of the largest of its kind and offers a privileged environment for this research, providing a test bed for entire cities.

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Introduction

Recent years have witnessed a great increase in 802.11 wireless local-area networks (WLAN) in cities around the world. Wireless Internet, which only a few years ago began as a tool in corporate offices, has come a long way forward, now covering entire urban blocks with uninterrupted networks. According to www.jiwire.com there are over 21,000 public 'hotspots' already available in the U.S. today. In Europe, London has the largest concentration of public and private wireless networks. While several forward-looking cities like San Jose CA and Philadelphia PA have launched projects to provide free wireless Internet for all citizens, WiFi is becoming a common urban service like any other, electricity or land-phones for example. The popularity of WiFi is further enhanced by its capacity to handle multiple types of communication over the same protocol: text, voice, images and video can all be streamed over WLAN networks instantaneously and globally. As we anticipate that complete WiFi coverage in many cities will come about soon, there is an urgent need to explore the spatial impact of this powerful new communication network, from the point of view of the urban planner or architect.

A number of studies exist which describe Wi-Fi signal availability and intensity. A culture of so-called Wi-Fi 'sniffing' has developed in recent years, which is often related to the mapping of public wireless networks on webpages (see for instance the global hotspot finder at www.jiwire.com) and warchalking: the drawing of symbols in public places to advertise an open Wi-Fi wireless network (see for instance Boutin¹, or the definition of warchalking on <http://en.wikipedia.org>). Several studies have used WLAN LOG information to analyse network traffic from a computer science or network engineering point of view. However, there have been very few attempts to analyse spatial patterns of traffic on large Wi-Fi networks based on the analysis of LOG information from Internet service providers (ISPs). The latter method distinctly differs from precedents of WiFi sniffing, as it can not only represent the existing networks on a map, but also shows the usage patterns of each network spatially and in real-time. Compared to WiFi sniffing, the analyses of WLAN traffic through LOG files can provide a much deeper insight into the geographic and temporal patterns of WiFi users in the city, as explained below. Such studies have been rare or nonexistent so far, possibly due to the difficulties of accessing raw data and combining it with geographic databases. In the iSPOTS project, carried out at MIT SENSEable City Laboratory (a new research initiative between the department of Urban Studies and Planning and the Media Lab) we have had the opportunity to work on the MIT campus in Cambridge, MA, as a case study, which is a unique setting due to the extent of the wireless network in its built environment.

We are asking ourselves whether the widespread use of wireless networks is also causing changes in the built environment or in the way the built environment is used. As WLANs allow a total location freedom for Internet-based workers, new daily live/work patterns are emerging for many. At the MIT campus around 16,000 students, faculty and staff attend the Institute every day. In the year 2000, when laptops were still expensive and wireless Internet new, MIT decided to undertake a vast operation of building a campus-wide wireless network. Today, this 168 acre campus has over 2300 wireless access points (APs), providing full coverage of WiFi in nearly all buildings on campus. It is expected to achieve a full 100% coverage by October 31, 2005. While full campus coverage has been achieved before on other campuses, Dartmouth College for instance, the number of access points at MIT is nearly 5 times greater (see for instance Kotz and Essein²). Over half (55%) of MIT students have a laptop computer with a wireless card, allowing them to freely use the entire network of Aps freely, and the proportion is increasing every semester. As a result, we have begun empirically to notice changes in the ways that people use the campus facilities for living and working. The intensive evening hours at multiple libraries and the infamous 'Athena clusters' are giving way to vast wireless traffic at the student dormitories. Similarly, many laboratories, which until a couple of years ago were bustling with people, now have students scattered in nearby cafeterias and lounge-spaces equipped with WiFi. As part of the iSPOT project, we are creating a digital infrastructure for quantifying such changes.

¹ Boutin P., 2002, "WiFi users: chalk this way", *Wired*, July 3

² Kotz D., Essein K., 2005, "Analysis of a campus-wide wireless network", *Wireless Networks*, 11:115–133

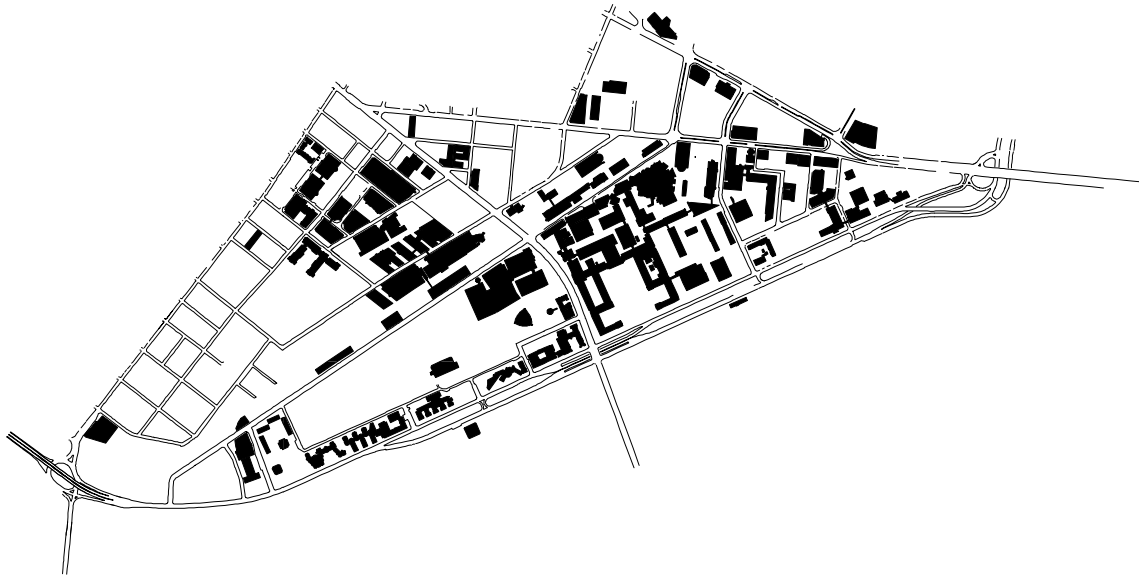


Figure 1 Diagrammatic map of the MIT campus.

Our goal is to use a Geographical Information System (GIS) and wireless LOG files, obtained from the MIT Information Systems & Technology (IS&T) Department, to construct an on-line map server, which will allow the MIT community to observe the real-time WiFi activity on a webpage. Simultaneously, we will collect the generated maps and traffic data into a database, which will allow comprehensive analyses to be carried out at a later date, exploring behavioral trends in a longer time frame. Thanks to the diffusion of GIS data about the campus and the relative precision of WLAN logs, the analysis can range from an individual user's point of view to a multilayered analysis of the campus as a whole. Eventually, we hope that the web page can accumulate different layers of real-time information about the campus, including data about WiFi activity, the amount of bytes transferred, a spatial reference to the real-time events calendar, parking availability, etc. which could evolve into a standardized tool for understanding the natural complexity of the campus on a real-time website.

The second phase of the project will enable students to voluntarily make their personal log files and movement patterns of their MAC addresses accessible to others on the web. This would allow friends, who have reciprocally agreed to share their movement patterns, to track their device locations on the campus map. In order to participate and expose one's MAC or I.P. location on the webpage, participants will register an agreement on-line and use an opt-in system to set up an identification profile that will characterize them to other participants. Only participating students can track each other's locations on the webpage. The profile identification will be similar to many existing internet communities like MSN Messenger, Skype, AOL Messenger and others. Besides providing a new tool of interaction, this project will also allow us to perform a social analysis of the campus use based on individual profile tracking. By understanding how a given type of people use the campus spatially, we can for the first time understand the urban environment as set of quantifiable processes of inter-relationships in real-time. Using the MIT campus as a test environment we will explore emerging privacy issues before they appear in larger urban contexts. The experiment at MIT is furthermore facilitated by the fact that

almost all of the WLANs are centrally managed by IS&T, which saves lengthy negotiations with numerous service providers in order to acquire the data.

The MIT campus environment:

Our test environment – the MIT campus – is such that it can be regarded as a miniature version of an urban neighborhood. 10,320 students and 9,414 total employees attend the campus, which consists of more than 190 buildings that cover a considerable portion of the city of Cambridge, MA.

In the WLAN data that has been made available to us so far, we have observed wireless traffic in 104 buildings containing 1614 distinct access points. Unfortunately we lack information about some recently constructed buildings in our GIS database, which is one of the reasons, why we cannot track all 2300 existing antennae, but we hope to be able to include that information very soon. In total, we can monitor 1398 distinct rooms on campus, some of which have several APs in them (in that case we sum their total activity into a single value and use only one antenna on the map to sum the other antennae in that room). Some rooms have changed names in the course of years and we were unable to find an exact match between them and their corresponding AP location. In this case we mapped the APs to the closest rooms nearby and again summed the traffic amounts together into one antenna. The latter two modifications should, however, not have a significant impact on the overall analyses of WiFi traffic, because we have not discarded any data available, but rather changed their representation from several overlapping points with different values into a unique point with summed values.

Of the 1614 antenna that we are currently measuring, 124 are located in service buildings, 326 in residential buildings and 948 in academic buildings. The majority (60%) of these access points are located on the first three floors of buildings. Figure 2 illustrates the average number of APs located at each level of the campus. As the average number of floor levels at MIT is 3.2, it can be concluded from Figure 2 that wireless access points are reasonably distributed in a uniform way on all floors of the campus. Among the 1398 rooms containing APs, 91 different space use types can be distinguished, varying between different departments, organizations, residences, etc.

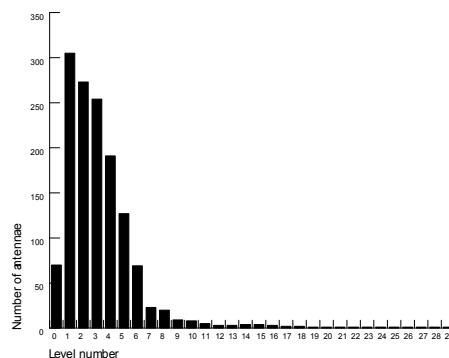


Figure 2 Number of antennae per floor level in the set measured

The MIT wireless network infrastructure currently uses the 802.11 protocol exclusively. There are other wireless networks on campus maintained independently within labs, departments, and schools through which one is able to connect to the MIT net; however, IS&T does not provide support to the MIT community for these networks (see for instance web.mit.edu/ist). The two large independent networks, on which we still lack data, belong to the MIT Media Laboratory and the Department of Computer Sciences and Artificial Intelligence. We plan to access their WLAN data in the near future and include the two buildings in the overall maps. All other antennae run by IS&T share the same 'MIT' network name, which permits wireless cards in people's devices to roam seamlessly from one access point to another.

The Information Systems & Technology networks division is currently using three different types of wireless access point units in the campus-wide wireless network: Avaya Ap-3, Proxim AP3000 and Enterasys AP-3000, with a signal radius from 130 to 350 feet indoors. Figure 4 shows the relative positions of the analyzed antennae on campus and Figure 5 illustrates the 'ideal signal availability' in the given set of APs without taking into account physical barriers, such as walls and floor plates, which in reality decrease signal propagation. A realistic picture of current availability indoors can only be formed by conducting real-life 'WiFi sniffing' throughout all the WLANs on the campus. As part of the iSPOTS project, WiFi 'sniffing' measurements will be carried out in the outdoor areas of the campus during summer 2005.

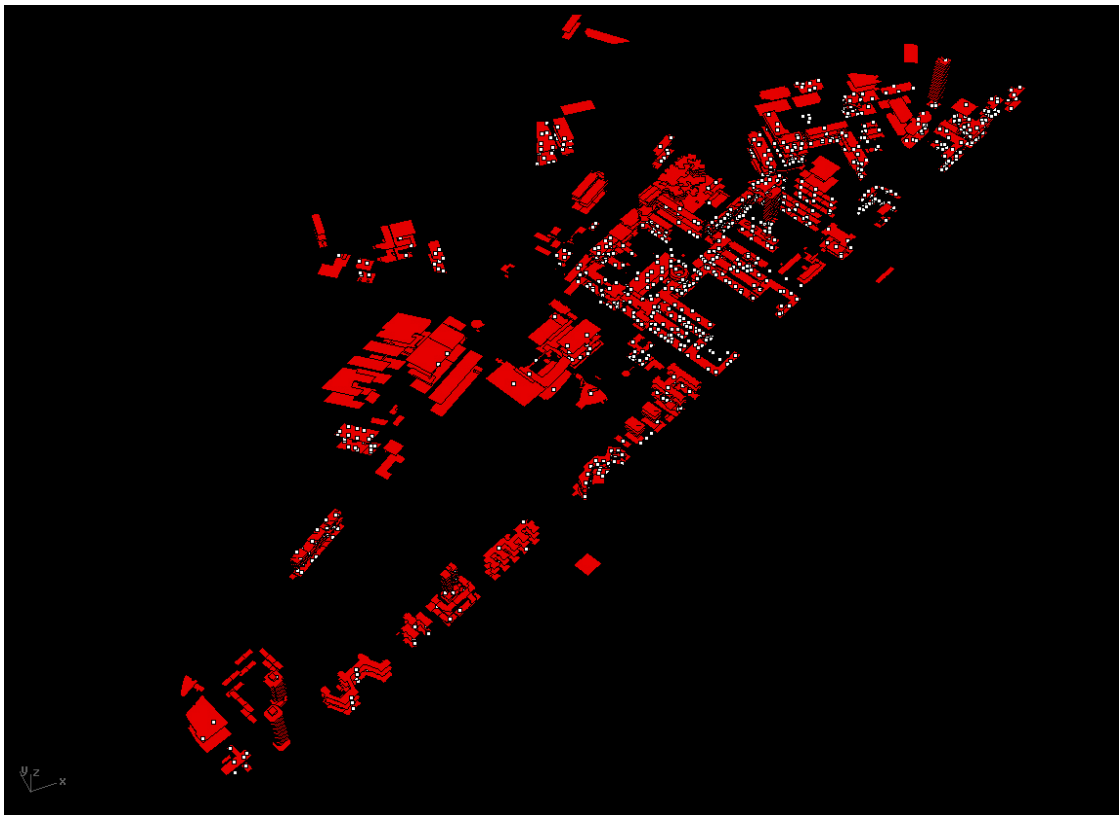


Figure 3 The preliminary set of 1614 access points at their locations on the MIT campus

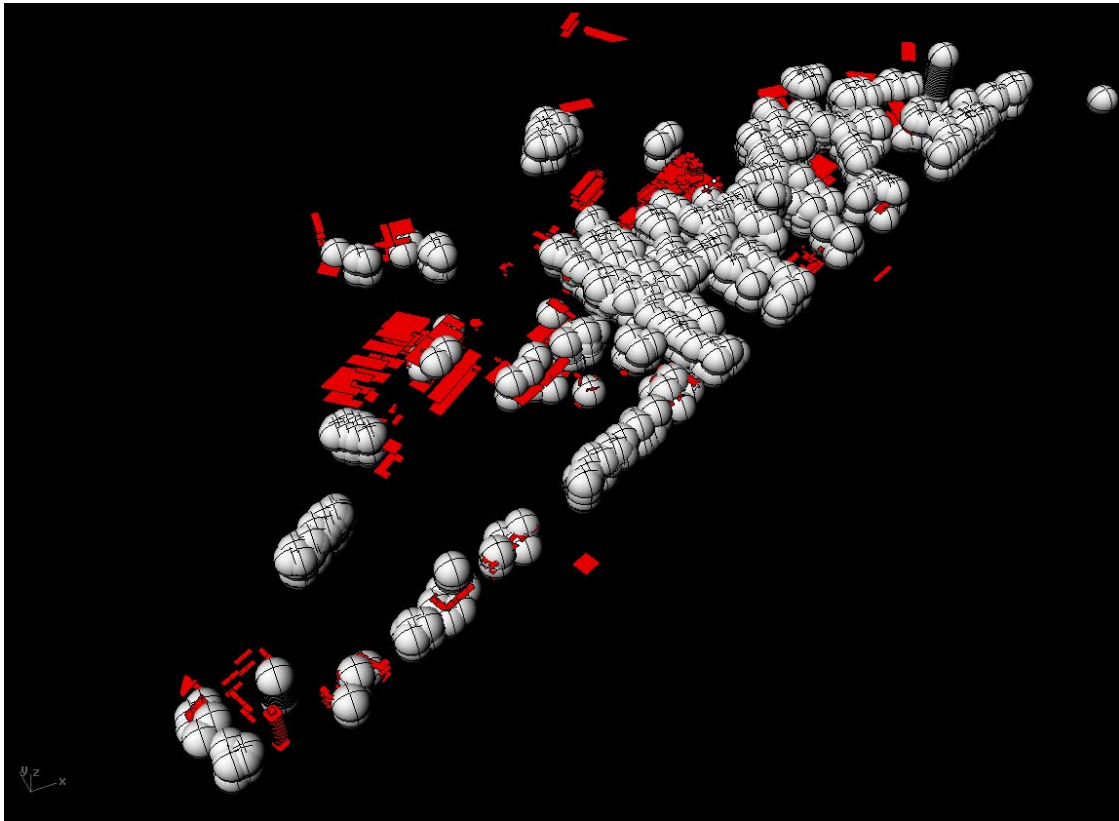


Figure 4 The 'ideal availability' of the MIT WLAN on campus

Preliminary data analysis and interpretation

The following data analysis is based on two sample measurements we have received from IS&T so far. The first measurement was carried out during the night of Sunday, June 19th, from about midnight until 4am. The second measurement was taken during 48 hours on Tuesday and Wednesday, from about 1pm June 21st to 1pm on June 23rd 2005. We are currently in the process of setting up the real-time stream of WLAN traffic data from IS&T to our on-line database. We acknowledge the fact that the two measurements were not taken during regular academic semesters. However, as the campus remains quite lively throughout the summer and several summer programs and research groups continue working full-time, we still see interesting WiFi usage patterns in these measurements.



Figure 5: Total number of WLAN users from midnight to 4am, June 19, 2005

During the first measurement the importance of residential WiFi usage clearly stood out. In the course of the night hours, from midnight to 4am, 186 WiFi antennae were used. Not surprisingly, 91% of WiFi users originated from dormitory buildings across the campus. 8% of the users were in academic buildings and 1% in service buildings. It is clear that residential computing plays an important role on campus and dormitory rooms are becoming widely used for work and leisure over the Internet.

If 10 years ago students and faculty could only access the Internet from desktop computers and Athena clusters³, now there are virtually no imposed spatial constraints. As the campus is approaching 100% coverage, new criteria for choosing a location for work are appearing. Instead of needing to locate the nearest Athena station, the question seems to be 'if I can work anywhere, where do I want to work?' Hence the majority of locations that people choose for work over the Internet are probably determined by factors other than the availability of the network. Choosing a location to open one's laptop can then become more related to factors like comfort, convenience, spatial qualities, presence of other people, presence of food etc. Naturally dormitory WLAN's, where one feels comfortably at home, rank among the highest. According to graduate resident tutors at the new Simmons Hall dormitory, designed by Steven Hall, most undergraduates spend long evening hours in comfortable lounge spaces, where they can socialize with other students, while working on their laptops. Simultaneous physical communication and Internet communication through e-mails, instant messengers, chat forums and video-conferences have become commonplace for most students. The notorious amount of problem sets and homework demanded from MIT students is often facilitated by consulting and checking answers with fellow students through Instant Messengers over the Internet and many homework assignments can be turned in on-line.

The second sample measurement was carried out between 1pm Tuesday June 21st and 1pm on Thursday, June 23rd, 2005. In total 1036 rooms with WiFi antennae showed activity during the 48-hour cycle. These rooms contain a total of 1182 distinct WiFi access points geographically distributed over the entire campus. The absence of activity in the remaining 432 can be explained by the more relaxed summer

³ Public Computer Labs, using MIT's own Athena Operation System.

schedule, compared to the regular academic period, with many students having left the campus. Nevertheless, 73% of all antennae showed activity during those two days, which is a relatively high value. In Figure 6, one can see a breakdown of the number of users in each building type at every hour.

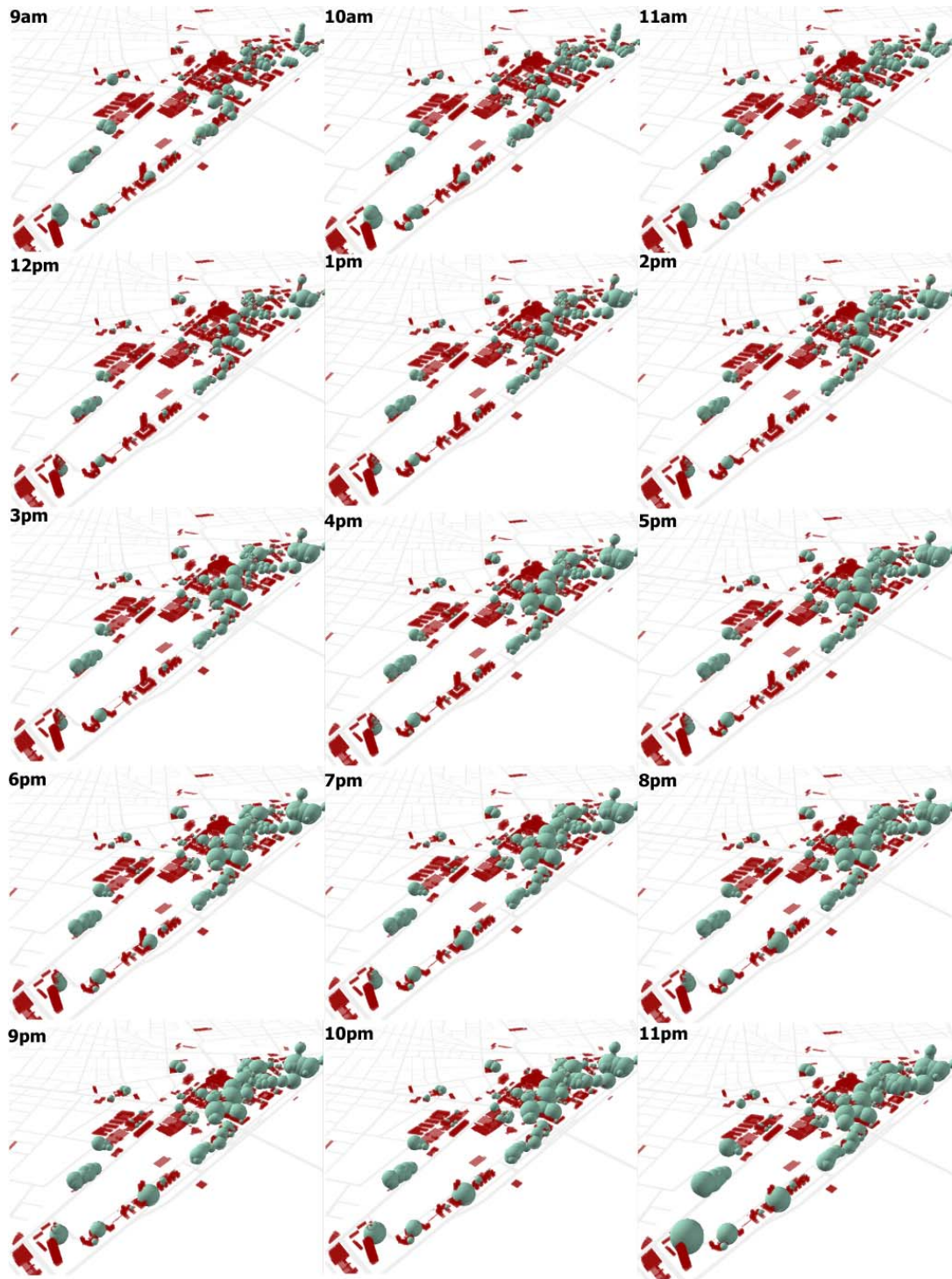


Figure 6 Number of WiFi users from 9AM to 11PM on 6/22/2005

Several interesting spatial trends can be distinguished in these images. First, one notices how dormitories again contain the greatest number of users during morning hours and late evening hours. After about 10am, the bulk of WiFi usage shifts to academic buildings in the central areas of the campus. Between 12pm to 1pm, the number of WiFi users in the academic buildings decreases as people move away to lunch and so on. During lunch time, one can observe many Wireless workers around cafeterias. When general lectures start in large auditoria, there are always people waiting behind the door, checking their e-mails or browsing the World Wide Web on their laptops. It is naturally convenient to use the spare minutes before an appointment or class to quickly update e-mails without needing to go to a special location, especially as e-mails are becoming increasingly common substitutes for phone calls and tools for scheduling meetings. Similarly, we have empirically observed that WiFi usage is very popular during lectures, which enables students to find additional information about the course topic quickly (or not...) on-line. Though one can quite frequently spot students working on laptops at seemingly random locations like staircases, window-sills, lobby floors or outdoors on the lawn, the new criteria for finding a place are often determined by other scheduled events, which require a fixed location. Hence the physical setting for wireless communication is often determined by other location-based events. When other appointments do not determine the location, then obviously comfortable and familiar spaces seem to be popular. However, the pattern surprisingly shows that the bulk of the activity moves back to dormitories only around 11PM in the evening, which reflects the awkward working schedules in the academic buildings at MIT.

From the above analysis, it is possible to better understand new behaviors and to substantiate with numerical evidence changes that have been simply anecdotal. The Planning Committee of MIT, for instance, could take notice of the emerging spatial changes of live/work environments, and redirect their efforts to support the new trends. A good example is the recently completed 'Steam café' on the fourth floor of the architecture building, which underwent a complete remodeling during January 2005 (see <http://steamcafe.mit.edu/>). The design and execution was left in the hands of students of architecture, who not only used the opportunity to redesign the cafe, but also re-conceptualize the cafe's image and menu. Before its conversion, the Steam Café was a place for few, used only during a very limited time of the day – the lunch break. Now, thanks to the overlapping of different activities, the presence of WiFi, and a new concept in design (not to mention better food), it is active 'round the clock'. Sales have increased three-fold and the Space Committee is beginning to recognize that by extending similar concepts to the whole campus a more optimized environment could emerge.

With the information available on the GIS database, several different types of queries can be made about WiFi users. For example, a query can show how many WiFi users are currently in a specific building. It can also find out how many users are around a given floor of that building or even around a precise room in the building. For example, based on different queries on the data, we can see that at 3.05 pm on Wednesday 21st June, 87.0 % of all WiFi users were located in residential buildings, 11.1 % in academic buildings and 1.0 % in service buildings all over the campus. We can then explore further and find out that in a given building, W1 - the Ashdown dormitory for example, there were 48 people using WiFi. We can even go further and explore a specific room in the Ashdown dormitory, room W1-100C, and find out that

there were 8 WiFi users near that room. If that room happened to be a dining hall, we might guess that there are more than 8 people in that space presently. In fact, there are many other ways that similar queries can be made analyzing various spatial occupancies in real-time or a posteriori. It is not hard to imagine how extensive the implications of such data are.



Figure 7 WLAN use by building type at 3.05.46pm 6/22/2005

Let's look at a few possible scenarios. When the MIT Space Committee engages in negotiations with a new evening snack cafeteria to open on campus, they might want to take a look at the iSPOTS archive. By running a couple of simple queries, they could find out that the best location for the new business would be in between the New House and the MacGregor dormitories, because that is where most people spend their afternoon and evening according to WiFi usage. By looking at the WLAN usage time patterns, they might even find out that the best opening hours for the cafeteria would be from 7pm to 11pm, as that is when most wireless usage occurs in the vicinity.

Looking at it from another perspective, if MIT gets a security alert, say a fire alarm or a toxic gas leak in a large building, then the security officers could easily check the current status of WiFi usage in that building and take an intelligent guess about how many people might be inside the building. Even though not everyone uses WiFi and as most people only use it for a limited period during the day, corrections could be applied to the data by using statistics that have been observed over longer periods of time. Hence, by knowing that 55% of people in a given building have laptops with wireless cards, and an average 25% of them use WiFi during the given time of the day, the total predicted number of people in the building can easily be determined with fair probability.

Most certainly, the real-time on-line database could become a useful and fun information tool for MIT students on a daily basis. For instance, an architecture student, who is working at home, might be wondering if it would be better to work in his/her studio at school, because other friends might be working there too. In this case he/she could go on-line to the iSPOTS map and run a query for the given studio space and see how many people were currently using wireless internet in that space. If the network turns out to be busy, then he/she might want to move over and join the others.

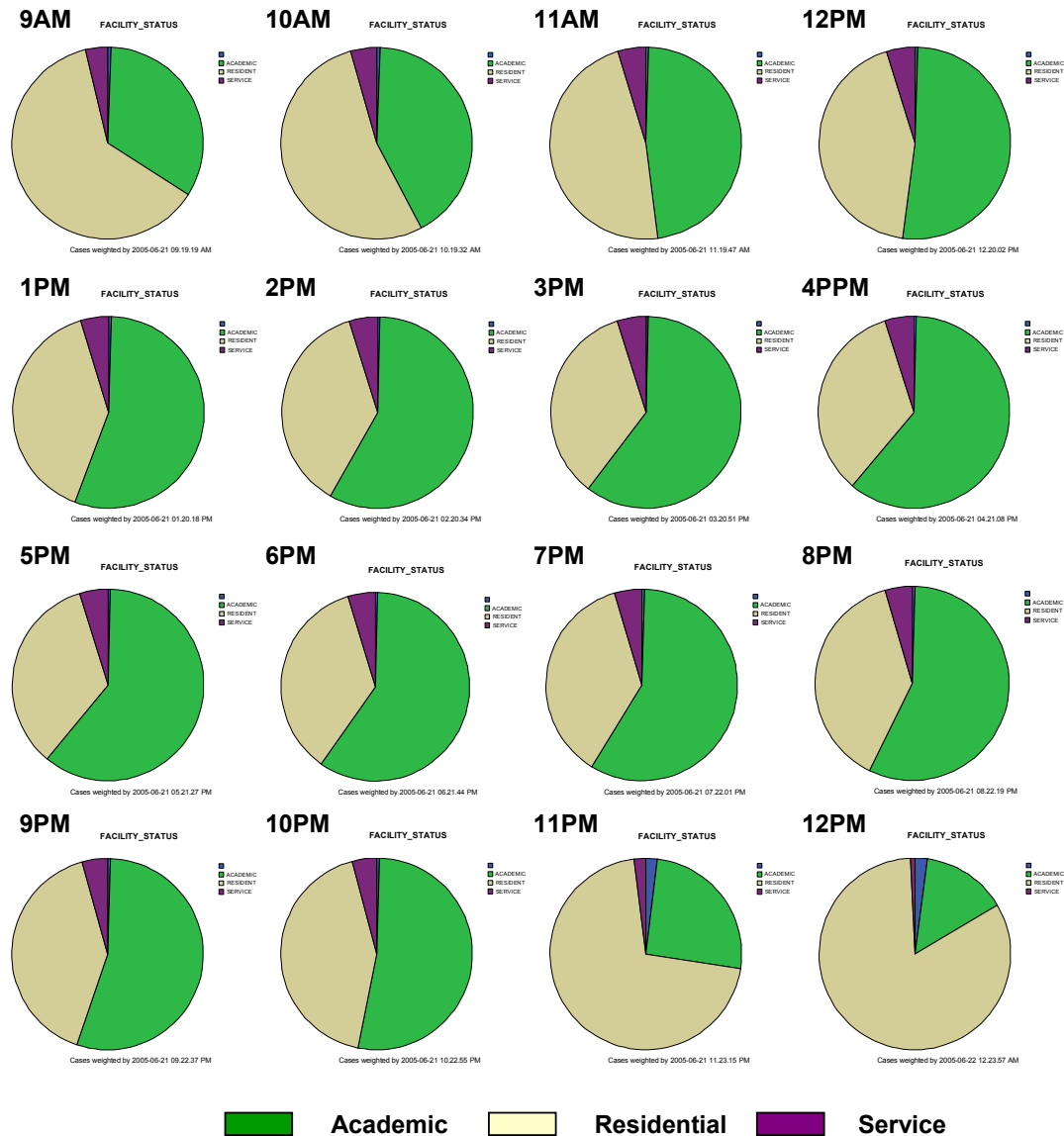


Figure 8 Number of WiFi users by building type from 9am to midnight on 6/22/2005

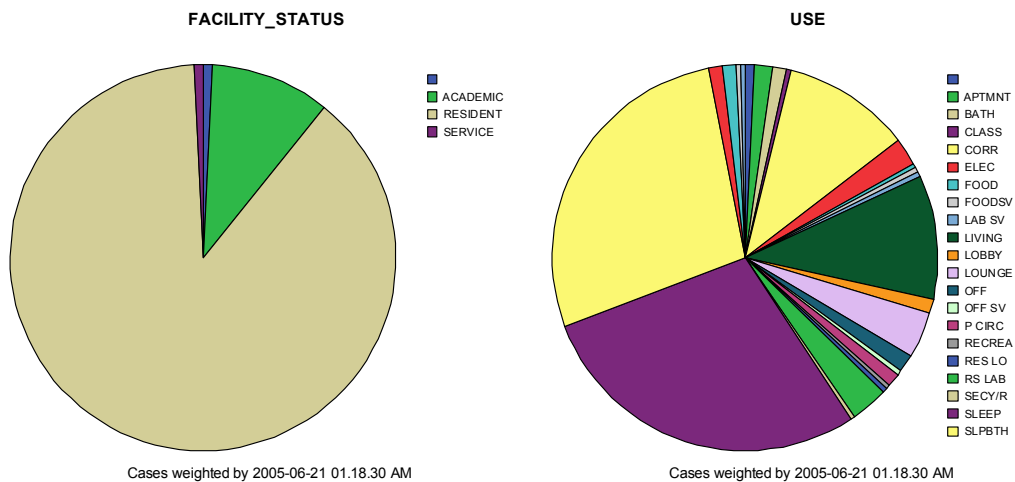


Figure 9 Number of WiFi users by building type and by room type at 01.18.30am, 06/21/2005

There are many other examples of possible uses for the real-time analysis capacities of the iSPOTS project. A similar situation might in the near future apply for neighborhoods or even cities. Multiply the iSPOTS concept to an entire city, and urban processes can be understood in real-time from the broadest flux in the city to the highly specific queries about single buildings. As GIS databases are expanding all over the world, greater opportunities are created for urban analysis. In addition, GIS data exchange over the Internet also enables information to be shared from multiple other databases in the city or around the world. In short, the ever-increasing gigabytes of urban data that are recorded every day with painstaking precision can now find many uses in an on-line environment, which enables either all or selected users to find vast amounts of accurate real-time information about the city around them.

The implications of a real-time mapping exercise are not only creating a new tool for mapping, but changing the perception of the campus or the city as a whole (Ratti and Berry⁴). We acknowledge that the goals and representations of such mapping are clearly different from traditional urban mapping, and we do not want to contest the value of such maps. Rather, we hope to enrich the palette of urban mapping by a new tool, which would help us visualize the city as a set of processes and broaden our perspective on the complex interrelationships of its elements. If the image of a map changes from static to dynamic and acquires different layers of real-time information, then the map is no longer a fixed reference, representing the durable objects and spaces of the city. A real-time map becomes as lively as the urban environment it represents, and is literally shaped by the users of the environment. In a real-time map, not only urban elements, but also processes are spatially represented. A public, on-line distribution of the map allows large numbers of people to monitor the urban flux simultaneously, thus raising the public's awareness of the dynamism of the contemporary city through simple cartographic evidence.

⁴ Ratti C., Berry D., 2005, "Sense of the City: Wireless and the Emergence of Real-Time Urban Systems" in Chatelet V. (editor), *Interactive Cities*, Editions XYZ, Paris.

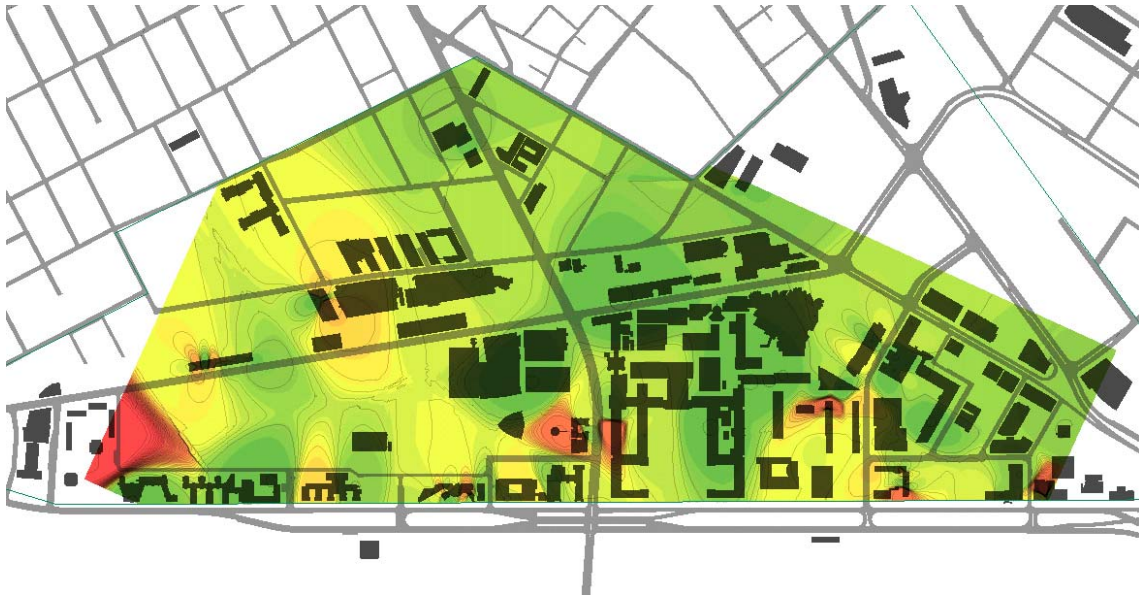


Figure 10 Interpolated representation of WLAN usage at a given time

Conclusions

This paper reviews ongoing research on the iSPOTS project at the MIT campus in Cambridge, MA. The aim of the project is to analyse usage of the wireless Internet network in order to describe occupancy patterns and movements. Interim results seem to suggest that this type of analysis is very powerful and could have many applications – whose relevance could extend to entire cities in future years when they become wireless.

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