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MIT Enernet: Correlating WiFi Activity to Human Occupancy

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SUMMARY
Most commercial buildings may reduce their energy consumption by 20% to 30% through continuous commissioning practices and energy efficiency strategies. The design and implementation of energy efficiency strategies can be promoted by pervasive infrastructures aimed at sensing the functioning of buildings and delivering real time comprehensive analyses to building operators. In this paper, we present the MIT Enernet information system, which supports the continuous monitoring of energy consumption, HVAC (heating, ventilation, and air conditioning) levels, and human occupancy over the entire MIT campus. We present here a component of the MIT Enernet that uses campus wide WiFi activity to dynamically approximate human occupancy in buildings in real time. We also discuss how this innovation and our platform can be successfully used to identify, assess, and communicate building energy efficiency opportunities, and improve the accuracy of building energy models and consumption forecasting techniques.

KEYWORDS
Energy Efficiency, Human Occupancy, Information Technology

INTRODUCTION
Commercial buildings account for nearly 20% of the US national energy consumption (EIA, 2008). Large commercial buildings contribute roughly 150 million tonnes of greenhouse gasses (GHG) per year, or 12% of our entire national contribution to annual global GHG emissions. Exhaustive reports from (TIAX, 2005) and (ACEEE 1998-2006) conclude that commercial buildings may reduce their energy consumption by 20% to 30% through continuous commissioning practices and the implementation of few energy efficiency strategies. In large commercial buildings, the return of investment for most energy efficiency strategies is estimated to be less than 2 years.

It is commonly contended that the design and implementation of energy efficiency strategies will be significantly eased and promoted by the deployment of pervasive infrastructures aimed at sensing the functioning of buildings and delivering comprehensive historical analyses and real time notifications to building operators and policy makers. The lack of pre-existing pervasive infrastructures capable of providing the necessary sensing capabilities has made it impossible to conduct effective experiments on large built areas, at reasonable cost, thus limiting the research in the field and limiting the development of tools to identify, plan, execute, and verify building improvement. Through this project, we propose the first experiment of this kind on a large campus space, using a pre-existing data collection infrastructure, aimed at identifying mismatches and planning improvements in energy allocation and efficiency.

In light of the above, we adopted the MIT campus as a testbed to develop the MIT Enernet information system, which supports the continuous monitoring, inference, and visualization of
energy consumption, HVAC (heating, ventilation, and air conditioning) levels, and human occupancy over the entire MIT campus. In this current context we present a component of the MIT Enernet for approximating real-time human occupancy from WiFi activity data collected on the campus wireless infrastructure. We also discuss how this innovation and our platform can be successfully used to identify, assess, and effectively communicate building energy efficiency opportunities, and improve the accuracy of building energy models and consumption forecasting techniques.

RELATED WORKS
The MIT Enernet evolved as the marriage of two pre-existing projects at MIT: the Intelligent Infrastructure for Energy Efficiency (I2E) project, and the iSPOTS project.

The I2E project (Gershenfeld et al, 2004), is a collaborative project between the MIT Center for Bits and Atoms, Building Technology, and Mechanical Engineering, dedicated to designing, developing, and deploying a scalable platform for achieving building energy efficiency. The technology base for I2E ranges from networking technology for data collection, statistical learning for data inference, and GIS for data visualization. I2E has already proved promising results in several buildings at MIT and beyond, identifying a variety of low-cost HVAC and lighting opportunities for reducing annual building energy consumption by 20% or more.

The iSPOTS project (Sevtsuk et al, 2008), developed by the SENSEable City Laboratory in collaboration with MIT Information Services and Technology, aimed at describing changes in living and working at MIT by mapping the dynamics of the WiFi network in real-time. The project revealed the complex and dispersed individual movement patterns that make up the daily life of the campus and helped to answer many questions like: Which physical spaces are preferred for work in the MIT community? How could future physical planning of the campus suit the community's changing needs?

ANALYSIS OF WIFI ACTIVITY
The MIT campus represents a unique opportunity to design, develop, deploy, and test a scalable system for identifying campus-wide energy efficiency opportunities, as for the first time we are able to collect and analyze data related to energy consumption, to HVAC levels, and to human occupancy of buildings at the scale of the entire MIT campus and at the fine resolution of a single room. This is made possible on one side by a unique network of more than 100,000 sensors that monitor the functioning of the MIT building automation system and measure the HVAC levels of most of the rooms over the campus, and on the other side by the ubiquitous Wi-Fi network of 5,000 hotspots, almost one per each room and hallway over the campus, that provide Internet access to the entire MIT community and allow to estimate human occupancy.

Our preliminary analysis of WiFi activity showed that the data can be used as proxy of human occupancy. (Sevtsuk et al, 2008) Figure 1 shows an example of campus-wide WiFi activity during an average day. The activity increases in the main and east campus between 8 and 10 am as the MIT community begin to populate academic buildings, and likewise it decreases after 5 pm. Zooming at the scale of the building, Figure 2 shows an example of three days of activity in building 37, an academic building that houses undergraduate and graduate teaching and research laboratories, classrooms, and offices. The WiFi activity matches the anticipated occupancy schedule of a 9 am to 8 pm work day, with a peak in activity between 11 am and 2 pm. Network activity is noticeably small in the off-work hours of 8 pm to 9 am.
DISCUSSION

The data implies that WiFi activity may be used as a surrogate to at least the daily profile of human occupancy within buildings, and in some cases perhaps even a scaled measurement of occupancy itself. WiFi activity, however, exhibits certain biases in actual user activity toward spaces where laptop owners are more likely to be present, and where people with laptops are more likely to connect to the network with their laptops. For instance, classes that restrict laptop usage and paper-based exams are just a few examples of situations where our system would not detect the presence of many people at work. A second source of bias could be the uneven distribution of laptop ownership; graduate students are currently the segment in the
MIT community with the highest proportion of laptop ownership, but this is likely to vary among different departments as well. In general, we also realize that laptops are often left connected to wireless Internet when not in use and the iSPOTS system directly measures wireless devices and not people. Despite these biases, a simple big-picture metric of human occupancy in buildings across campus may still facilitate significant energy savings.

A large network of dedicated occupancy sensors may provide the most accurate description of dynamic building occupancy to facilitate occupancy-driven efficiency measures; however the cost of implementing this infrastructure is prohibitively high. On the other hand, occupancy based lighting and ventilation strategies rank near the top of any list of commercial building energy efficiency strategies; this is due to the tremendous energy waste associated with extraneous lighting and ventilation when a space is empty of people. The cost of collecting already existing network activity data is inherently low, and it appears that this data may provide a sufficiently good approximation of dynamic building occupancy to support campus-wide occupancy-based energy efficiency strategies.

CONCLUSIONS
Our initial results with network activity data show promise for a low-cost and easily implemented approach to occupancy based lighting and ventilation strategies across MIT’s campus. Further research will drive out the uncertainty of this occupancy approximation over the course of a full year, and test its applicability as an input for occupancy-based HVAC and lighting controls. We have also introduced the MIT Enernet as a platform that is dedicated to combining diverse data sets towards the singular goal of generating actionable energy efficiency information. By combining here-to-for disparate network and energy data, we hope to discover facile methods for implementing successful energy efficiency strategies, create processes for updating building energy models that cannot account for occupancy effects, and improve the performance of energy consumption forecasting techniques that have also suffered from a lack of dynamic occupancy data.

In the short term, we hope to create the MIT Enernet as a platform that will enable MIT Facilities to develop a complete and dynamic energy efficiency strategy for the campus. Over the long term, we expect the platform to gain widespread usage in other university campuses, commercial and tertiary buildings, and residential complexes both for applied research and the development of energy efficiency strategies.

REFERENCES