# Building a wireless network infrastructure under budget constraints

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**Abstract:** This paper examines wireless networking and provides a case study of a wireless network infrastructure's development at an urban university of 11,000 students. The University of Houston – Downtown (UHD) incorporated wireless technology to help users stay connected to the school's network for access to curricula-related products at any time and from any location.

**Keywords:** wireless network; infrastructure; case study; mobile technology; urban university; curricula-related products.

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## 1 Introduction

Wired networks trace their roots to the success of the Ethernet project at Xerox's Palo Alto Research Center (PARC) in the early 1970s (Metcalfe and Boggs, 1976). Such wired networks were possible because standard protocols became available, they were able to operate at fairly high speeds using inexpensive connection hardware, and Local Area Networks (LANs) brought digital networking to nearly every computer (Lough *et al.*, 1997). It was not until after these wired networks became widely used in business operations and users depended on those networks that advances in wireless technologies resulted in further implementations. Furthermore, as wireless business networking continues to increase, more companies realise that a wireless environment impacts the three critical success factors for mobile-commerce – speed, billing, and security (Massoud and Gupta, 2003) – in such a way that can help them reduce their company's Total Networking Cost (TNC). These TNC reductions not only include actual cost savings derived from companies reducing their need for additional wired network installations, but can include intangible benefits as well. Examples include:

- increased flexibility in office design and equipment layout
- addition of new generations of portable devices such as laptops and Personal Digital Assistants (PDAs)
- user freedom from being tied to desktops and offices.

Additionally, companies may impose restrictions on wireless network capabilities that improve both business efficiency and security.

Continuous training is a necessity in today's business environment, and higher education is one of the resources for such training. Thus, companies often encourage workers to take classes or even seek additional degrees and subsidise them. Of course, such continuing education is more feasible in an urban university setting because, responding to demand, universities create extended campuses, branches or at least some sort of learning centres at strategic locations in large population centres around the country.

Studies have shown that acceptance of wireless Internet mobile technology is related to six major factors: a wireless trust environment, a perceived usefulness, a perceived ease of use, facilitating conditions, systems complexity, and social influences (Lu *et al.*, 2003). Therefore, a well established wireless environment could provide the foundation for delivering content in a mobile education environment as well.

Higher education, by the very nature of its business, can benefit from the inherent flexibility of wireless networks. Classrooms must be reconfigured to meet the demand for electronic classrooms. Universities, like more traditional companies, can reduce TNC and derive significant benefits from incorporating a wireless networking environment that offers portability and flexible integration if such an environment incorporates the variety of hardware components and software solutions usually found in a higher education environment. The portability and flexibility available with wireless networks can help reduce barriers to learning – be they physical or conceptual – by reducing the networking frustrations that may prevent students from learning.

In the last five years, many universities have implemented wireless networks on their campuses. A 2003 national survey known as the Campus Computing Project found that more than three-quarters of the 559 institutions (or 430) participating in the survey reported having their own wireless networks (Olsen, 2003). This paper examines wireless networking and describes some of the challenges and solutions encountered with the implementation of wireless networking at The University of Houston - Downtown. Since typical urban universities are built with similar constraints as many corporate facilities, lessons learned can be extended to the corporate environment as well.

## 2 Wireless networking in education

During the spring 1999 academic semester, staff at the Mildred F. Sawyer Library at Suffolk University found their computing resources constrained. Since space was limited, the library staff investigated using a wireless network of laptop computers. Students checked out laptop computers that could be used anywhere inside the library for a period of two hours. Phase I of the programme included 12 laptops and proved very popular with the students, although Internet connections were only available if plugged into the wired network. Phases II through IV of the laptop programme included wireless access to the Internet and student freedom of movement within the library (Dugan, 2001).

Drexel University claims that in June 2000, it became the first university to establish a fully wireless campus (Carlson, 2000). The university president hoped that the wireless system would be an attractive convenience for students and faculty members who could walk from the library to class and never even have to stop 'bidding on eBay'. The wireless network also has the potential to make laptops rise to the status of cellphones on campus, according to John Bielec, Vice President of Information Resources and Technology at Drexel (Carlson, 2000).

Carnegie Mellon University in Pittsburgh, Tulane University in New Orleans, and many others are reported to have implemented wireless networks via wireless LANs, or WLANs, in 2001 (Smith, 2001). The following year, Seton Hall claimed to be not only the 'most wired' but also the most 'wireless' campus in academia. The 56-acre campus was blanketed by a wireless LAN as well as a private cellular network (Higgins, 2002). The wireless connectivity explosion is not limited within the USA. Two examples show universal growth of the wireless concept. Anna University in Chennai, India, installed wireless equipment in 2001 (Anonymous, 2001) and the University of Toronto followed suit shortly thereafter (Fruitman, 1991).

Bill Drew of SUNY Morrisville College described a student working effortlessly on a computer while strolling through his local university's library. Looking for books and magazines, the student logs onto the network, conducts searches, emails information to himself, prints locally and chats with others online while connected to a wireless network that 'blankets' the entire library (Drew, 2003). Universities throughout the country are offering students wireless connections like this at least within their libraries. Drew has begun by creating a partial list of universities that have informed him of such connections. Currently, the online listing shows 19 such institutions in Texas (Drew, 2004). One of the listings on his website is a prime example: students at the University of North Texas can check the school's website to verify wireless availability at the school's library and surrounding buildings.[1] Another of Drew's listings contains an explanation of the library loan system available for wireless portables at the University of Texas Pan American Library.[2]

These successes may point out the benefit of having a wireless environment but they also highlight the problems some universities face. Few universities around the country can afford allocating resources to build such infrastructures without affecting other instructional needs. It is much more efficient to design wireless systems when buildings are built with this technology in mind. Therefore, the cost of creating a wireless infrastructure in older schools, although less than pulling wires through the old buildings, is still higher than adding wireless requirements to more modern buildings. Finally, the less endowed universities require significantly more resources to bring their students, staff and faculty up to date. The resource requirements often widen the digital divide.

## 3 The university and its challenges

The University of Houston – Downtown is part of the larger University of Houston (UH) system, located in Houston, Texas, one of the largest cities in the south. The UH system also has four satellite campuses in a 100-mile radius. The UH system also has four satellite campuses spread out over a 1600 mile area surrounding the central campus. UHD first became a component within the UH system in 1979 as the open-admissions component of the UH System. Currently, UHD has the second highest enrollment in the UH system with 10,974 students (Ackerman, 2003). UHD is a 100% commuter, real urban university. The primary mission of the university is to provide access to higher education to the general public. One of its most important goals is to overcome the *digital divide*, defined as the income/locational/cultural gap between those comfortable with computerisation and those who are not (Ackerman, 2003,p.230) in our information-based economy.

The principal UHD campus is located at the northern edge of the city's downtown section and is basically a single, yet historic, ten-story building formerly used as a manufacturing site. The present UHD facility is unique in that its single-building campus atmosphere was actually maintained when constructing a new academic building. The new facility was added in the form of an outcropped extension and was simply joined to the nearly 100-year-old manufacturing building 'at the hip' where the two buildings now share elevator systems. Additionally, it is a unique fact that the UHD campus is the only US campus with an active train system passing under a portion of the campus building's structure.

Like all universities, one of the biggest challenges at UHD is providing continued increases in computer access within the limitation placed on the resources made available. Adding to the challenge at UHD is the fact that the ratio of funding per student is the second lowest in the state. That combination makes the task of keeping UHD technologically advanced an extremely difficult one. On the bright side, the UHD's single-building campus does help reduce some technology expansion costs. This is because the distances between network components and even the numbers of those components as well are minimised. On the other hand, the age and original construction materials used within the conjoined buildings make typical networking techniques difficult and expensive. Even the simple act of pulling wires through a wall may involve long, expensive detours over thick concrete ceilings, walls and floors.

Because the construction of this historical building used thick concrete I-beam materials, pockets of non-reception, which act as barriers to wireless transmissions, exist pervasively throughout the building. These structural difficulties were similar to the problems encountered in other similar buildings, such as the MD Andersen Cancer Center (Brewin, 2001) and others (Lough *et al.*, 1997). Although the use of wireless technologies might often be more economical than pulling wires in such heavy construction, the cost remains higher than in installations in a more open environment.

## 4 Approaches to finding solutions

At UHD, it was determined early by managers of the Information Resources (IR) department that a networking solution could only evolve after taking a comprehensive look at the overall problems facing a full-scale implementation, and the solution would have to take advantage of all available resources. The strategy then centred on searching for one resource that would address multiple problems and, thus, facilitate combining resources from multiple sources so as to implement a complete solution that would reduce redundancy and make limited dollars stretch further. The primary approach is to be 'cooperative' with all departments in the university rather than be 'competitive' when obtaining resources.

Since the construction of infrastructure serves the common needs of the community, it was determined that it would be built one piece at a time with the assistance of many seemingly unrelated projects. With the advancement of this type of growing infrastructure, the system can be used as a support mechanism when obtaining additional funding for future projects that serve the diverse individual needs of the community.

## 5 Laptop pilot project implementation

When the time came for going mobile, UHD was ready for a change. It turns out that UHD's pilot project, which had originally been aimed at just a segment of its diverse student base, laid the groundwork for what has ultimately developed into a high-quality, university-wide networking project that involves near-total immersion into the wireless technologies available. The fact that UHD is a single-building campus in its historic building along one of the city's important bayous also played a part in the system's development into a wireless network environment. As the IR department looked into wireless implementations, they were able to start by implementing a system with a limited reach, and they could do it in a relatively small, confined location.

The IR department began the first phase of the system's development process – the scope definition phase – when they began looking into the magnitude of the project and the problems they would encounter. They then took advantage of a short-termed opportunity and implemented a programme in response to a university need (Whitten *et al.*, 2004). They provided wireless networking capability as a direct support mechanism for a small fraction of the extremely diverse student population. They discovered that the ideas of mobility and flexibility were important to their intended users and that the scope would be limited to a relatively tiny test bed of laptops, originally intended to enhance the learning experience of underprivileged students. That initial project, because of its innate simplicity, was accomplished quickly and was determined to be a great success.

Thus, the laptop programme's implementation actually began as a Title V grant. The intent of that grant was to increase the likelihood that a targeted group of underprivileged students would continue attending school if their attendance was facilitated by a new type of network more suited to their needs. It was further intended that this group of students would be retained as students and graduate from UHD as a result of the increased attention paid to the mobility needs of what was then a relatively small segment of UHD's student population.

The actual implementation process of the initial laptop pilot project was also simple. The idea was to purchase laptops and empower the targeted learners by 'giving' the computers to the students and easing their immersion into the technology by facilitating movement in a contained, learner-oriented location within the university. The IR department decided on operating the pilot programme with a prototype system consisting of 60 laptops loaded with educational software and a simple wireless networking configuration. The initial laptops were thus purchased with the initial grant money, and the IR department created a wireless network environment in a somewhat confined area of the campus. This configuration is referred to as an *ad hoc* architecture whereby "computers are brought together to form a network on the fly" (Lough *et al.*, 1997). At-risk students were located and enrolled into the programme, faculty members were trained,[3] and courses were designed to take advantage of the mobility that could be achieved by coupling laptops to the freedom of movement afforded to individuals using wireless networks.

Sample zone maps from UHD's website[4] showing the wireless networking implementation, including the initial coverage furnished with the pilot programme, can be seen in Figures 1 and 2. Due to the success of the pilot programme, a campus-wide wireless programme shortly followed completion of the first wireless laptop location. All further expansion of the wireless programme, which later included incorporation of the initial pilot programme's location, followed the infrastructure architecture. This infrastructure architecture uses fixed network access points with which mobile nodes can communicate and which often includes connecting landlines to widen networking capability. The wireless nodes are thus bridged to the wired network components (Lough *et al.*, 1997). Accordingly, the project was implemented in the following three phases based on its approved and allocated budget:

1 wireless access coverage through all areas of the Academic Building by Fall 2002

2 wireless access coverage through all areas of the North tower of the Main Building by Fall 2003

3 wireless access coverage through the entire UHD campus by Fall 2004.

**Figure 1** Coverage in the academic building

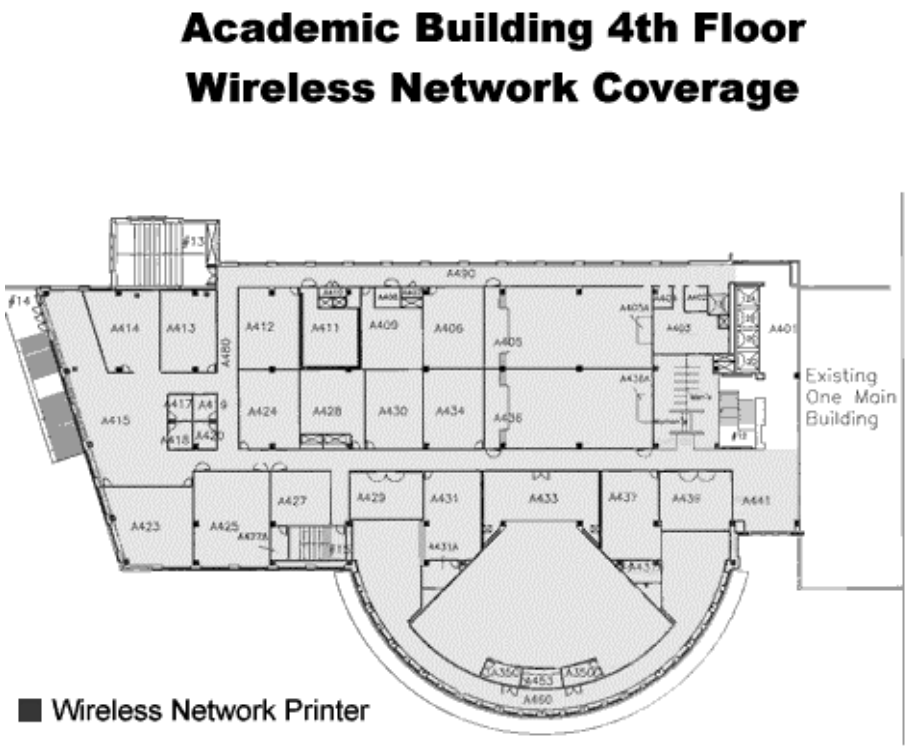
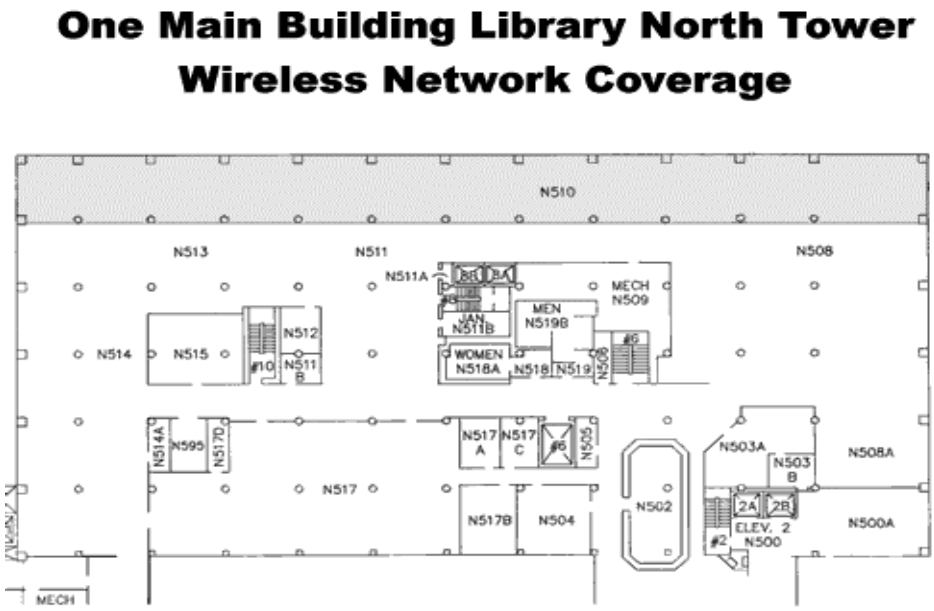



**Figure 2** Coverage in main building



The UHD involvement in wireless media was initially mentioned in the Information Strategic Plan for 1999–2003 as a potential cost-effective upgrade to services.[5] UHD's President announced the addition of laptops in 1999 as a means of bridging the digital divide that he said was threatening to leave behind large segments of the community. In April 2001 he tied the laptop project to a wireless environment and announced the arrival of those laptops during that fall semester. At that time, the President also named the programme the Laptop Pilot Project and said that it targeted First-Time-In-College (FTIC) freshmen enrolled in UHD's new Learner's Community programme. He further stated that the project was chosen because it offered a web of integrated services and support to students who enter UHD in that FTIC category. The Laptop Pilot Project was intended to address the barrier of technological access for economically disadvantaged students, many of whom were not computer-literate, had had little or no introduction to computer technology in their high schools, and could not afford to own home computers or subscribe to internet access providers (Castillo, 2001).

Toward this end, UHD gave laptop computers to a group of newly entering students who were enrolled in selected sections of linked courses that fall. Among other applications, the laptops provided to the students were to have Microsoft Office software for use at home and in the classroom, as would the comparable laptops provided to each faculty member participating in the test group.[3] The faculty members were to work collaboratively to design a curriculum that utilised instructional technology. The project, according to the President, was to create a wireless environment in an area of the university where students and faculty would be able to develop a sense of community (Castillo, 2001).

As a result, the UHD Learners Community was established in Fall 2000, through the assistance of a Title V grant, to aid entering students with their transition to the university experience. The Learners Community project was designed as a web of integrated services to offer Hispanic and low-income students who enter UHD as FTIC freshmen a support structure during the first year of university enrollment.

The initial goals of the Learners Community project[6] were to:

- increase the persistence rate of those students enrolled in the programme
- improve the academic performance of students
- enhance the students' adjustment to college during their first year
- increase the chance that students' will attain a baccalaureate degree within five to six years.

The Laptop Pilot Project is being assessed by the Learners Community to measure the effect of technological access on student academic performance.[6] Location management is always an important part of current and emerging wireless networks (Varshney, 2003a–b). Since two of the three main buildings were built back in the 1920s, their thick concrete walls and rebar hamper data transmission and, therefore, reduce the coverage area. Thus, additional access points had to be strategically placed to maximise effective coverage. These problems are not uncommon. The MD Andersen Cancer Center in Houston encountered similar difficulties (Dubie *et al.*, 2002).

## 6 Laptop project results

In June of 2001, the Title V Planning Council Report announced that the Laptop Pilot Project was in full swing.[7] It also stated there were current activities in progress related to seeking funds in support of the project, identifying and acquiring computer hardware and insurance and creating a wireless environment on the fourth floor of the Academic Building.

The SWOT Assessment of September 2001 contained a New Technologies section that cited the significance of that year's creation of 'wireless environments' in selected areas of the university that enhanced student access to the Internet.[8] It further endorsed the expansion of the programme in the years to follow, such that wireless access would be provided campus-wide. It noted that the university had made substantial upgrades to its technology security infrastructure during the previous year and that it would continue to adapt its security to meet emerging technology requirements.

By November 2001, 75–80% of the library, 90–100% of the Technology Teaching and Learning Center (TTLC), and 100% of the Academic Computing Lab (ACL) had become wireless. In January 2002, additional wireless classrooms and an associated funding of $50,000 were proposed. Further discussions about this proposal occurred on February 14, 2002 and the proposal was quickly approved on February 28. When the Academic Vice President noted that the Departments of Urban Education and English had both requested wireless areas for their programmes and asked if these areas would be covered by this request, Information Technology Service (ITS) stated that the longer-range plan was to make the entire campus wireless. As a result, the $50,000 initiative to expand the wireless network was moved up on the priority list.[9]

At the February 2002 Instructional Technology Services (ITS) User Group (for information diffusion among the UHD computing community) meeting, the wireless project was open to discussion concerning the standards, training and security issues. Based on experience from the Laptop Pilot Project and the Learner's Community programme, ITS was certain that 60–70% of network cards in the market could be supported then, and the goal was to be able to handle 80–90% of network cards.[10]

In March of 2002, the ITS User Group set out to identify long term plans, including experimenting with Breezenet, standard operating procedures for network card specifications and wireless network access. One of the goals was to have the identical look and feel for the wireless and wired computer desktops used throughout the campus at the time. In addition to looking for a more secure open network, the order of integrating wireless environment into the whole campus was also a focus.[11]

Even the infamous state budget cuts of 2003 that slashed expenditures statewide (Anonymous, 2003) apparently did not stop the progress of the UHD Wireless Project. At the start of the Spring 2004 semester, wireless connectivity was available from nearly all areas within the UHD campus. What started out as a programme to help entice a small underprivileged group to stay within the educational system – and hopefully graduate from UHD – has turned out to be a benefit to the entire campus community. More and more students can be seen in the hallways carrying laptops and sitting in locations all around the campus, working on their own portable workstation, all the while staying continuously connected to the school's network as originally described by Drew (2003). In fact, the system is so successful that students oftentimes bring their personal laptops to class, log into the network and conduct research while working

on class projects. On one such occasion, a student who no longer felt he was "Netologically-challenged" (McMahon, 2003) was so proud of himself that he demonstrated to his classmates the process of connecting his new computer to the school's network, and he did it in class without the help of the university IT staff.

## 7 Looking toward the future

The implications are profound. While computing flexibility and efficiency were enhanced through the use of wired networking, they expanded even further in a wireless environment. However, providers of wireless products acknowledge that wireless LANs will be, now and in the future, both more expensive and slower than wired LANs.[12] As a result, an in-depth analysis should be undertaken to document educationally oriented wireless implementations. This analysis needs to include installed component selection criteria, system costs, overall benefits, and also troubles encountered, fixes implemented and developer suggestions for future users. Additionally, a system of tracking these implementations should be put in place to assist the participants with future enhancement adoptions.

The ultimate goal for information availability is to provide users access whenever and wherever they want. Wired networks such as the internet and the World Wide Web provide the 'whenever' part of the equation and wireless technology will facilitate the 'wherever' autonomous communications envisioned by Wellman (2001). With microwave and satellite transmissions, access can be provided virtually anywhere on earth. However, regarding revenue shares earned by wireless carriers, US wireless service ranks last in the world according to a recent Merrill Lynch study (Huber, 2003). Today, however, network users can simply visit their local Starbucks and gain wireless access to the internet (Barnes, 2003), but mere access might not be enough. Studies should find ways to bring US service capabilities up to higher levels while expanding wireless immersion among universities such that their enterprise mobility needs (Barnes, 2003) are supported in geographically independent ways.

Although the wireless system at UHD is fully operational, no standard has been established to measure the success of the implementation. Further investigation should establish a cost/benefit assessment and should identify numbers and types of users (faculty, staff or student) and perceived versus actual user benefits. This information would then facilitate a post-effect rating structure of UHD's wireless community similar to that discussed by Liebowitz's explanation of David Vance and Jim Eynon's knowledge transfer function (Liebowitz, 2003,p.60) which would then help determine the implementation's success.

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