Abstract

Bluetooth is still a relatively new technology to the wireless world. It is designed for wireless communication between a wide variety of different Bluetooth enabled devices; from computers and PDAs to GPS systems and heart monitoring devices. There are a growing number of companies continually adopting this technology. As Bluetooth becomes a standard feature in many products that we use everyday, it seems that the use of the technology will grow even faster in the future. This paper provides an analysis of the technology’s features and how companies should go about deciding if they should adopt Bluetooth or another wireless alternative. First, the paper talks about what Bluetooth is and how it compares with other wireless standards. It then goes into an analysis of how feasible integrating Bluetooth into a business would be, and how some industries are already using the technology. These case studies are followed by a look at what steps need to be taken through the implementation cycle, and deciding what technology makes a better fit for a business. The paper ends with a look at the pros and cons of Bluetooth, as well as a look into what the future may hold for this technology.

Keywords: Bluetooth; Feasibility study; Frequency-hopping spread-spectrum (FHSS); Mobile commerce; Systems analysis and design; Wireless communications

1. Introduction

With technology changing at such a rapid pace and the weakened economy, it is hard to determine what is going to become the next dominant technology or just another fad. When computers first came out to the public market, technology was not growing as fast, and there were not many variations in the products from one month to the next, unlike today. There were also new technologies being created on how to interconnect all these computers. First, they had to be connected by wires and users were confined to limited work areas. More recently, the trend has shifted towards wireless communication because of the freedom that it gives the user to move about without much restriction. In addition, advancements in wireless technology are developing and expanding rapidly. New standards and protocols are being created in order to meet the goal of uniformity and cohesiveness between all technologies. This rapid change can make companies hesitant to choose one technology over the
other, because something new may come out very soon to better fit the needs of the company.

Even though it is difficult to predict which technology will last in the future, businesses must strive to stay ahead of the competition and maintain the leading advantage to better meet their own challenges and their customers’ needs. One way to stay on the move is to upgrade from a wired system to a wireless system. Many companies have already started engaging in a wireless system, but some are still hesitant because of lack of standards, and more importantly, security issues. There are also many different types of wireless technologies out there to choose from. If a company has made the decision to go wireless, they must decide which technology better fits their needs. With any wireless technology, employees would have the flexibility to facilitate the communication and information access/retrieval with a limited restriction. This could lead to a more productive working environment, due to fewer, physical location constraints imposed on the employees.

One wireless technology that companies should consider is Bluetooth. Bluetooth is relatively new to the wireless era, growing at a rapid pace, showing much promise, and acting to bring more productivity and efficiency to the companies’ operation in the future.

This paper gives an overview of what Bluetooth is and how it works. It also explores other wireless technologies and how they measure up to Bluetooth. Some companies and industries have already adopted Bluetooth as their wireless solution. A few of these companies will be discussed, as well as the criteria that other businesses need to look at in order to determine if Bluetooth is the right choice for them.

1.1. Bluetooth definitions

Bluetooth is a wireless technology that can be used for short-ranged communication between different Bluetooth enabled devices. Some of its common functions are passing and synchronizing data, such as a PDA and computer, and connecting to the Internet. Bluetooth works in the unlicensed 2.4-GHz industrial, scientific, and medical (ISM) band and uses frequency-hopping spread-spectrum (FHSS) communication, which transmits data over different frequencies at different time intervals. This is accomplished by making “hops” to different frequencies through the ISM band. A device makes about 1600 hops per second, which is spaced out over 1 MHz [9].

Unlike most devices, Bluetooth enabled devices communicate with each other automatically. There is no need to specify what type of action to take place or when it should to happen. When two devices are within range of each other, they will communicate back and forth to determine if there is any information to be passed. During initial communication, it is necessary to create a relationship between unknown devices; this process is referred to as pairing. During the paring process, a secret PIN is created that is only known by the two devices that are communicating. It is better for the user to manually enter a PIN, and make it complex, in order to make the code hard to break.

Since Bluetooth is a wireless protocol, anyone with an appropriate receiver can intercept transmissions. In order to reduce hacking, Bluetooth supports device authentication, which means, devices that share information use a shared secret key, or link key to authenticate one another. If the devices have communicated in the past, they will share a common link key, which can take two forms. The first, and least secure, is a unit key. A unit key is the same secret key for every device that has established a connection. For example, if a PDA and a Mobile Phone exchange information, then later that same PDA and notebook computer share information, all three devices will share the same unit key, leaving them much more accessible to attacks. It is recommended that a unit key only be used for devices with limited memory and limited user interface devices. The second, and much more secure, is a combination key. Combination keys are unique and change each time the devices make a new connection, so no two devices share the same key. Since the keys are different, it is much easier to protect the communication between the devices [3,25].

1.2. History and evolution

Bluetooth is named after a Danish king, Harald Bluetooth, who ruled from 940 to 985 AD [9]. During his rein, Bluetooth was able to unite Denmark and part of Norway into a single kingdom. In 1994, Ericsson started researching short-range wireless technology
that could be used between their cellular phones and peripheral devices, such as a headset [3]. In 1998, Ericsson, Nokia, IBM, Toshiba, and Intel came together to form a Special Interest Group (SIG). These companies were chosen because of Ericsson and Nokia’s leadership in mobile telephones, IBM and Toshiba’s leadership in laptop computing, and Intel’s leadership in digital signal processing technology. In four short years, the original five companies, in the SIG, have turned into 1500 [20].

Bluetooth’s original mission was to replace all of the cables that tie up today’s complex world. There are many cables plugged into the back of a computer, for instance, a monitor, a keyboard, a mouse, and a printer. The location of the correct plug can become very confusing for the user, as more “plugged-in” devices are introduced; this is where Bluetooth comes in.

The developers of Bluetooth soon realized that this technology is capable of much more than just connecting peripheral devices. It can work as a lower speed wireless network, allowing connection through access points at any location. Bluetooth is also a universal standard and can be used wherever you go, which makes it extremely powerful.

Some current devices that are not Bluetooth enabled can add Bluetooth capability via PC cards or USB adaptors. As this technology continues to grow, more and more devices will come with Bluetooth chips built-in. There are many devices on the market that already have Bluetooth built into them, such as phones, laptops, and PDAs. As more of these devices are released to the public, Bluetooth’s place in society will be sealed. Table 1 summarized all the discussion above with major milestones and lessons learned in each age.

### 1.3. Architecture

When Bluetooth devices connect with one another, a small network called a piconet is formed. There can be up to eight devices in one piconet at any one time. Even though there is a connection between devices, that connection is not always open to communication. One of the devices in the piconet will take the role of the master and the rest will be slaves. Since Bluetooth uses frequency-hopping spread-spectrum, the slave devices will synchronize their hops along with the master’s hops. This will allow the devices to continue to communicate without each device hopping over to different frequencies and losing the connection. Bluetooth devices will automatically form a connection when they come within range of one another. They can also be set up to automatically synchronize data, such as between a PDA and a computer [9].

If it is necessary for more than eight devices to be involved in a network, piconets can be connected together to form a scatternet. Within each piconet, one device is selected to act as a bridge to another piconet [9].

<table>
<thead>
<tr>
<th>Year</th>
<th>Age</th>
<th>Major milestones</th>
<th>Lessons learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>Introduction</td>
<td>Ericsson started research on a short-range wireless solution for peripheral devices</td>
<td>Bluetooth is capable of much more than originally expected.</td>
</tr>
<tr>
<td>1998–2000</td>
<td>Growth</td>
<td>SIG was formed and is continually growing</td>
<td>Bluetooth is showing what it is capable of and with growing support many more uses are coming into play, but there is still a need for security.</td>
</tr>
<tr>
<td>2000–2003</td>
<td>Maturity</td>
<td>Bluetooth is being used in conjunction with other wireless standards, such as Wi-Fi</td>
<td>2.4-GHz band may become too overcrowded, is there a need for a new solution?</td>
</tr>
<tr>
<td>2003–Current</td>
<td>Current/Future</td>
<td>Once Bluetooth has more support in the commercial, and consumer market, prices will begin to drop</td>
<td>Price will not drop until there is more support and there will not be much more support until prices drop.</td>
</tr>
</tbody>
</table>
1.4. Comparison with other wireless technologies

There are many ways to create a network between different devices. The following is a short overview of just a few of the wireless technologies available.

1.4.1. Induction Wireless

Wireless devices that utilize radio frequencies for data transfer, such as Bluetooth, use an electric and a magnetic field. Induction Wireless, invented by Aura Communications, uses only the magnetic field. Data can only be transmitted within a 3-m radius at speeds of 204.8 Kbits/s [10]. This short range communication adds extra security, because in order to receive the data, someone would need to be very close to the source. Compared to Bluetooth, Induction Wireless requires lower power consumption and costs less.

1.4.2. Infrared Wireless

Infrared Wireless (IrDA) may have been the first personal area network technology used to transfer data over short distances. Most IrDA devices can only transmit up to 1 m; beyond that range, the signal quickly weakens. There are two versions available that have a transfer rate at either 4 or 16 Mbits/s [10]. In order to transfer data, the sender and receiver must be in line-of-site. This characteristic of IrDA adds an extra security feature that most wireless technologies cannot offer because its signal is not sent out in all directions.

1.4.3. Ultra Wideband

Ultra Wideband is fairly new to the commercial and consumer market. Its main use has been for military and government applications, such as short range, high-resolution radar and imaging. Like Bluetooth, the signal can penetrate walls, but it can be used anywhere in the 3.1- to 10.6-GHz band. It also has an astonishing transfer rate at 100 Mbits/s [10].

1.4.4. ZigBee

Philips created a slower, less expensive, and lower power cousin to Bluetooth, called ZigBee, and has many of the same characteristics of Bluetooth. ZigBee works in the 2.4-GHz band, and uses frequency-hopping spread-spectrum. Unlike Bluetooth, it takes 25 hops spaced out over every 4 MHz and transfers data at 250 Kbits/s. For an extended range of 134 m, and greater reliability, ZigBee can transfer at 28 Kbits/s. It has the capability of attaching up to 254 nodes to one network, but so far there are no chips available to the public [10].

1.4.5. IEEE 802.11b

Bluetooth is sometimes confused with another wireless technology, 802.11b. 802.11b is a standard specification for wireless LANs, but Bluetooth is capable of so much more. 802.11b also work in the 2.4-GHz band, but uses direct-sequencing spread-spectrum (DSSS), which sends data over several different frequencies simultaneously, instead of individually. Device authentication is also different. 802.11b frequently will reuse the packet keys, leaving the devices open to more attacks. 802.11b will also use this same key for the authentication process and encryption, whereas Bluetooth uses separate keys for each [10]. Table 2 provides an overview of all different technologies.

1.5. Bluetooth vendors

Cambridge Silicon Radio (CSR) and Silicon Wave are two of the largest Bluetooth chip vendors, shipping millions of chip sets every year [1]. CSR’s main focus is on solutions using Bluetooth personal area networking. They were founded in 1998 with a goal to develop single-chip radio devices. The founders came from Cambridge Consultants, and they continue a development partnership today. CSR also receives

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Table 2

<table>
<thead>
<tr>
<th>Transmission</th>
<th>Bluetooth</th>
<th>Induction Wireless</th>
<th>IrDA</th>
<th>Ultra Wideband</th>
<th>Zigbee</th>
<th>IEEE 802.11b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation frequencies</td>
<td>Radio wave</td>
<td>Magnetic field</td>
<td>Infrared</td>
<td>Radio</td>
<td>3.1-10.6-GHz</td>
<td>2.4-GHz</td>
</tr>
<tr>
<td>Speeds</td>
<td>1 Mbit/s</td>
<td>204.8 Kbit/s</td>
<td>4 or 16 Mbit/s</td>
<td>100 Mbit/s</td>
<td>250 Kbit/s</td>
<td>10 Mbits/s</td>
</tr>
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</table>
funding from some of the world’s leading venture capital investors, such as, Capital Research, LDC, and Sony [5]. Silicon Wave was founded in 1997 and is based out of San Diego [1]. They manufacture products such as Radio processors, Radio Modems, Baseband Processors, and Coexistence Technologies. Silicon Wave is partnered up with 7 Layers Inc. for Bluetooth testing and qualification services [1].

1.6. Bluetooth pros

Bluetooth has several advantages, one of the most notable is its ease of use. As with every other wireless technology, Bluetooth frees up the user from being bogged down by wires. With an increasing number of peripheral devices, all the wires can become overcrowded and, at times, confusing. If all the wires and slots are not color-coded, it can become very difficult to figure out the location that each wire gets plugged into, even for a professional. With Bluetooth, all these wires disappear, saving the user the time that would be spent trying to figure out how to get all the devices connected. When two Bluetooth devices come within range of each other, they automatically make a connection and decide if there is any information that needs to be passed, or if one needs to control the other.

Not only is the fact that Bluetooth devices use wireless communication an advantage, but also that the communication is done automatically. This reduces user interaction time, and tasks can be accomplished more efficiently. Within a wired environment, if the user wanted two devices to be synchronized, data would either need to be reentered by hand or connect the devices by wires. If the user would forget to do the synchronization, the data would eventually become outdated, and could lead to data discrepancies. Because of the automatic communication between Bluetooth devices, the user does not need to worry about forgetting to synchronize, so the data between devices would always match and be up-to-date.

Another advantage of Bluetooth is its added security features. The fact that it is a short-range technology (about 3 m) adds some security in itself, because someone would need to be close to the communicating devices to be able to intercept the signal. As discussed earlier, the authentication process is also much more in-depth and harder to crack than that of other wireless standards.

1.7. Bluetooth cons

Even though Bluetooth’s short range helps security, there is still the possibility that someone can intercept the signal. The signal that Bluetooth devices send out is sent in every direction, and can travel through walls. Intercepting the signal could be just as easy as sitting in the next room and listening to someone’s conversation. With the increasing speeds of computers, programs and hacking equipment can be made to quickly and easily crack any code. With a wired network, a hacker needs to somehow tap into the company’s network. This makes it harder for hackers because they need a physical connection, whereas with Bluetooth, all they need is a receiver that can catch the radio signals being sent out. As this technology continues to grow and mature, there will be better security measures, and someday may be as secure as some of the wired technologies.

The short range poses another disadvantage for Bluetooth. Only being able to transmit to distances up to 30 ft away can be very limiting in an office or production setting. Users cannot go too far away from the device that they are communicating with without losing the signal. If a company were spread out over separate buildings, Bluetooth would not work without help from another networking technology, such as a wired system.

Another disadvantage of Bluetooth is its speed. Today there is a greater need than ever for fast speeds to transfer large quantities of data. Bluetooth is only capable of transferring at speeds of 1 Mbit/s, but the SIG is working on a newer version that would allow speeds to reach 10 Mbits/s. If companies need to continuously exchange large files, Bluetooth would not work for their demands. Bluetooth is only meant for small amounts of data to be transferred at one time.

2. Bluetooth: an analysis framework

When a company is thinking about investing in a new technology, there are many options that must be considered, and Bluetooth is no exception. One of the most important questions that a company must ask is, “Do we need this new technology and is it technically
It is important to know if the company has the monetary funds, the time, and the know-how to be able to implement a new technology. It is essential that the technology follows the company’s objective. Along with the cost, the solution that a company decides on must be technically feasible. A company should not adopt a new technology that has not proven its usefulness, because support for that technology will not be around very long if it fails. If the technology is available, the company must make sure it is legal and operationally sound for their company. The technology must also be able to be implemented in a reasonable amount of time, allowing demanding tasks to be completed on time. Therefore, the analysis framework of investing Bluetooth is shown in Fig. 1.

2.1. Technical feasibility

Bluetooth is a relatively new technology, but is gaining more and more support in the consumer market. One of the first devices used with Bluetooth is a simple headset that allows people to talk on their Bluetooth phones hands-free. Now Bluetooth has broadened its accessibility to be used with PDAs, laptops, cameras, GPS receivers, watches, printers, keyboards, mice, and access servers, to just name a few. The technology is already available and continuing to develop based on the needs of the businesses.

What makes Bluetooth such an important standard is that it is supported world-wide. No matter where you go, if you have a Bluetooth device, it can interact with
other Bluetooth devices. This is especially important in today’s companies that are continually globalizing.

Bluetooth has been incorporated into many new devices. One concern that may arise is what to do with all the old computers and equipment that do not support Bluetooth; should it all be scrapped? The answer is no. Bluetooth is by no means a cure-all solution, but it can do many useful things. If companies want to start integrating Bluetooth into their current systems, there are ways to upgrade computers and devices into Bluetooth-enabled devices by adding PC cards or USB adaptors. Some phone companies even make Bluetooth adaptors for phones. Another concern is the interference with other wireless devices that work on the same 2.4-GHz band. Although there are collisions that happen from time to time, because of Bluetooth’s frequency hopping, interference does not pose a big threat. More collisions occur between Bluetooth and the 802.11 standards than any other devices that work in the 2.4-GHz frequency range. Using a separate antenna for each standard will help reduce the collisions and make operations safe from three or more ft apart.

Bluetooth is also not meant for high-speed access. As of now, it can only transfer at speeds up to 1 Mbit/s. It can also only attach up to eight devices to one piconet at a time [9]. For companies that need faster data access and more device support, Bluetooth may not be the solution for them.

### 2.2. Economic feasibility

Another major concern companies have about applying a new technology is the startup cost. Most businesses today have some type of wired network setup and want to postpone adopting a new networking scheme in order to see where the wireless world is headed.

Wireless networks can, however, reduce costs because of less maintenance and setup costs. With a wired network, many cables need to be purchased and installed, which can become very expensive. There are also maintenance costs to keep all the wires in good working conditions. If a wire were to accidentally get snapped or kicked out of the correct socket, it can take time to get someone to come and fix the problem. With wireless, all these costs are eliminated, except for some maintenance. There are no longer any cables to buy or install, and much of the maintenance costs are decreased because there is not much more to maintain than the interface cards and access points.

The companies that have invested in the production of Bluetooth chips want to have the cost of a single chip down to $5. Right now the price range is hovering between $20 and $30 and will not be able to get down to the target price until Bluetooth has a wider acceptance and the chips are being mass produced [20]. If the $5 mark is attainable in the near future, many more companies will most likely invest in Bluetooth because of its accessibility and cheap cost to implement.

One area where cost will be high is security. Since there is no physical barrier to protect systems, keeping hackers from intercepting data will be harder than ever. It is estimated that security cost will be where most money is spent when implementing a wireless network.

### 2.3. Legal feasibility

It is important for any business to identify legalities or any other regulatory requirements they have. This is important in order for the company to assess their capability of meeting these requirements. By doing further investigations of a company, they can find where they are legally liable and should take caution, such as with contract obligations.

The security of Bluetooth is not to be taken lightly, and is the area of most concern. Bluetooth certification does not require high-level security and interoperability between products, so the user interfaces, default configurations, and usability choices are left to the manufacturer. This can cause many problems with Bluetooth devices between manufacturers that are not compatible, and safeguards against data corruption and theft can be at a minimum.

Since Bluetooth is also a worldwide standard, business practices and laws of other countries need to be taken into consideration when setting up a network for a global company. If policies of other countries are not followed, a business may lose market share in a country, or even be kicked out and no longer be able to operate within that country.

### 2.4. Operational feasibility

Bluetooth would likely be considered operationally feasible if it meets the company’s needs and expect-
ations. User acceptance and ability to work with the new technology is also an important factor in considering feasibility. Some other factors that need to come under careful consideration is the corporate culture, management’s support of the new technology, impact of the technology on work practices, and training requirements. If management does not support adopting a new technology, then the idea might as well be scrapped, because without the support of management, it would be very difficult to get anything done. Also if training requirements are too expensive, or would take too much time, it might not be in the best interest of the company to change to a completely new way of operating.

From an operational standpoint, Bluetooth has the capability to make a business run smoothly and be more productive. Since Bluetooth devices can communicate automatically, many applications are possible. For example, a Bluetooth-enabled PDA could act as a virtual wallet. If someone walks into a restaurant that uses Bluetooth, that person can order their meal, then pay for the check automatically, without waiting for the check or digging through their wallet for cash or a credit card.

Another application could be the transfer of data between to business people during a meeting. Clients would be able to transmit presentations and business cards automatically. More operational benefits are discussed further in the case studies.

2.5. Scheduling feasibility

When starting up a new project, it is important to set a time frame from when the implementation is going to begin and end, and what needs to occur in between. The proposed time frame must also be reasonable. If the time frame is set too short, the workers my try to put everything together too fast in order to meet the managers’ expectations. If this happens, important steps can be overlooked and the new system my not work properly once the time frame has ended. On the other end of the spectrum, if the time frame is too long, time is being wasted when workers could be focusing on another project.

When scheduling a task, the staff must be committed to the selected time frame and there must be an adequate number of people to complete the task. If there are not enough workers, those that are working may have too much pressure on them. This may cause work quality to decline and the project to suffer. Again if too many workers are assigned to the project, valuable time is wasted that could be spent somewhere else.

Scheduling the amount of time to complete a project is only one part of implementing a new system. Management must also look at how the scheduling of tasks will be affected once the new system is up and running. If the new system would require workers to take longer in completing the same tasks as compared to the old system, the current system may be adequate for the company’s current needs.

3. Case studies

The purpose of this section is to discuss four different industries that are currently using Bluetooth, how it has helped, and where Bluetooth has fallen short. The first industry discussed is the travel industry with a focus on Hotels. It then refers to the medical industry and how Bluetooth is making some hospitals more efficient. The third industry mentioned is the automotive industry and how some car companies are using Bluetooth in its new models. The last industry cited is the delivery services industry.

3.1. Travel industry

Hotels are not normally associated with new technology, but in this age of international business, the demands on the business traveler are changing the way hotels run. In 2001, Hotels started embracing Bluetooth as a way to increase customer satisfaction. Starwood is one such hotel and leisure company to incorporate Bluetooth into selected hotels.

Starwood is one of the largest hotel companies in the world, and since 1998 has acquired companies such as Westin Hotels & Resorts Worldwide and ITT. Some of its brand names include St. Regis, The Luxury Collection, Sheraton, Westin, and Four Points [4].

In 2001, Starwood partnered up with Clasewave Wireless to develop software applications for the travel industry using Bluetooth [2]. Starwood’s goal for this project was to reinforce their commitment to utilize the latest innovations in technologies and provide customers with the best possible experience.
With Bluetooth, they wanted to be able to provide guests and employees with a new level of information. Bluetooth devices would enable guest of the hotel to automatically check in, by walking through the front door. Instead of waiting in lines at the front counter to fill out the check-in papers and getting a room key, Bluetooth devices would automatically transfer information about the guest to the hotel. The guest would also be able to get into their rooms without the use of a key. By pushing a button on a Bluetooth phone, the door would unlock. When the customer is ready to check out, the Bluetooth devices would tell the hotel that the guest is leaving and send payment information directly to their computers [12].

To make guests’ stays more pleasurable, the hotel can use other information to adapt to the needs of the guest. If eating in an in-house restaurant, the meal could be paid for with the Bluetooth device, getting rid of the need to carry a wallet and credit cards around. The same principle could be applied if a guest wants to get a snack out of a vending machine. Access points can also be used to enable guests to access the Internet wirelessly.

This technology is not only for the guests, but also the employees. It allows managers to be more mobile. Bluetooth can also provide employee chat services, instant messaging, and access to corporate data.

One concern about using this technology is that it is still relatively new. Classwave is worried about interoperability problems; so many of their devices used come from single vendors in attempts to reduce the risk. Another problem could occur if the system breaks down, and there is no one at the front desk to take care of guests trying to check in and out.

One of the greatest limitations is not everyone, even some business travelers, will be carrying around devices that are Bluetooth-enabled. It could take many years before a system like this could be fully integrated, or even worth pursuing.

3.2. Medical industry

The medical industry is another area where Bluetooth can make a drastic change in how hospitals operate. Tablet PC’s or PDA’s integrated with Bluetooth would give the medical staff access to detailed patient records, which are updated in real time. No more paperwork would be necessary, leading to a faster and better diagnosis.

A wireless system in a hospital could drastically improve the way they operate. Most of the equipment hospitals use is fixed to one place because of all the wiring. The same thing is true of patients that are on heart monitors; they are confined to their room, or maybe even their bed. When different tests need to be performed on a patient, instead of moving them from room to room, the equipment would be able to be easily transported without worrying about how to hook all the wires back into the correct spots. Code Blue Communications [23] created a portable patient monitoring solution that would give patients more freedom and keep them from being confined to certain areas. This type of device would even allow a hospital to monitor a patient in his or her own home. With all the monitoring equipment hospitals have today, it is also important for a low power solution, and Bluetooth is just that.

When diagnosing a patient, a doctor can enter their diagnosis into a tablet PC or PDA that would automatically update the Hospital database. This can greatly reduce confusion if paperwork gets lost or somehow switched. Not only is this good for reducing paper clutter, but also improves the efficiency of the doctor. When prescribing medicine or treatment, the doctor has access to the patient’s entire history record in front of them to check for conditions such as allergies, before prescribing anything. Not only would the doctor have access to the patient records, but they could also tap into a database for drug dosages and interactions, or a list of symptoms and disease libraries.

A study was done at a hospital where 15 doctors and a pharmacist were given Bluetooth-enable PDAs to see how much of an impact they could make. On average, each doctored saved 30 min of time per day, and sometimes up to an hour [18]. This means that the doctors would have more time to spend with the patients and improve the quality of care.

As with any other implementation of Bluetooth, there is the possibility of interference from other RF devices, and this could prove critical in a hospital setting. If two signals collide, some monitoring systems could fail. Security is also a big issue, because patients’ records need to be kept safe from unwanted manipulation. Another draw back in the medical industry is that the producers of medical equipment are known to be slow to pick up new technology.
Once they have something that works, they are hesitant to change until they know the new technology will work.

3.3. Automobile

With new legislation being passed all over the world requiring hands-free communication while driving, the automobile industry is beginning to adopt Bluetooth as a wireless solution. With Bluetooth integrated into an automobile, it would allow users to control different devices by voice while staying focused on the road. BMW is one car manufacture that is researching the use of Bluetooth in their cars.

BMW’s goal is to develop a personal area network within the car; connecting navigation systems, audio systems, telephones, and other car and consumer appliances [6]. An example of one of its uses could be when taking a trip, before even getting into the car, driving directions are downloaded from the Internet onto a Bluetooth-enabled laptop or PDA. Then once inside the car, the navigation system would automatically upload the directions from the laptop. While driving, if a Bluetooth cellular phone rings, the signal could be transmitted through the car speakers so the driver would never need to touch the phone. BMW offers Bluetooth as an extra on their X5, 3 Series, and 5 Series cars [5].

A Bluetooth chip could also be installed during the production of a car to add more capabilities before it is even off the line. If a car has been fitted with a Bluetooth chip, it could be tracked during production and be used to help dealers keep better track of what cars are in stock and what cars are selling faster than others. Then once off the lot, the function of the chip can change to meet the consumers’ needs.

One area of concern is how Bluetooth devices that are in different cars will be able to communicate, or even if they should be able to pass data. Cars traveling in opposite directions would have a very limited amount of time to be able to connect and pass data between each other.

3.4. Delivery services

UPS is one delivery service that is already using Bluetooth technology in its warehouses, and they plan to expand the use of Bluetooth into a new system they are developing called Deliver Information Acquisition Device (DIAD) IV. Over the next 5 years, UPS has planned to spend $127 million in developing this new technology [7,8]. Bluetooth will allow the company to stay flexible by being able to add more peripheral devices in the future, such as printers or credit card readers. The Bluetooth system would also allow customer computers to communicate with the new DIAD IV system as long as they use UPS shipping software and Bluetooth compatible devices [8].

In UPS warehouses, package sorters use scanners that fit on their finger and transfer data via Bluetooth to a terminal on their hip. Before using Bluetooth, the scanning device was connected to the terminal with a wire that could get tangled and caught between boxes. When implementing this new system, they wanted to see an increase in worker productivity, by making it faster to move from one box to another without all the cords getting in their way.

If Bluetooth chips drop down to the projected $5 per chip, UPS could begin to offer a new way of tracking packages. For an extra fee, a customer could purchase an advanced tracking method where they would be able to track their package at any location, at any time. The way UPS has their system currently set up, customers can track when their package has arrived and departed from different sort facilities, but they cannot find out where on the road it is located. With the Bluetooth network UPS plans to have in place, they would be able to attach a Bluetooth chip to packages that would transfer its exact location through the UPS network. This way, customers would be able to tell if their package is coming down the street, or going the wrong direction across the country. Table 3 summarized all the discussion above.

4. Bluetooth: an implementation framework

This implementation framework is not unique to Bluetooth, but should be used whenever a company is thinking about implementing a new technology. There are five main phases that need to be completed, and then one more phase that continues through the life of the project. This section begins its discussion with the opportunity definition phase and steps all the way
through the maintenance phase. The implementation cycle of Bluetooth is also shown in Fig. 2.

### 4.1. Opportunity definition phase

The opportunity definition phase is the very beginning, and takes the least amount of time to complete. This phase mainly consists of managers exploring different areas of the business they feel need to be updated. Maybe they just hear of some new technology that they think could add to and help their current system.

For Bluetooth, this phase would consist of someone in the company saying there is a need for some

<table>
<thead>
<tr>
<th>Industry application</th>
<th>Unique characteristics</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Starwood Hotel and Resorts</td>
<td>Do everything without human interaction: check-in, check-out</td>
<td>Greater flexibility</td>
<td>Still few users with Bluetooth devices</td>
</tr>
<tr>
<td>Medical Code Blue Comm.</td>
<td>Able to monitor patients from own home: gives patient more freedom</td>
<td>Greater flexibility Hospitals function more efficiently</td>
<td>Information is very sensitive to information loss and hacking Bluetooth needs to be secure and reliable Cars travel too fast to synchronize</td>
</tr>
<tr>
<td>Automotive BMW</td>
<td>Forms cars own personal area network</td>
<td>Hands-free control of phone Improved production and stock analysis</td>
<td></td>
</tr>
<tr>
<td>Shipping UPS’s DIAD IV</td>
<td>Customer would be able to find the exact location of package</td>
<td>Provide better customer service Keep better track of inventory</td>
<td>High startup cost Need a way to work simultaneously with other wireless standard</td>
</tr>
</tbody>
</table>

Table 3
The characteristics, strengths, and weaknesses of Bluetooth technology by different industries

![Fig. 2. Implementation cycle of Bluetooth.](image-url)
type of wireless computing. Maybe they just heard about Bluetooth being used at another company, and they think it would also work for them. After the decision is made on what they think is needed, they move into the second phase.

4.2. Information-gathering phase

During the information-gathering phase, information about the new desired system is sought after. Managers and employees research the capabilities of Bluetooth, along with other wireless technologies. Based on the needs of the company, one technology will show some advantages over another. A “perfect solution” is hard to come by, and companies usually have to go with the best fit.

During this phase, information about the current system and how it is used should also be taken into consideration. Employees that would be affected by a change should be able to provide some input into what areas they feel need to be changed. This point is extremely important, because the employees that use the system need to have some say into how things need to change. If these employees are not consulted, then changes for the worse could occur and the time and money spent on implementing the new system would be wasted.

4.3. Feasibility analysis phase

The feasibility analysis phase consists of the same principles discussed in Section 2. First, the managers must decide on what technology is readily available. They should make sure the technology is not so new to the market that there are no cases to display its real world effectiveness. One of the biggest areas a company needs to analyze is the technology’s economical feasibility; does it cost too much? A third area is legal feasibility, and this addresses any malpractices a business could face as a result of using the new technology. The last two areas are operational and scheduling feasibility, and this deal with how effective the technology will be and how long it will take to implement.

4.4. System analysis phase

This is the last phase before the company decides they want to start using the technology. This phase might also be the most important because it can determine if the technology will be adopted or not. During the system analysis phase, the system that is currently in place is tested and analyzed to see how it would react when or if the new system is put in place. If it appears that the current or new system would fail, the project should be stopped at this point. If the project is continued on to the next step without passing this stage, the system could fail and the company would be spending even more money than first estimated on trying to fix the old system.

4.5. Development phase

The development phase is where the system is really tested. This is the phase where the new system is built and integrated with the old system. There are two main ways this can be accomplished. The first, and the safest, is a slow integration where you change over or add the system to one area at a time. The second is an all or nothing approach, where the system is turned on all at once. The first is much safer because if there is a problem early on, it can be addressed and fixed before moving on to another area. If the second approach is taken and something goes wrong, it could bring down the whole system and the company could lose a lot of money.

4.6. Maintenance phase

Once the new system is in place, the maintenance phase will begin, and continue throughout the life of the system. Anytime something goes wrong with the system, someone needs to be there to fix the problem before it causes something worse to happen. This phase also includes keeping the system current with any new versions or updates of system hardware or software.

5. Future implications

The future of Bluetooth is still fuzzy at this point. Depending on where you look people either say the Bluetooth is growing so rapidly, it will easily become the next wireless standard or that Bluetooth does not have enough support and will lose out to the 802.11 standards. Bluetooth and 802.11 compliment each
other if different ways, but most people will use them for many of the same functions.

5.1. Outlook of technology

Most articles you will come across will tell you Bluetooth is here to stay. The biggest reason Bluetooth is looking so good right now is many more companies are integrating it into their products. By 2005, as many as 780 million units are expected to be shipped. This figure is down from previous years predictions of 955 million, and in 2000, it was predicted that 1.4 billion units would be shipped [24]. Part of this drop has to do with the slow economy, but there is still plenty of optimism with the decreasing price. Bluetooth also has support from big names in the technology world such as 3Com, Ericsson, IBM, Intel, Microsoft, Motorola, and Toshiba. With these companies, and more, investing in the future of Bluetooth, it is bound to be around for a while longer.

Some people believe that Bluetooth has already lost in the race for wireless and is just trying to hang on. With the growing Internet and wide variety of data, many people need high band width and fast speeds. Bluetooth falls behind 802.11b in speed. Bluetooth 1.1 will only transfer at 1 Mbps. A new version of Bluetooth, 2.0, is being developed that would boost data rates to 12 Mbps, which is similar to 802.11b [17]. Another concern area is interference between the two wireless standards. A solution, that is being worked on, would keep Bluetooth and 802.11b devices from working on the same frequency at the same time. This may be done with adaptive frequency hopping, which would insure that the two technologies would not use the same band at the same time.

Another setback to Bluetooth’s growth was Microsoft’s decision to leave Bluetooth out of Windows XP [21,22]. The reasoning behind this was that there are not enough Bluetooth devices out there yet, but if production, for hardware and software, increases, Microsoft will most likely incorporate it into new versions of their operation system.

5.2. Future market analysis

Bluetooth’s market share is on the rise. 802.11b has hit a slowing period in its growth while Bluetooth continues to grow. From the technologies first use to connect cell phones to accessories wirelessly, to the many applications it can be used for today, Bluetooth seems to keep finding new areas to sink its teeth into. Still, much of its growth is in the cellular phone industry.

5.3. Limitations/challenges

There are many limitations and challenges that Bluetooth must face. Two of its greatest limitations are its transfer speed and communication distance. Some of Bluetooth’s challenges will be its security, the 2.4-GHz band becoming overcrowded, and many more unforeseen changes in the industry.

The speed of many current Bluetooth devices is not great today, but as Bluetooth keeps spreading to new applications, it will become very limiting. With the Internet continually growing and the various types of data out there, Bluetooth will need to evolve to meet the demands of a high band width and lightning speed access if it is going to grow beyond where it is today.

The distance restrictions on Bluetooth may not be as great of a limitation once the technology continues to grow and there are many more access points installed throughout the world. Another reason Bluetooth has a short range is because it does not consume much power. By increasing the power consumption, the products may get bulkier and more expensive; just the opposite of what the SIG wants. A third key issue that is keeping Bluetooth at such short distances is security. Security is a big concern and challenge that must be overcome in the wireless field. Once Bluetooth becomes much more secure, it would be possible to increase the distance that the radio waves can travel, but until then it is safer to keep it at a shorter distance.

Overcrowding of the 2.4-GHz band will become a challenge to all wireless devices in the future when more people are using the technology. Some steps are already being taken to minimize the impact of overcrowding. Using higher frequencies are being worked on as well as different methods of sending out signals [16].

6. Conclusions

Despite much skepticism about Bluetooth in its initial growth phase, it looks like the technology will
continue to grow and expand into new markers. It has the capability to unite the worlds of computers and telecommunications. Bluetooth will make it possible for businesses to become more flexible in how their environment is setup and can also help companies make better use of their time.

The advantages to using Bluetooth are constantly growing as it spreads into different markets. The four industries that were discussed in this paper have found many different uses of Bluetooth. Each application where the technology can be used is unique in its own way. As new industries pick up Bluetooth, who knows what different types of applications it will be used for.

Even though Bluetooth is showing much promise, there are still many challenges that it must face. One of the biggest problems Bluetooth needs to face head-on is security. The 128-bit encryption scheme it uses may be enough for some data, but sensitive business data that is passed needs to be protected from interception and manipulation. Security will continue to be a problem no matter how advanced it becomes.

References


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