Technical Paper

Radio Frequency (RF) Technology in Handheld Controllers

An Overview of Audio, Video, and Home Control

Key Technologies

- Z-Wave
- RF4CE
- ZigBee
- Bluetooth
- Wi-Fi

Introduction

The proliferation of technology in the home creates a wide range of choices for the consumer. Serving this audience requires deciding on what types of technology to integrate into control devices - the main access point for home entertainment and appliance control. Radio Frequency (RF) has emerged as a leading option that offers many benefits. A methodical approach is required in selecting the optimal technologies within a handheld controller and the partner in the process.

Summary

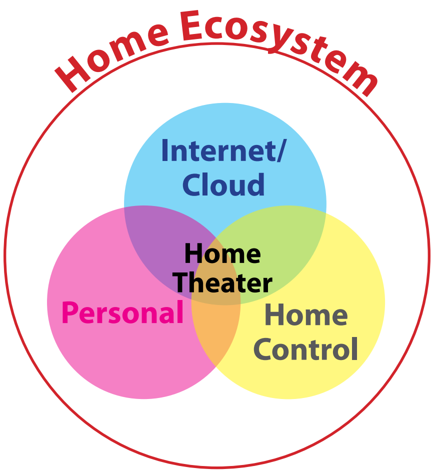
Throughout the market, we can observe a new wave of convergence in progress where service providers are examining new means to include value-added services that add incremental revenue to their business models. Content is now available from new sources and delivered through multiple devices, e.g. set-top boxes, connected TVs, and game consoles. The traditional separation of portals to access the World Wide Web, Broadcast Content and Gaming is fading and new paradigms appear in usage models.

A wide range of factors must be considered when contemplating the technology to be used in control devices to enable these business goals. Cost considerations could impact budgets, while the user experience could be deciding factors for how a product is received by customers in the market. After all, technology is only the means to achieve the desired experience.

Inherant capabilities and possibilities of a technology should be considered as well. As we will discuss here, selecting the technologies in harmony with the desired feature set will enable a natural experience, as opposed to independent selection processes which may end up on a collision path.

An optimal approach will consider the original intent of a technology, the current capabilities, limitations and cost factors; as well as future roadmaps which will prolong the lifespan of a solution. The technological capacity also sets the parameters for the type of environments a device can be used in and for what applications. In short, looking at a wide range of variables is critical to making the decisions that will determine failure and success in the marketplace.

Ecosystems: Conceptualizing Technologies



Home theaters are at the critical intersections of the home ecosystem

Looking at the various ecosystems within the home environment can help in selecting the optimal communication interfaces within a handheld controller.

1. Personal – this short-range ecosystem includes personal devices such as cell phones, PDAs, handheld gaming devices, computers, and network peripherals. The original intent of this ecosystem is simply "short cable" replacement while maintaining the end-to-end throughput. The popular technology of choice for the personal ecosystem is Bluetooth.
2. Home control – a rapidly growing ecosystem impacted by control devices is that of automating home control. Included in this ecosystem are lighting controls, thermostat, security, and energy/utility systems. As expected, the main intent in such an ecosystem is achieving ultra low power consumption for simple and cost effective nodes which is achieved by sacrificing throughput. Competing technologies in this arena include Z-Wave® and ZigBee®.
3. Internet/cloud – this ecosystem previously was the sole domain of personal computers. New home entertainment devices look to tap directly into the intranet/internet, access digital media on the PC throughout the home as well as access all services in the "cloud". Wi-Fi® is the main technology in this ecosystem.

The "home entertainment system" is now at the intersection of these ecosystems where the next wave of convergence is occurring.

Handheld Controllers are the only component in the system physically touched by the end user. As such, the ability of a controller to access media and services in a quick and intuitive manner is critical. The end users' needs in each individual or overlapping ecosystem should be the starting point in any discussions on selection of control technology. After all, technology is nothing more than the enabler for market needs.

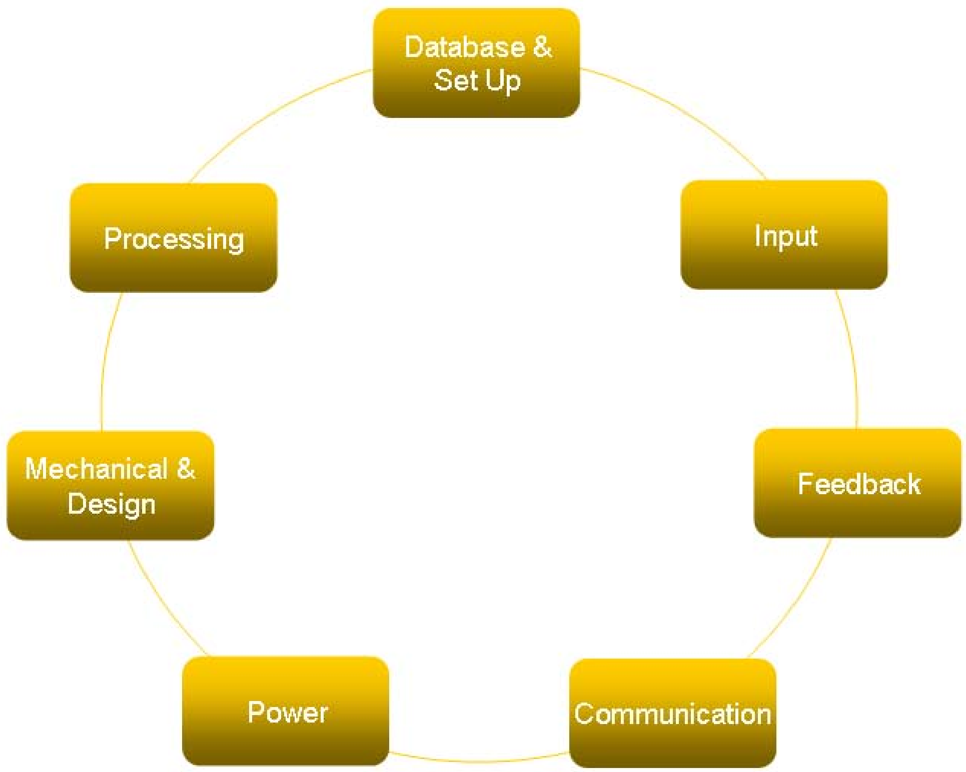
The traditional enabling technology within the home theater ecosystem is infrared (IR) and each of the newly emerging ecosystems are designed around their own wireless communication standard. All communication mediums have their merits and drawbacks depending on the use cases. The main focus of this paper will be on discussing the development, benefits and drawbacks of relevant RF technologies.

Building Blocks: Key Determinants for Selecting Technologies

The next step in selecting technologies for control devices, after understanding the target ecosystem, is to look at the building blocks of a controller interface.

Building blocks are the fundamental pieces of the puzzle which should be selected in synergy with one another. The interaction paradigm will decide the optimal technologies to use as the means of input to the system. A handheld controller based on Capacitive Sensing technology requirements on the design and ergonomics of the handheld differs from a traditional push-button approach. A motion based precision pointing solution has strict requirements on latency of the communication medium compared to a gesture or voice recognition approach where discrete commands are identified and transmitted to the target.

The Dolphin controller utilizes motion based pointing and selection

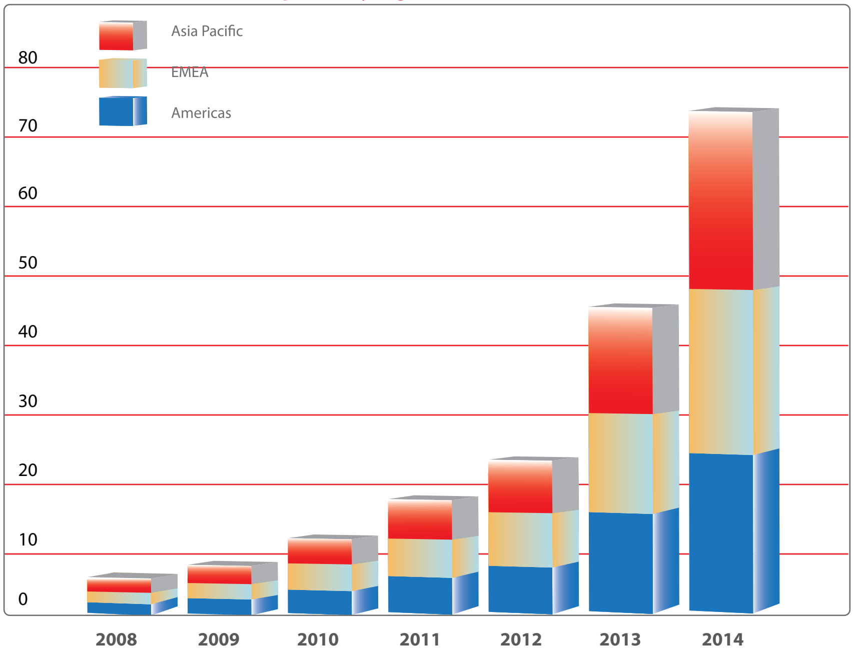


As seen above, each building block has its own unique requirements that allow service providers the freedom to pick and choose based on their needs. Compromises will need to be made by selecting one block versus another. The priorities will be different for each company due to differing user needs, business goals, and ecosystems.

Market size and growth

According to ABI Research, the market for RF remote control shipments will grow 12% over the next five years from 5.4 million units in 2008 to 74.7 million units in 2014.

RF Remote Control Shipments by Region, World Market, Forecast: 2008 to 2014



Source: ABI Research

What are the main questions which should be considered while selecting the wireless technology for a handheld controller?

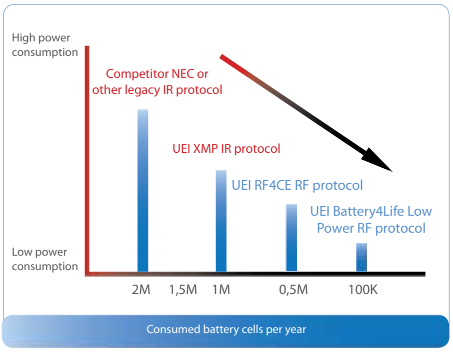
Service providers should review all the various aspects of technology under the frameworks of "ecosystems" and "building blocks". Having a clear understanding of what environment the device is to work within, as well as the benefits and limitations of building blocks, will assist in making an informed decision.

What is the ultimate goal of the control device? What are the short-term and long-term goals?

Within the framework of these questions, companies should consider the following:

- **Line of sight.** If a remote control device must be pointed directly at the application to work, its overall range is limited. If the device can get around the line of sight issue, it can be used in a much larger environment and from a remote location. Radio Frequency technology removes line of sight limitations.

Universal Electronics energy efficient solutions



Consumed battery cells chart based on:
- 300 key presses per day
- 1 million subscribers

- **Range is critical.** Without sufficient range or coverage, a remote control device is unable to control or monitor anything outside its immediate vicinity. With extended range, a remote control device can be used in several different scenarios across the many different locations where applications are based in the household. As seen later in this document, certain technologies are intended for a single room control, some allow whole home coverage, and others enable remote access through the cloud.
- **Ramifications of power consumption.** There are feature and performance tradeoffs to be made which can drastically improve or degrade the battery life of a design. Is the final intent a move towards a "Green" solution, or would you prefer a rechargeable handheld for digital media browse and control?
- **Latency and throughput.** The flow of data being transmitted must occur smoothly and efficiently. If there are noticeable levels of latency, the user experience will be negatively impacted and the ability of the device to communicate will be jeopardized.
- **Cost factors.** Some wireless technologies are much more expensive to implement, affecting the retail price and the service provider's bottom-line.
- **Interoperability.** The ability to work within an ecosystem provides a level of efficiency and convenience that may be crucial to the user experience.
- **User experience.** The user experience is a derivative of many factors: line of sight, latency, power consumption, throughout, and interoperability. Service providers must evaluate all these factors when assessing the total user experience. A positive user experience translates into higher sales and is a key ingredient to the overall success of an offering.
- **Advanced features.** These "bonus" features empower the user and enhance the utility of the device. More is not necessarily better, but devices that have good features enhance the user experience and translate into a tangible amount of real value. As an example, in the new paradigm the handheld is now considered to be the "second screen" within the home enabling status or even content retrieval from local and remote sources. The source and type of content displayed will have certain requirements on selecting the optimal communication interface.

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What options are available for use in handheld controllers?

		Z-Wave	RF4CE	Zigbee	Bluetooth	WiFi
	Ideal Application	Home Entertainment Home Control Home Awareness	Home Entertainment	Industrial Applications Commerical Building Home Entertainment Home Control Home Awareness	Mobile Applications Wireless Peripherals Music Streaming Digital Media Control Home Entertainment	Digital Media Control Home Entertainment Asset Tracking Wireless Sensing
Remote Control Features	**Frequency Band**	866/908/921 MHz	2.4 GHz	2.4GHz (Sub-GHz not much used)	2.4GHz	2.4GHz
	Data Rate	Depending on version up to 40 Kbits/Second	250 Kbits / second	250 Kbits / second	Up to 3 Mbits / second	1-2 (up to 54) Mbits/second
	RF Range (open air)	30 meters	10 - 75 meters	10 - 75 meters	1 meters (Class 3) 10 meters (Class 2) 100 meters (Class 1)	50 meters
	Network Type	Mesh	Point-to-Point	Star, Mesh	Piconet, Scatternet	Ad-hoc, Infrastructure
	Battery Life	Years	Years	Years	Days-Months*	Days-months
Specifications and Certification	**Interoperability**	Z-Wave	Zigbee RF4CE	Zigbee PRO	Bluetooth	WiFi
	MAC/PHY Specification	Proprietary	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.1	IEEE 802.11b/g
	# of Channels	1	3	16	79	11-14
	Security Types Supported	AES-128 Encryption	AES-128 Encryption / Authentication	AES-128 Encryption / Authentication	8-128 bit Block cipher	64/128 bit WEP, WPA
	Stack Size (without application)	32KB	32KB	40KB-100KB	~100KB+	200KB+
	Certification & Membership	Z-Wave Alliance	Zigbee Alliance	Zigbee Alliance	Bluetooth SIG & BQB	WiFi Alliance

* Bluetooth 3.0 is able to extend battery life to 1-2 years. Bluetooth low energy will improve this further

Sirius Conductor utilizes RF to transmit station metadata to controller

Z-Wave®

Z-Wave is a wireless technology developed and maintained by Zensys® , now a division of Sigma Designs® . The Z-Wave Alliance is the consortium of companies that oversees the Z-Wave standard formed in January of 2005.

Z-Wave is a low power wireless technology employing low frequency radio waves, operating in the sub-Gigahertz range, to connect a wide range of consumer electronics into an integrated wireless network for automated control. The topology of a Z-Wave network is based on a mesh networking approach where certain nodes will act as routers within the network enabling whole home coverage even when the destination is not within direct reach.

Z-Wave nodes are classified based on capabilities which decide whether a node will participate in routing, can start a new network, can store network configurations, and so forth. Certain nodes are optimized for minimal footprint or battery operation and; therefore, do not participate in message routing.

The range of a Z-Wave signal is strongly influenced by the environment; for example the number of walls that the signal has to move through. Typical ranges achieved by Z-Wave customers are 30 meters (98 feet) indoors and over 100 meters (328 feet) outdoors in the open air. In the United States, Z-Wave uses the 908.42 MHz ISM band, and the 868.42MHz band in Europe. First generation Z-Wave had a data rate of 9.6kbps and by the second generation the data rate was increased to 40kbps, while still maintaining backwards interoperability with the previous generation.

Z-Wave is optimized for short messages for control and status retrieval; therefore, commonly used for basic functionality such as turning on and off home entertainment systems, lights, thermostats, garage doors, and AV equipment. On a slightly more sophisticated level, Z-Wave can be used to retrieve and display short text based metadata in products such as Sirius Conductor .

Remote control devices deploying Z-Wave can be used manually or set to make automated decisions such as turning on and off lights at a set time in the day. Z-Wave devices can also be accessed online through a gateway combining Z-Wave and Internet access. The convergence of Z-Wave and IP will allow users to control Z-Wave devices from the Internet. This will provide another access gateway that opens the door to web-based applications like reporting and status information.

Benefits

The main benefit of Z-Wave is **interoperability of nodes**, which is the result of a single provider for the solution as well as rigorous certification processes for the end products utilizing this technology. The close control of the technology from a single silicon provider has led to a broad range of products compatible with the Z-Wave standard.

The features and capabilities of Z-Wave devices are based on a predefined set of "Command Classes" (similar to the concept of profiles in Bluetooth, ZigBee and RF4CE) which define how a certain feature can be controlled and what the expected response is. This interoperability extends beyond an RF layer standard and assures the end products are able to properly interact.

Z-Wave delivers several additional benefits. The first benefit is **low power consumption**. Due to the original intent of this technology, it is designed to support "instant on" (or connectionless) functionality. This means that on a battery operated handheld device, the radio is turned off most of the time and is only turned on when a command is to be transmitted, therefore, it does not consume a lot of power.

Also, the technology is **easy to deploy** and does not require the user to have any technical knowledge. The user plugs the device or appliance they want to control into the Z-Wave module and they are up and running. Assistance from installation technicians or complicated wiring or device programming is not required. Ultimately, this translates into cost savings and convenience for both the service provider and the customer.

In addition, Z-Wave gives the user **flexibility and choice**. Z-Wave can be used for only certain devices or specific areas of the home as each node and network has a unique identity and can coexist in the same environment. The user makes that decision.

Since Z-Wave runs at sub 1 GHz frequencies, **it avoids interference** from common household appliances such as microwaves, wireless Internet routers, cordless telephones and Bluetooth devices that operate in and around the crowded 2.4 GHz ISM band. The separation of the frequency spectrums also enables elegant designs of dual RF handhelds such as where Wi-Fi and Z-Wave are operating within inches of each other.

Importantly, the underlying architecture of Z-Wave enables it to reach all corners of the home environment undisturbed. This is accomplished by building a network with multiple nodes - known as mesh networking. If a signal or command is not able to directly reach a node on the network, it simply re-routes and finds an alternative path through the remaining nodes. Mesh networking allows Z-Wave to avoid and circumvent radio dead spots created by multi path interference or interference presented by walls, floors and other household obstacles.

A notable practical application for Z-Wave technology is energy conservation. With Z-Wave, users are able to control and regulate energy consumption. This ties in with another important benefit of Z-Wave technology: **intelligence**. Z-Wave allows the user to link select devices and appliances in the household, allowing them to "talk" to each other. For example, when the garage door is opened, it can be set to automatically turn on the lights at the same time. Thermostat temperature can also be set to change when sensors detect outside light. This produces potential environmental as well as financial benefits.

Drawbacks

The inherent nature of Z-Wave's proprietary system means there is **only one provider** without competition. Businesses will need to weigh the benefits and drawbacks of using a proprietary system for their products.

Furthermore, due to the original intent of this technology, applications which require Quality of Service (QoS) or higher data rates, such as digital media transfer, are not suitable for this **low data rate** ecosystem. The **latency** requirements of some applications also limit the usability of the mesh networking feature where delays due to route discovery may result in undesirable delays that can impact the user experience.

Finally, a consumer product intended for **global markets will require different hardware variations** to account for regional frequency spectrums. This tends to drive up the cost of design and certification of the device. The software, however, is fully compatible regardless of region.

RF4CE's low power consumption, robustness, and long range all make it an attractive option for the right products.

RF4CE

RF4CE is designed for a wide range of remote-controlled A/V consumer electronics products, such as televisions and set-top boxes. The RF4CE (Radio Frequency for Consumer Electronics) Consortium was formed in mid-2008 by a conglomeration of the top consumer electronics manufacturers (Panasonic, Philips, Samsung and Sony) to jointly deliver a standardized specification for RF remotes. The RF4CE specification is now a special group under the ZigBee umbrella with its own steering committee. The alignment of these two organizations is designed to create a single global standard for radio frequency-based remote controls.

UEI's "Glimmer" demonstration platform ultilizes a combination of IR and RF4CE communications

The RF4CE consortium defined a simple and secure networking layer for point-to-point communications working on top of IEEE 802.15.4 specifications for Medium Access Control and Physical layers (MAC/PHY). In the past few years dozens of proprietary solutions were defined based on the popular IEEE 802.15.4 compliant transceivers, notably SimpliciTI® from Texas Instruments, SMAC and EC-Net from Freescale (latter is known to be the origin of RF4CE effort) among others. RF4CE can be deemed as the first attempt at a standardized and simple point-to-point solution in star topology for command and control.

There are more sophisticated network layer standards which fully utilize IEEE 802.15.4 features such as ZigBee and 6LoWPAN (IPv6 over Low power Wireless Personal Area Network). However the intent behind RF4CE is to simplify the solution, thereby making it easier and cheaper to implement while still utilizing a proven radio technology.

RF4CE runs in the 2.4GHz ISM band with a data rate of 250kbps. Frequency agility operation over 3 channels (upper and lower boundaries of the spectrum as well as one in the middle) reduces mutual interference as well as other sources of noise within this crowded band. Among the two types of nodes within an RF4CE network, controller, and target, it is the responsibility of the target to monitor the channels and choose the best option based on a set of criteria which defines the reliability of a channel. This standard also incorporates power saving mechanisms for all device classes taking into consideration the power requirements of battery operated handheld devices.

This standard also defines a common profile for standard AV control command set (CERC – Consumer Electronics Remote Control) to assure interoperability for control of basic functionalities. The standard also allows for vendor specific profiles to be used in order to support device specific features such as metadata retrieval.

Benefits

RF4CE is one of the most **cost-competitive** standards-based solutions, and offers an alternative to Bluetooth with certain limitations. RF4CE is not based on a new chipset but rather uses silicon that is already in millions of products used. The network layer is a lightweight software stack and is easy to integrate into existing solutions. Therefore, it is enjoying the stability of a mature radio technology as well as the reduced cost due to the sheer volume.

RF4CE's **low power consumption, robustness, and long range** all make it an attractive option for the right products. The outdoor range can reach ~300 meters (984 feet) dependent on the design. Also due to the nature of the technology an ultra low power solution can be achieved for short sporadic messages for command and control, such as the typical interaction with AV equipment.

Certain Sony television models with the predecessor of RF4CE have been shown in previous years, as well as the exhibition of new Samsung TVs and Dish Networks' ultimate set-top box in 2009.

Drawbacks

The inherent nature of RF4CE technology means it is **restricted to simple point-to-point uses**, such as between a remote device and a television or a cable set-top box. It is not designed with the intent of whole home coverage and is limited to the indoor controller-target range within the home.

Although RF4CE has more than 6X the data rate of a 3rd generation Z-Wave solution, it is still **not suitable for audio/video streaming**. Operation within the crowded 2.4GHz spectrum carries certain boundary cases which should be taken into consideration. As an example, unlike Bluetooth with proven solutions for coexistence with Wi-Fi in a single handheld, this technology does not specify solutions for such a design.

The **existing ecosystem is small** compared to Bluetooth, but should continue to grow with the new ZigBee association. However, integration with ZigBee at the time of writing is only a roadmap and has yet to be realized.

ZigBee, a single standard, allows devices manufactured by different vendors to work with each other.

ZigBee

ZigBee, is based on the IEEE 802.15.4 standard for low data rate wireless personal area network communications, set by the Institute of Electrical and Electronics Engineers (IEEE). The ZigBee standard is maintained by the ZigBee Alliance, an association of companies that are dedicated to creating an open global standard for enabling wireless monitoring and control products in the consumer market. Development of the standard began in 1998 when certain controller manufacturers realized that Bluetooth and Wi-Fi were not able to satisfy the needs of low power, low data rate applications such as home automation and sensor networks. The ZigBee standard was made publicly available in June 2005.

ZigBee was chosen for Crystalis due to global coverage and low power requirements

ZigBee is typically used in wireless controllers or monitoring devices that require low power consumption and transmit low data rates. ZigBee can be found in higher-end consumer electronics devices with a strong presence in industrial applications and home area networks (HAN) as part of a smart energy grid. The technology is starting to emerge as an attractive choice for home automation functions such as controlling lights, smoke sensors, temperature, home theater, and various other appliances.

ZigBee network topology is fairly similar to that of a Z-Wave network, where nodes are classified based on capabilities and their role in the network. The fundamental concepts of a mesh networking topology apply, however, the routing is done with a different approach compared to Z-Wave. The ZigBee standard is more comprehensive with a larger footprint compared to Z-Wave and supports more configurations and interaction models.

Although ZigBee defines standard profiles, most current solutions do not take advantage of these capabilities and use the technology as a transport layer for their closed ecosystem.

ZigBee runs on the 868 MHz band in Europe; the 915 MHz band in the U.S. and Australia; as well as on the popular 2.4 GHz band globally. The data rate is much higher when compared with Z-Wave, at up to 250 kbps (on the 2.4 GHz band), but it is less than that of Bluetooth or Wi-Fi. ZigBee supports data rates at 40 kbps per channel on the 915 MHz band and 20 kbps on the 868 MHz band.

There are 16 channels defined in the 2.4 GHz ISM band which allows the selection of an optimal channel based on the environment. The typical channel access paradigm in a ZigBee network is simply checking the airwaves before transmitting to minimize collisions. ZigBee also implements extensive security measures. There are three security keys and the AES 128-bit encryption standard is used.

Battery life averages are 100-1,000 days and the transmission range is from 1-100 meters (3-328 feet). A ZigBee device is capable of activating from sleep to active mode in less than 15 milliseconds enabling a low latency, "instant on", experience.

Benefits

ZigBee provides the promise of **interoperability**. A single standard allows devices manufactured by different vendors to work with each other. This gives customers flexibility of choice and allows vendors to create products that work in any environment.

ZigBee-enabled devices can **control and monitor across longer distances and through typical obstructions** found in the home. Building a network with multiple nodes - a practice known as **mesh networking** – makes this possible. If a signal does not reach a node directly, it finds an alternative path through the other nodes on the network, enabling whole home coverage.

ZigBee is relatively **cost-effective** and because of the low data rates transmitted, does not use up a lot of power. This helps the consumer and vendor. Consumers experience longer battery life and cheaper prices, while vendors benefit from competitive wholesale and production costs.

Unlike Z-Wave, different hardware is not required as the **2.4GHz ISM band used by Zigbee is globally accessible**, there are **many silicon vendors with solutions based on this open standard**; and unlike RF4CE, **ZigBee is able to provide whole home coverage**.

Drawbacks

Similar to RF4CE and Z-Wave, the intended use of ZigBee means its lower data rate limitation is **not suitable for audio or video streaming**. Also, the comprehensive set of features defined in the ZigBee protocol consumes additional memory resources.

An **interoperable ZigBee ecosystem has not yet been achieved** due to the proprietary nature of applications deployed thus far. However there has been additional focus in this area by the ZigBee alliance which holds the promise of upcoming interoperable solutions based on standard profiles.

There is inherently **no access to the cloud** in ZigBee, although some research shows promise through 6LowPAN efforts to port IPv6 onto IEEE 802.15.4. To this point it has been difficult and considered impractical to extend Internet protocol to low-power, wireless personal area networks (LoWPAN) because of the resource and bandwidth-intensive nature of the exercise. Vendors have opted for application specific protocols – such as ZigBee - but there is progress being made towards IP-based technologies within industry circles. The Internet Protocol for Smart Objects (IPSO) Alliance is an organization whose objective is to research and document the use of IP-based Technologies for wireless networking. An important development is 6LoWPAN, which is designed to incorporate IEEE 802.15.4 into IP-based architecture. 6LoWPAN introduces an adaptation layer between the IP and radio-based network layer to enable transition of IPv6 data over 802.15.4 radio links while reducing IP overhead through compression technologies. This is in the earlier stages of development, but the ultimate end game is the extension of remote control devices to access Internet-based content, media, and applications.

Although 6LowPAN might be deemed as a competitor to the ZigBee standard, building on the same foundation and providing similar functionality, however the concept of an "IP-connected super node" with the ability to communicate on all IEEE 802.15.4 based networks is intriguing with limitless applications.

At time of writing, the newer Zigbee ecosystem has a **narrow range of compatible products** compared to Z-Wave and Bluetooth. Incorporating global IT standards from the Internet Engineering Task Force (IETF) into the ZigBee specification portfolio will help expand and advance the growth of smart grid applications that adopted the ZigBee Smart Energy public application profile.

Since its launch, Bluetooth has grown to become integrated into the daily lives of many consumers.

Bluetooth

Bluetooth is a wireless protocol developed and licensed by the Bluetooth Special Interest Group (SIG) that is used to create personal area networks for short-range communications. Bluetooth transmits and receives on the 2.4 GHz radio frequency band and is typically used with mobile devices for transmitting sound and in laptop computers for transferring byte data. Bluetooth 2.0 + EDR can transmit up to rates of 3 mbps and is designed for low power consumption with a typical battery life ranging from 1-7 days.

Since its initial development in 1994, Bluetooth has gone through multiple iterations. Bluetooth 1.0 and 1.0B were plagued with problems which 1.1 and 1.2 addressed. By the time Bluetooth 2.0 was released in 2004, the introduction of Enhanced Data Rate (EDR) for faster data transfer of up to 3 mbps helped increase the popularity of Bluetooth for accessories within the Personal Area Network (PAN). Bluetooth 3.0 included a main new feature of AMP (Alternate MAC/PHY), the addition of 802.11 (or UWB – Ultra Wide Band) as a high speed transport when needed while still utilizing the simplicity of the features (profiles) defined in Bluetooth.

Starting with Bluetooth 1.1 the specification has been ratified as part of the IEEE 802.15.1 working group. The 802.15 working group is mainly focused on the wireless personal area networks (WPAN), where 802.15.4 addresses the low data rate application needs such as ZigBee and RF4CE, and 802.15.1 is targeted towards applications such as Bluetooth with higher data rate requirements and less restrictions on power consumption.

The basic topology of a Bluetooth network consists of a single master and a maximum of seven active slaves where communication can occur only between a master and a slave. This simple configuration is called a piconet. The standard allows connecting piconets to achieve larger networks called scatternet, however, this feature is not typically used/enabled.

Bluetooth devices are divided into three classes dependent on the radio output power, where a class 1 radio can achieve ~100 meters (328 feet) in range, class 2 which is the most popular option widely deployed in cell phones is ~10 meters (33 feet) and a class 3 has the shortest reach of only about a meter (3 feet). A class 1 solution exhibits the shortest battery life among the three.

Similar to ZigBee, application behaviors are standardized as profiles, assuring interoperability among solutions. As an example, "Headset Profile" defines an interaction model between your headset and cell phone including audio transfer and control functionalities.

Benefits

A key benefit of Bluetooth is the **prolific ecosystem of products surrounding the technology**. Since its launch, Bluetooth has grown to become integrated into the daily lives of many consumers. The Bluetooth brand has become quite well known and accepted.

Another benefit of Bluetooth is its **positive impact on the user experience**. Bluetooth is moving quickly into the world of home entertainment. Sony PlayStation3 was among the first major deployed solutions utilizing this technology due to the inherit benefits for advanced controllers, recently manufacturers such as Sharp and LG have integrated this technology into their television sets and handheld controllers to further enhance the user experience. The users can access content stored on digital cameras and cellular phones and use Bluetooth-enabled peripherals such as wireless headsets to enable new usage paradigms. The handheld is now able to receive and display digital media from the TV and be used as the second screen within the home.

Bluetooth **implementation costs are declining**, making it cost-effective to implement. It is also a standardized technology that guarantees device compatibility. This is good for both the service provider and end user.

Bluetooth **performs well in noisy environments** using a technique called adaptive frequency hopping in order to avoid interference. Through a dynamically selected hopping sequence across channels, the effects of environment noise are minimized.

Drawbacks

While Bluetooth offers a number of advantages, its most significant drawback is **limited range** of up to about 10 meters (33 feet) for the most common class of device deployed. Given the use case of Bluetooth for devices within a PAN, it is well suited for its purpose. While data rate transfers are relatively robust, it is still **not fast enough for native high fidelity of music** without some down sampling.

Prior to the Bluetooth 3.0 release (April 2009), the standard did not account for sporadic short messages as the main usage paradigm. The protocol was mainly **focused on connection oriented interactions** and the initial latency was not an issue. In Bluetooth 3.0 release, it is now possible to transmit "Unicast Connectionless Data" (UCD) without an L2CAP channel. Adaptive Frequency Hopping (AFH) setup process is also bypassed as the usage is intended for short bursts of data where frequency hopping will not provide much benefit.

The 3.0 specification is an attempt to address startup latency, thereby also reducing the power consumption by allowing a Bluetooth device to only enable the radio for short messages. This release does not however provide a feasible solution to another step in connection setup process, initial baseband connection setup.

The Bluetooth protocol divides the 2.4 GHz ISM band into 79 channels, each 1 MHz wide. The baseband connection process requires both sides to "meet" on a common channel. As you can see, with a possibility of 79 channels, this process can take a noticeable amount of time which is dependent on the "scan mode" used. With a higher scan rate, the delays will be shorter while increasing the power consumption and load. An R1 Page scan can introduce ~1.28s delay and a continuous scan results in ~40ms of delay.

Bluetooth Low Energy (LE) is an entirely new protocol stack introduced by the interest group, and may one day compete directly with RF4CE. For smaller Bluetooth-enabled devices, Nokia, Broadcom and others developed Wibree, which is the pre-cursor to Bluetooth Low Energy, a digital radio technology adapted from the Bluetooth standard and designed for extremely low levels of power consumption. Bluetooth LE operates at ranges of between 5 and 10 meters (or 16.5 to 33 feet) at a data rate of about 1 mbps on the 2.4 GHz radio band. Bluetooth Low Energy is intended to be a complement to Bluetooth and is commonly found in smaller devices such as wristwatches. The current draft of the specification simplifies the connection model by limiting the number of channels, profiles, and data rate with the hope of removing the latencies and reducing the total solution cost.

Wi-Fi makes it possible for many different types of devices to have direct access to the Internet

Wi-Fi

Wi-Fi is a wireless networking technology based on the IEEE 802.11 set of wireless local area network (WLAN) communication standards, certified by the Wi-Fi Alliance which enables Internet access across the higher frequency 2.4, 3.5 and 5 GHz radio bands. The standards also facilitate interoperability between the various Wi-Fi enabled products produced by different manufacturers.

Wi-Fi's data rate is substantially higher than Bluetooth or ZigBee, with increased data rate from one generation to next, where 802.11b was only capable of 11mbps and the 802.11n is able to handle up to 600 mbps. It is important to note the actual throughput, similar to other standards, is not equal to the data rate. As an example, an 802.11n deployment has a typical throughput of ~144mbps. The average battery life for a typical 802.11g handheld can range from half a day to 5 days.

NevoS70 successfully combines Z-Wave, Wi-Fi, and IR all on one platform

A wide range of existing applications and devices support Wi-Fi including video game consoles, mobile devices, routers, operating systems, printers and other consumer electronic devices. These devices get online simply by accessing a wireless access point that is connected to or is itself connected via a broadband connection to the Internet. The typical usage of Wi-Fi is the use of a laptop computer or mobile device sharing a home broadband connection or to use the Internet connection provided at a Wi-Fi enabled hotspot.

There is also growing usage of IP based networking to access Internet-based content on the television. Vizio, Sony, Samsung, and LG have introduced television sets that allow users to access internet content based on the Yahoo Connected TV Platform. The content appears on their television normal, but the transmission is taking place over an IP network rather than using traditional cable formats. The Microsoft Mediaroom Platform, Open IPTV forum are other examples of delivery of content through the IP infrastructure with more interactivity. Apple TV and iTunes, Amazon, Netflix, and Blockbuster are all exploring content delivery to the living room over the existing IP infrastructure.

The movement to standards adoption is strong across the industry as manufacturers, vendors, component and software developers all have a vested interest in more uniformity. Digital Living Network Alliance (DLNA), for example, publishes interoperability guidelines based on open industry standards in an effort to promote compatibility across devices, platforms, and software. DLNA has 245 members, including names such as Comcast, Cisco, HP, Microsoft, Nokia, Motorola, Sony, Toshiba, Samsung, LG and others. Included in DLNA specifications are features defined as part of the Universal Plug and Play (UPnP) standard to allow devices to seamlessly connect and control digital media across the home network.

Wi-Fi is distinguished as technically different from other standards like RF4CE, Z-Wave, ZigBee, and Bluetooth. The other standards attempt is to define all components of the system with their own complete definitions, commands, services, classes, and final applications that the user can interact with. In contrast, Wi-Fi only defines the interaction with the physical mediums and how data is passed back and forth using raw data streams and open pipelines.

Benefits

By defining only how data is exchanged, **Wi-Fi allows flexibility**. Wi-Fi enables a diverse set of applications to be built on top of it such as streaming audio, voice and HD video as well as high-end applications requiring high bandwidth or guaranteed data delivery. Wi-Fi is interoperable with other IP networks enabling seamless integration with both the Local Area Network (LAN) and the Wide Area Network (WAN). Because it extends beyond a Personal Area Network (PAN), with the use of a wireless bridge, Wi-Fi can interface with different network types including wired Ethernet and fiber optic networks while remaining completely transparent to the user. An IP based ecosystem is not limited by RF limitations and can continuously convert back and forth.

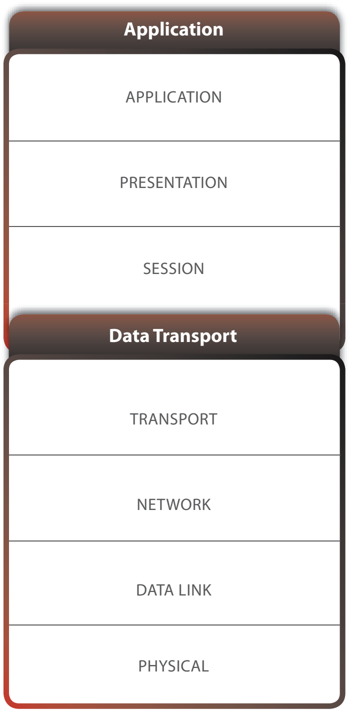
Wi-Fi makes it possible for many different types of devices to have **direct access to the Internet** - from a laptop computer to a small handheld remote control. The IP networking standard allows for remote control of any IP enabled device such as the pan, tilt and zoom of a security camera outside of the house monitoring a yard or pool while watching the video in the comfort of the living room. Wi-Fi also eliminates the constraints on Internet access posed by wiring and cables, enabling Internet access in places not previously possible such as in outdoor areas and in rooms not fitted with network cables.

Wi-Fi significantly **expands the amount of accessible information** to handheld controllers. For example, devices can be used to download and display content such as weather or sports scores. This is an alternative to changing the channel on the television or reaching for the laptop computer. Wi-Fi also **makes web-based services accessible** from the cloud by the handheld. This is of particular value to vendors, which can leverage this capability to enrich the user experience, while providing a cost-effective way to reach and service customers. For example, service providers could allow their customers to manage their accounts, access support and order additional services from the palm of their hand without needing to display potentially private data on the TV screen and without interrupting the content that is currently showing.

Drawbacks

Wi-Fi provides significant flexibility and bandwidth with certain limitations. Given the diverse Wi-Fi solutions available there can be **significant differences in performance between different devices**. Some older Wi-Fi networks running on 802.11a, b or g can have limited range, up to 35 meters (115 ft) indoors and up to 95 meters (310 ft) outdoors. The **range also differs across the radio frequency bands**. However the release of 802.11n has substantially increased Wi-Fi range and data rate transfer, enabling over the air HD streaming. The enhancements are due to new features such as Multiple-Input Multiple-Output (MIMO), channel bonding and frame aggregation.

Two Sets of Layers Make Up the Wi-Fi OSI Standard



Above the Wi-Fi communications medium, multiple layers are required to interact with each other before features can be delivered to the user.

The Open Systems Interconnection Reference Model (OSI) is a standard developed by the International Organization for Standardization (ISO) to help describe layered communications. In its most basic form, the model divides network architecture into seven layers: Application, Presentation, Session, Transport, Network, Data-Link, and Physical.

These multiple layers have requirements for association, authentication and finding IP addresses that interact to send data along a path to the user.

Standards such as Bluetooth define all required layers to enable final features exposed to the end user. However Wi-Fi simply defines the bottom two layers for pure data delivery. Examples of layers above include IP for network layer, UDP as the transport protocol and HTTP handling other layers of web based content delivery.

Multiple layers of protocols defined and optimized for compatibility and functionality translate into a **higher processing requirement** of the system. The multiple layers and requirements for association, authentication, finding IP addresses and such add to connection delays. This is in comparison to Z-Wave and ZigBee which allows instant-on functionality. Wi-Fi also has relatively higher power consumption, putting pressure on battery life.

Security and setup are other areas of concern. The original encryption standard, Wired Equivalent Privacy (WEP), has proven to be breakable even when properly configured. Newer WPA and WPA2 are much more secure but add even more layers and latency. To be enabled, security generally requires a user configuration, which may eventually involve support from the service provider. Research continues on improvements to encryption standards, including WPS (Wi-Fi Protected Setup) to enable a simple push-button type network setup procedure similar to that of previously discussed standards for Personal Area Networks.

Research also continues on low power Wi-Fi to address the drawback of the **high power requirements** of traditional Wi-Fi. Low power Wi-Fi makes compromises on data rate for devices with a smaller footprint: handheld controllers compared to laptop computers, for example.

Proprietary RF Technologies

While the development of open standards continues, certain application specific deployments utilize an optimized proprietary technology. Decisions to go the proprietary route should be made with a clear understanding of future roadmaps. Proprietary technologies may solve one problem but thus exclude all aftermarket remote devices, limiting options for the consumer.

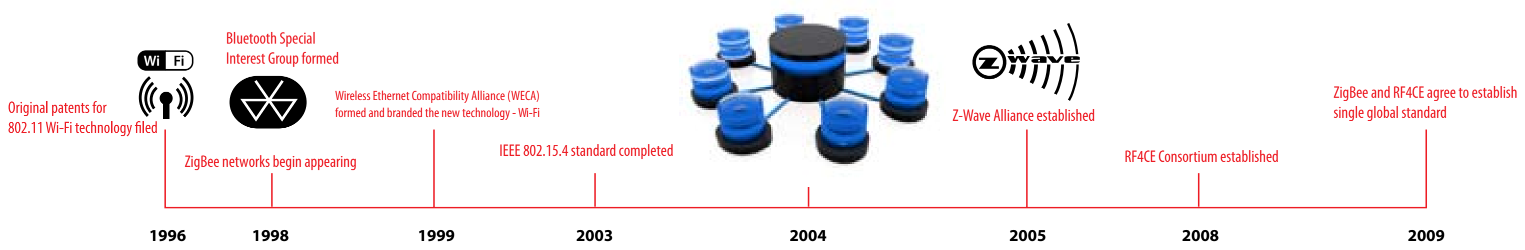
However, a standards based approach may, and probably will, include features not directly applicable to an application. This adds cost and complexity to satisfy compliance to a standard. This trade off should be made with care dependent on the expected lifespan of a solution.

The main commonly mentioned benefit of a radio frequency based controllers is non-line of sight control. If this is the only enhancement required by the solution, cost and performance can be optimized with a proprietary solution. As an example, DIRECTV® utilizes a unidirectional Sub 1 Gigahertz radio technology specifically tailored to enable non-line of sight control. As a result, the handheld controller is compatible only with DIRECTV receivers.

An Infrared (IR) Alternative to RF

Radio frequency-based wireless technology is not the only communication option. **eXtensable Multimedia Protocol (XMP®) and XMP-2 two-way IR** are proprietary wireless connectivity protocols, developed by Universal Electronics, that offers strong data rates and power consumption for IR protocol.

XMP enables the delivery, exchange and control of digital media in the home by using a wireless communication technology available to support OEM platforms and their interactive applications and services. XMP offers communication between the application/STB and its controller that scales as the interactive environment expands, from basic device control to high-speed, two-way interaction.



Conclusion

The proliferation of technologies and options for consumers has triggered a growing race. Cable, satellite, Telco TV, IPTV, Video On Demand, DVDs by mail and gaming providers are all battling to be the provider of choice to the consumer. Companies are thus looking for ways to grow their business without adding significant costs.

The question frequently asked is, who will win? The answer is no "one" technology or provider will win out. Rather, a collection of optimized integrated solutions living in harmony will provide various services and applications to the end user.

The decision on what technology to use for remote devices thus requires a clear and accurate understanding of ecosystems, user needs, and consideration of numerous other business and technological factors. Having a vendor with no vested interest in the success of any particular technology but an in-depth understanding of the technological landscape is invaluable. The proper vendor can translate application and user requirements into selecting the right RF technology for today's and tomorrow's needs.

Universal Electronics Inc. (UEI)

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Mr. Hatambeiki holds a Master of Science degree in Computer and Communications Engineering from San Francisco University and has taught and studied advanced electronics and math at multiple levels. Over the last 5 years at Universal Electronics, he has applied his experience and talents with math, engineering, and wireless solutions to create effective, efficient, software and hardware applications for consumer control devices. UEI control devices and technology are deployed with large and small communications and electronics companies all over the world.

UEI control devices and technology are deployed with large and small communications and electronics companies worldwide.

Universal Electronics: A History of Wireless Innovation

Founded in 1986, Universal Electronics Inc. (UEI) is the global leader in wireless control technology for the connected home. UEI designs, develops, and delivers innovative solutions that enable consumers to control entertainment devices, digital media, and home systems. The company's broad portfolio of patented technologies and database of infrared control software have been adopted by many Fortune 500 companies in the consumer electronics, subscription broadcast, and computing industries. UEI sells and licenses wireless control products through distributors and retailers under the One For All® brand name. UEI also delivers complete home control solutions in the professional custom installation market under the brand name Nevo®.

- UEI has shipped over 500 million remote control devices worldwide
- UEI led the introduction of Wi-Fi into remote control devices, with their acclaimed Nevo line of controllers
- UEI was also one of the first to integrate uPnP (Universal Plug-and-Play) as part of a software solution for Nevo on Viewsonic displays and Compaq iPaq PDAs
- UEI is a founding member of the Z-Wave Alliance and among the first to showcase the potential of integrated home control of lighting through a remote control device. UEI develops and produces a wide range of Z-Wave remotes under UEI and other major consumer electronic brands.
- UEI provides the bridge to connecting the different ecosystems of home entertainment. The result is seamless control and interaction across all mediums.

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