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Hybrid Coax-Wireless Multimedia Home Networks Using 802.11 Technology

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Introduction

Wireless home networking has emerged as the preferred technology for distribution of data services within the home. With prices comparable to wired alternatives, and with the promise of connectivity throughout the home without any wires, new or old, 802.11b is a natural choice for users who wish to set up a home network. The high demand for 802.11b products in the enterprise market has made 802.11b even more attractive as a home networking technology by driving costs down and offering users a common interface to both home and corporate networks.

The main driver to-date of home networking has been the sharing of a broadband connection over multiple computers in the home. With raw data rates of 11 Mbps and ranges of 300-500 feet, 802.11b offers a very good solution for this need. As new services are introduced over the home network, follow-on standards 802.11 g/a address the growing need for capacity and 802.11e and 802.11i address the growing need for Quality of Service (QoS) and security respectively. However, as the demand for capacity in the home network increases, the coverage of the wireless connection may limit operators' ability to offer new bandwidth intensive services and applications such as in-home video distribution. Whereas the state-of-the-art 802.11a/g standards, with up to 54 Mbps throughput, offer sufficient capacity for distribution of multiple MPEG video streams within the home, the range and coverage of products based on these standards, when operating in the highest throughput mode, may be insufficient in many cases. The high throughput modes of operation of 802.11a/b/g are those most susceptible to path loss due to obstacles such as walls, and to fading due to time-varying multipath, and therefore, reliable delivery of services using these modes of operation cannot be guaranteed.

We introduce in this paper a new concept that allows operators to overcome the coverage barrier in offering bandwidth intensive services, specifically video distribution, throughout the home. We propose using the in-home coax network as the backbone for the wireless home network with 802.11 a/b/g as the transmission protocol over the coax lines.

By using the in-home coax network to increase the range and coverage of the wireless network, operators will be able to offer reliable video distribution, as well as other services, throughout the home with guaranteed high capacity coverage at every point in the home while enjoying all the advantages of 802.11b/a/g/e/i, including QoS, security and low cost.

General Concept

We propose a home network based on 802.11 transmissions both over the air and over coax (throughout this paper the term "802.11" will refer to all 802.11 based standards including all the various extensions, 802.11 a,b,g,e and i). Figure 1 illustrates a basic block diagram of such a combined wireless/coax 802.11 network. The network illustrated includes an Access Point (AP) with an antenna for wireless 802.11 home networking, as well as a coax connection. The network also includes two stations (STA): one connected to the network through a coax line and a second STA connected through a wireless link. On one of the nodes of the in-home coax network there is a coax to wireless bridge/repeater.

Every packet that is generated at the AP can be transmitted both over the air and over coax. Consequently, each data packet can reach its destination through one of three signal paths. One possible path is a direct wireless connection using the antenna connected to the AP; a second possible path is a combination of coax line until the repeater, and then wirelessly to the wireless station; and a third path is confined to coax cable. All transmissions, both over the air and over the coax cable will be in the 2.4 GHz frequency band (used by 802.11 b and g).

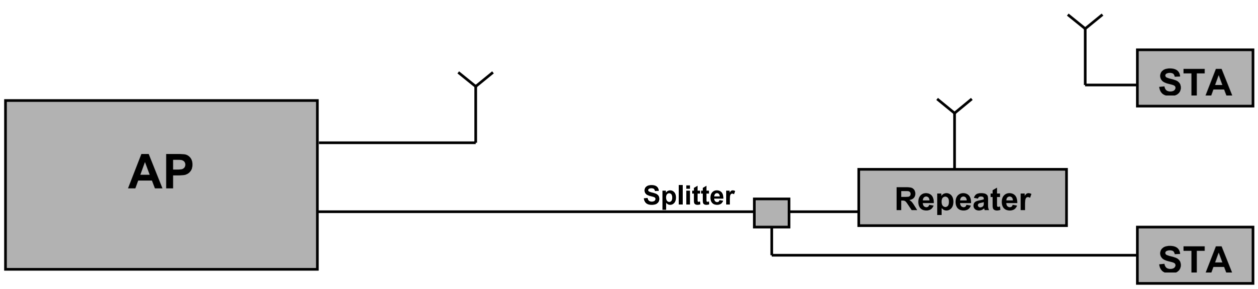

Figure 1

In most homes the propagation loss of 802.11b/g in the 2.4 GHz frequency band is lower over the coax than over the air especially when accounting for obstructions to the wireless signals such as walls. The coax line therefore allows extending the reach and expanding the coverage of the network by bypassing a high-loss wireless path with a low-loss coax path or a hybrid coax/wireless path. The all-coax path between the AP and stations on the coax network is particularly of high quality, allowing reliable operation at high throughput mode of 802.11g (54 Mbps).

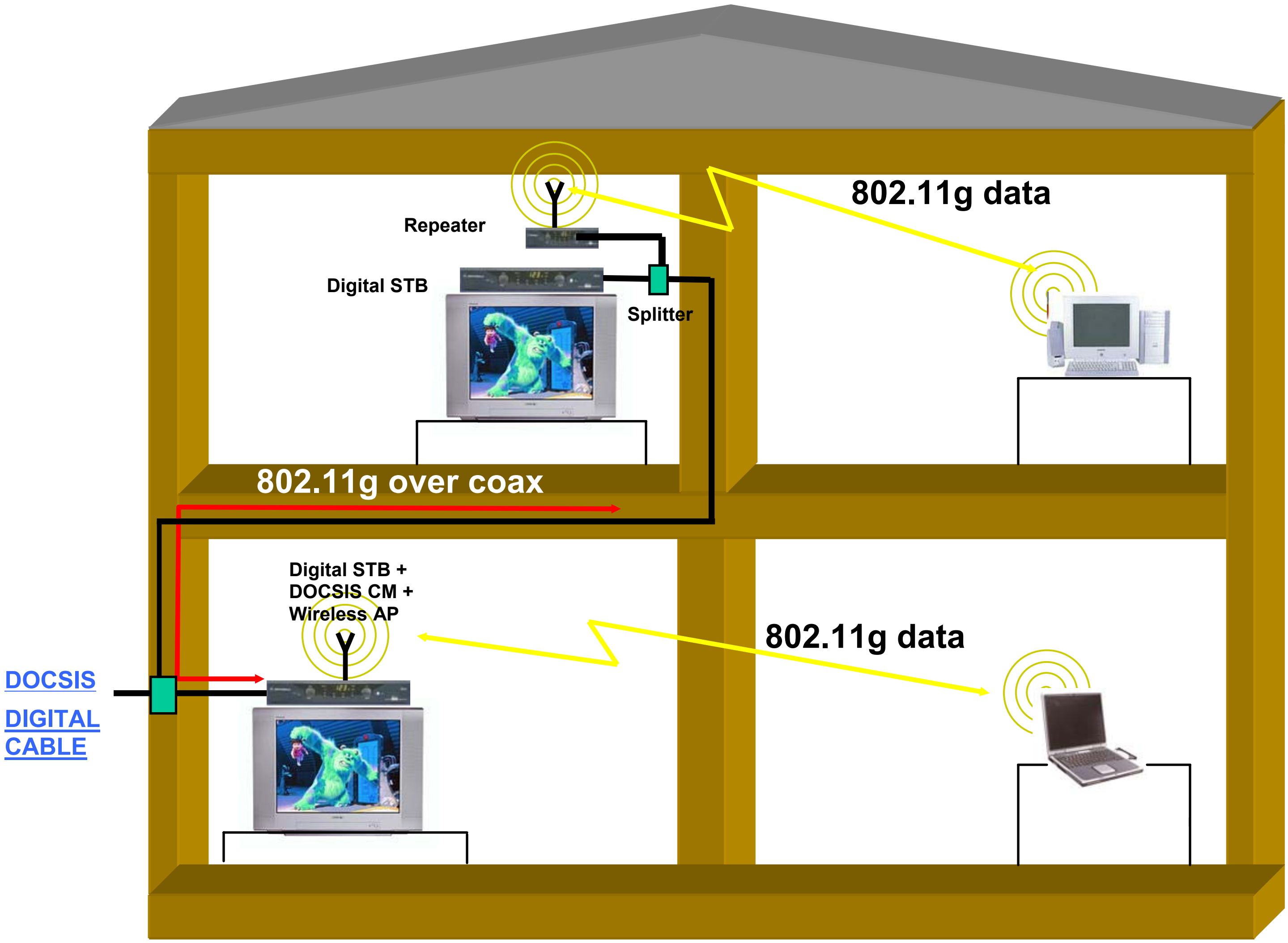

Figure 2

Figure 2 illustrates an example of such a network in a typical home. The home in this example uses 802.11g for data and video distribution. The Digital Set-Top-Box (STB) on the first floor has an integrated DOCSIS™ Cable Modem and an 802.11g AP with data rates of up to 54 Mbps. The two computers in this home share the broadband connection for Internet, email etc. using a wireless link. The computer on the first floor is connected to the STB/AP through an 802.11g wireless link. The second computer on the second floor, which is possibly beyond the reach of the wireless signals generated in the STB, is connected to the network via the coax/wireless repeater on the second floor that extends the reach of the wireless network. In this example, the ability to connect the computer on the second floor to the wireless network is one important benefit achieved by this hybrid coax/wireless network.

The second important benefit is the high capacity connection between the two STBs in the house, allowing the distribution of video signals from one room to another. The distance between the two rooms may be enough for a 2-11 Mbps wireless connection that is sufficient for data service (Internet, email etc.), however higher throughputs of up to 54 Mbps needed for video distribution requires the coax link between the two STBs. The high capacity link between the two STBs enables the sharing of recorded material on PVRs, as well as allowing access from all STBs to email, Internet etc. The STB with AP can become the home media center with stored video and audio, with other scaled-down STBs having access to this information through the coax network. All STBs could also have access to data services and computer resources in the home such as printers, scanners, cameras etc.

The QoS capabilities of 802.11e will ensure efficient use of the shared medium, as well as guarantee allocation of bandwidth and limit latency for services requiring QoS. CableHome™ functions implemented in the STBs will facilitate the management of the home network.

The combination of a high capacity coax channel and 802.11e assures operators that bandwidth intensive services such as video distribution can be delivered reliably and consistently between stations on the coax network.

Hybrid Coax/Wireless Technical considerations

Although all the components in the in-home coax network are designed for signals below 900 MHz, the 802.11 signal is robust enough to tolerate the attenuation resulting from operation at 2.4 GHz. With typical attenuation of 0.5 dB per meter cable and 20-30 dB attenuation of common splitters (measured between splitter outputs and between input to output at 2.4 GHz), the in-home coax path is still less demanding than even good wireless channels. Existing 802.11b/g systems can tolerate 90-100 dB of attenuation between transmitter and receiver (while still maintaining high throughput) allowing a link attenuation budget that can accommodate hundreds of feet of coax cable and several splitters.

The hybrid coax/wireless network will introduce multipath due to unterminated cables and splitters. However 802.11 devices are designed to mitigate even severe cases of multipath given the many reflections and signal paths in a typical wireless environment. 802.11 has also inherent security features which can address any security concerns resulting from signal leakage to neighboring homes.

Comparisons to alternative solutions

Various solutions addressing the problem of multimedia distribution within the home have been proposed to cable operators. Below is a comparison of these solutions to the one proposed in this paper:

1. Analog Distribution

Analog distribution provides a simple solution to the problem of video distribution within the home, with the distinct advantage of not requiring a separate converter box to decode the upconverted video signal. However, this solution is very limited both in its functionality and in its quality. Data delivery, including remote control data, will require a separate medium and additional components, and the quality of the picture can be poor due to micro-reflections in the coax channel. The digital signal of 802.11 is much more robust to micro-reflections, providing consistent and reliable delivery of video as well as high-speed data over the in-home coax network.

2. Pure 802.11 a/b/g + e network

While providing in most cases complete home coverage at rates that support the sharing of the broadband connection for data services throughout the house, it may be insufficient for multimedia distribution. The high throughput modes of operation are the ones most susceptible to wireless path loss and multipath, and coverage for modes that can support video distribution may not be complete.

To expand the reach of the network, wireless repeaters can be used. Repeaters indeed improve the coverage (at the expense of additional spectrum usage), however without careful planning complete coverage is still not guaranteed, and this solution is less robust and more expensive than the hybrid coax/wireless solution proposed in this paper.

3. HPNA and HPNA over cable

HPNA 2.0 has not been successful in the market as a home networking technology. Even though its data rates are sufficient for high-speed data service, it has lost market share to the much more popular wireless alternatives. Coverage in many homes is incomplete due to locations of phone outlets, and the use of the phone wire for home networking is not as intuitive to many users as wireless. In fact, as the number of silicon and system vendors developing 802.11 based solutions has increased dramatically, the number of silicon and system vendors developing HPNA based products has decreased, making this technology even less attractive due to lack of competition.

For multimedia applications HPNA 2.0 is not suited at all. Practical data rates are not high enough for video distribution, and the QoS mechanisms in the specification are minimal leading to inefficient usage of the shared medium and not allowing operators to guarantee QoS for revenue services. The next generation standard HPNA 3.0 may address this problem, however it still has many of the other problems that made HPNA 2.0 so unattractive as a home networking technology.

There have also been proposals for using HPNA 2.0 over cable in a similar way that this paper proposes for wireless. However, unlike the high rate modes of 802.11g/a with the QoS option, HPNA 2.0 is not capable of distributing multiple MPEG streams over the coax cable due to insufficient throughput and lack of QoS.

In addition, HPNA over cable requires frequency conversion in order not to interfere with cable upstream transmissions (the spectrum of HPNA 2.0 overlaps with the cable upstream spectrum). This introduces a non-standard element to this solution, requiring additional components to the ones used in phone-line HPNA, and requiring an additional standard if multi-vendor interoperability is to be achieved. The frequency conversion may also be a problem for standard HPNA components given that HPNA 2.0 does not allow such conversion. These issues coupled with the lack of HPNA 2.0 silicon vendors, make this solution essentially a proprietary solution.

Moreover, to bridge between the coax and phone network, there needs to be at least one point in the house where coax and phone lines meet. Since in many homes coax and phone outlets are on opposite sides of the rooms, bridging the two networks may not be as simple as in the wireless case.

Also, given the popularity of wireless home networking, it is likely that wireless home networking may still be required at the AP. Wireless handheld devices, and corporate computers equipped with a wireless LAN interface, as well as other devices not near a phone or coax outlet, cannot be served by a HPNA coax/phone-line solution. Complementing HPNA with 802.11 will lead to an inefficient, redundant solution compared to the 802.11 coax/wireless solution.

4. Dedicated coax transceiver ('HomeCNA')

Several companies have proposed coax based home networking solutions that use a non-standard transmission protocol. Indeed, an optimized protocol for delivering multimedia over coax can provide a good technical solution, but it is less likely to be adopted than a solution that is already based on an existing standard, especially one so popular as 802.11b/a/g. Developing a new dedicated standard and new components for cable home networking is a long and expensive proposition. Chances of multiple vendors signing up for such an effort are slim. Any technical advantages that such an approach may have over using 802.11b/a/g as the transmission protocol are by far outweighed by the advantages of relying on existing, proven standards and, more important, existing 802.11 silicon.

Even if such an approach is adopted, STBs will still require another home networking technology, in addition to the coax networking technology (presumably wireless), to connect to devices that are not near a coax outlet. This is an inefficient (and costly) solution compared to a single 802.11 interface in the STB that transmits both over the air and over the coax.

While dedicated coax home-networking solutions may claim a higher throughput than those supported today by 802.11 (100 Mbps and above compared to 54 Mbps), it is worth noting that 802.11 has a dedicated task group looking at higher rate extensions to 802.11 that will provide even greater capacity for bandwidth intensive applications and services.

Summary

We have introduced the concept of a hybrid coax-wireless home network for bandwidth intensive multimedia applications and services using existing 802.11 standards and components. With data rates of up to 54 Mbps, guaranteed QoS and complete home coverage, operators can now have a solution that will allow them to deliver and distribute reliably throughout the home services that require both high capacity and guaranteed QoS such as video distribution.

By using the existing 802.11 standard, operators ensure the availability and interoperability of components from multiple vendors and take advantage of the competition and high volume in the 802.11 market space leading to a low cost, low risk solution.

The popularity of 802.11 both in the home and enterprise space, and the many 802.11 based products such as notebooks with integrated wireless, wireless enabled PDAs, and 802.11b security cameras, will also facilitate wide adoption of this hybrid coax-wireless 802.11 home multimedia network.

For more information, visit the Texas Instruments Web site: www.ti.com/cablemodem