

MoCA: Ubiquitous Multimedia Networking in the Home

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ABSTRACT

The Multimedia-over-Coax Alliance (MoCA) standard is rapidly emerging as the de-facto standard in North America for multimedia home networking. This is driven by the desire to have digital content from various sources such as DVRs, audio devices and PCs reliably available anywhere in the home using the in-home existing coaxial cable wiring. The MoCA technology coexists with other services at the home such as cable TV, cable modem, and satellite services. This technology achieves MAC throughputs exceeding 100 Mb/s in 97% of all outlets in the home with no changes to the home coax infrastructure, and with packet error rates less than 10^{-5} , and with an average latency of less than 3.5 milliseconds based on extensive field trial results.

1. INTRODUCTION

The Multimedia-over-Coax Alliance (MoCA) standard is emerging as the de-facto standard in North America for multimedia home networking [1]. It has been adopted and deployed to the mass market initially through the Verizon fiber optic service (FiOS) deployment. The market for multimedia home networking is driven by the desire to have digital multimedia content from various sources such as DVRs, audio devices and PCs reliably available anywhere in the home. While consumers may be willing to accept degraded multimedia content viewed on mobile and handheld devices, visual degradations will not be tolerated for digital entertainment in a home with multimedia consumer devices such as digital TVs, DVRs, STBs, and media center devices. This paper is organized as follows. In section 2, the home usage model and the MoCA channel characteristics are explained. Section 3 provides an overview of the MoCA physical (PHY) layer and media access control (MAC) layer features based on the MoCA MAC/PHY Specification v1.0 for the home networking. The current development of the next-generation MoCA specification is reviewed in section 5. The MoCA field test results are briefly discussed in section 6, and the MoCA certification process is explained in section 7.

2. MoCA USAGE MODEL

Figure 1 shows an example of a home usage model with triple play services (voice, video, and data). The multimedia signal enters the home via an optical termination unit (ONT) or via cable gateway, digital subscriber line (DSL) gateway, or via a satellite dish. The multimedia content is distributed to each room in the home using the in-home coaxial network. The home must support multiple simultaneous HDTV, SDTV, audio, data, voice-over IP, gaming, and other multimedia usages both from the broadcast network and from the in-home DVR or storage devices. Each room and device may be either, or both, a source or sink of multimedia content both to and from multiple simultaneous entertainment devices in the home.

The in-home coaxial network connectivity model must provide a reliable room-to-room, peer-to-peer, full-mesh connectivity among all sources and sinks in the home. In order to support multiple simultaneous HDTV and SDTV multimedia streams, the in-home network is required to have at least 60 Mb/s, and in many cases greater than 100 Mb/s MAC throughput with low packet error rate ($PER \leq 10^{-5}$) and low average latency (≤ 3.5 milliseconds). These network performance requirements must be satisfied when other services are added or when a neighbor or a housemate runs services in the home.

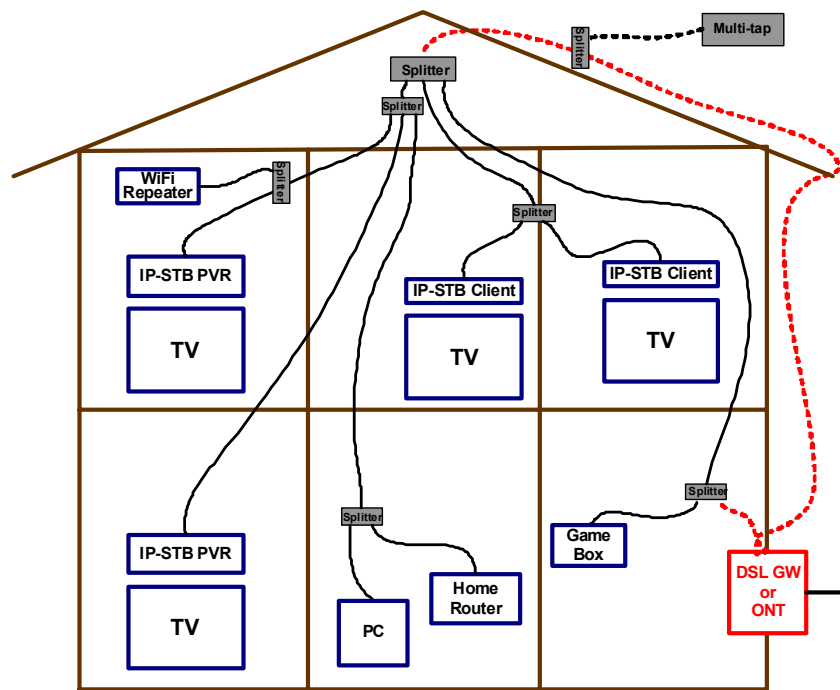


Figure 1: A home usage model using the in-home coaxial network connecting to external networks.

3. MoCA PHY AND MAC LAYER FEATURES

The MoCA technology, which uses the existing in-home coaxial network, is based on the MoCA MAC/PHY Specification v1.0 standard [1]. Although the in-home coax is a relatively static channel, the presence of coaxial splitters creates a highly dispersive multipath channel that can cause significant echoes in addition to high signal attenuation when communicating between various MoCA devices.

3.1 MoCA PHY Layer Features

To overcome multipath degradations and achieve a PER less than or equal to 10^{-5} for large packets (>1500 bytes), the MoCA PHY layer defines a broadband orthogonal frequency division multiplexing (OFDM) signal in a 50 MHz channel where each subcarrier can be independently modulated from BPSK to 256-QAM modulation is defined. Knowledge of the channel at the MoCA receiver enables adaptive bitloading on all the subcarriers at the transmitter. Different probes are used to characterize critical information about the MoCA channel condition. After a probe analysis, modulation profiles are selected to optimize all the point-to-point links while maintaining a low PER. To provide robustness against system impairments, Reed-Solomon forward error correction is applied to all the data packets. All PHY layer transmissions over the coax are achieved using time-division duplexing (TDD) with PHY data rates in a two-node network exceeding 250 Mb/s. The MoCA specification defines MoCA channels at seven MoCA bands located between 875 MHz and 1550 MHz.

3.2 MoCA MAC Layer Features

The MAC layer operation is based on distributed mesh network architecture with time domain multiple access (TDMA) based on a fully scheduled access. The MoCA network supports communications up to 8

nodes. Any MoCA node can become a network coordinator (NC) node, which is automatically selected. Any node in the MoCA network is capable to become the NC node. The NC node broadcasts beacons every 10 milliseconds to enable other MoCA nodes to detect the presence of a network, and join the network. It controls all the transmissions in the network by broadcasting scheduled transmission opportunities to every node in a control packet called a MAP. Every MoCA node must go through an admission process, before becoming part of the MoCA network. Every node gets a reservation opportunity to send a certain number of packets per MAP, which is transmitted by the NC node approximately every one millisecond. For robust network operation, every node in the network periodically updates its transmit power levels and PHY profiles using the link maintenance operation (LMO). After a new node is admitted to the network, it goes through an LMO. In addition, for seamless network recovery, a node is designated to be the backup NC node, which is communicated to all the nodes so they are aware of which node will take on the role of NC node if the current NC node were to fail. The MoCA network is a secured network, which means that all the transmitted data packets in the MoCA network are encrypted. The NC node generates periodically the link privacy keys and distributes them to all the nodes. The MoCA protocol supports the transport of Ethernet packets across the MoCA network using the Ethernet Convergence Layer. When receiving Ethernet packets from upper layers, the ECL performs the functions of packet encapsulation and forwarding to the destination address of the MoCA nodes.

4. MoCA DEVICE CATEGORIES

MoCA devices are classified into four main categories, intermediate devices, terminal devices, operator-service provider (OSP) devices and non-OSP devices. The primary function of an intermediate device is to bridging of user content between the MoCA network and an external device using an industry standard interface such as Ethernet or USB. In contrast, the primary function of a terminal device is to source or sink user content over the MoCA network. Both intermediate and terminal devices can be either OSP or non-OSP devices. If OSP MoCA network has privacy enabled, then the OSP devices must provide the end-user the means to read the password so that non-OSP devices can be configured by the end-user to join the MoCA network.

5. MoCA SPECIFICATION DEVELOPMENT

The MoCA spec working Group (SWG) is developing the MoCA MAC/PHY Specification standard. The initial MoCA specification v1.0 draft was released in February 2006. The SWG is developing the next-generation of MoCA specifications, which includes the following features:

1. Parameterized quality of service (QoS) to enable guaranteed bandwidth support.
2. Support for 16 node MoCA network
3. Packet aggregation to improve MAC throughput.

Service Providers anticipating the convergence of consumer/retail devices with OSP networks have driven the need for guaranteeing network bandwidth. This is achieved through the use of applications that can take advantage of PQoS features in the Layer 2 protocols. A QoS Manager requests reserved bandwidth for traffic flows from the Layer 2 resource scheduler. If the bandwidth is available, a PQoS flow is set up and the bandwidth, typically reserved for OSP premium content traffic, is guaranteed. PQoS flows can also be updated and torn down.

The MoCA 1.0 specification supports throughputs up to about 135 Mbps on a two-node network using 1518 bytes packets and up to about 120 Mbps on a four-node network. The MoCA specification v1.1 draft provides

significantly higher net throughputs through the use of packet aggregation. For example, a two-node MoCA 1.1 network can support up to about 160 Mbps of net throughput.

6. FIELD TEST RESULTS

The purpose of conducting field tests was to validate the performance and coverage of the MoCA technology in real world conditions. Field tests were conducted in about 250 homes in 15 cities across the U.S. All MoCA members including multiple operators and service providers participated in these tests. The tests were conducted under normal living conditions without modifications to the existing cable plant. Existing devices and service were connected to the cable plant. Multiple MoCA nodes were deployed at each home cable outlet, and the tests were coordinated by a laptop with multiple statistics on coverage, performance, and links collected. Figure 2 shows the measured MAC throughput and PHY rates versus the percentage of the in-home paths. Net usable MAC data rates with no changes to the home coax system in 97% of all paths in all homes achieved ≥ 100 Mbps. Furthermore, the net usable MAC data rates with a simple remediation to the installed coax cable system in 100% of the homes achieved ≥ 95 Mbps on every path in the home. The

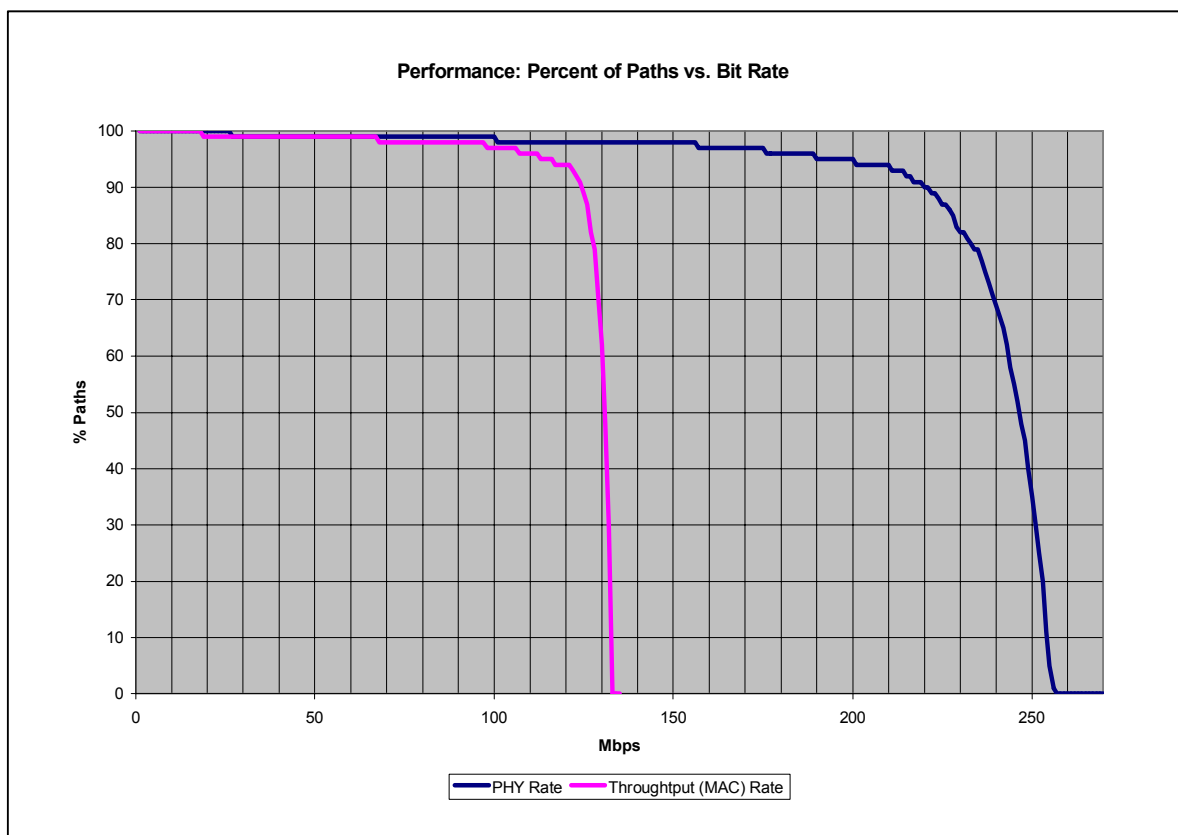


Figure 2: The percentage of paths versus the measured PHY and MAC rates.

measured PER was less than 10^{-5} with an average one-way latency less than 3.5 milliseconds. These field test results provide a real-world validation of MoCA as a robust home networking technology.

7. MoCA CERTIFICATION

The MoCA Certification Working Group (CWG) has developed a certification test plan for both intermediate and terminal devices that covers both OSP and non-OSP devices. To obtain MoCA certification for a product, each vendor must submit the self-test results for the product according to the MoCA test plan to the designated MoCA certification lab before it can start the official certification testing. The submitted product is tested in every MoCA channel that the product is designed to operate. If the submitted product failed one or more of the MoCA certification test cases, then the vendor must take a corrective action and resubmit its product with the self-test results to the designated MoCA certification lab for MoCA certification.

8. CONCLUSIONS

In summary, the MoCA technology was shown to provide a reliable room-to-room, peer-to-peer full mesh connectivity of digital content among MoCA devices using existing in-home coaxial cables. Field test results show MAC throughputs exceeding 100 Mb/s in 97% of all the paths in the home with PER less than 10^{-6} for large packets (> 1500 bytes). Furthermore, the MoCA technology coexists with other services such as cable TV and satellite TV services at the consumer home. The MoCA network is a robust and secured network with multiple layers of redundancy. The Verizon FiOS fiber-to-the-home (FTTH) deployment is based on the use of MoCA technology in the home. This large scale deployment of MoCA technology with more than one million consumers provides a real-world validation of the MoCA technology as a robust home networking technology.

9. REFERENCES

- [1] For more details about MoCA see www.mocalliance.org.
- [2] MoCA MAC/PHY Specification v1.0 (April 5, 2007).